The Hong Kong Polytechnic University

Institute of Textiles & Clothing

Studies on Seam Quality with Sewing Thread Size, Stitch Density and Fabric Properties

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CERTIFICATE OF ORIGINALITY

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written, nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

-- (Signed)

Sumit Mandal

-- (Name of student)

DEDICATION

To

my late-grandparents , parents and brother

for

their never-ending love, support and understanding

ABSTRACT

Different sewing threads sewn on different woven fabric will provide different effects on seam quality. The expectation on seam quality for various apparel products will also be different. For example, sportswears focus on seam performance, whereas shirts focus more on seam appearance. However, the definition of seam quality is still ambiguous. As a result, analysis of seam quality can provide a more realistic study.

The purpose of this study was to analyse the seam quality with commercial sewing threads in woven fabric. This study focused on four major objectives: 1) to study the critical dimensions for measuring seam quality; 2) to study the effect of sewing thread size on each critical dimension for seam quality evaluation under various fabrics and sewing conditions; 3) to evaluate the effectiveness of modelling techniques for each critical dimension of seam quality evaluation; 4) to study each dimension for seam quality evaluation in various apparel products using proposed model.

In this study, seven different sizes of spun polyester sewing threads were sewn on 20 cotton, 15 cotton-polyester and 15 cotton-spandex woven fabrics respectively. To study the effect of sewing thread size, stitch density and fabric properties on seam quality, the multiple regression models were selected in this study. They were- linear and logarithmic models. To compare the performance of these two models, the coefficient of determination (R^2), standard error and the

mean square error (MSE) were used to identify which model fits for measuring seam quality. Based on the proposed model, each dimension of seam quality evaluation could be integrated in five apparel products- blouse, shirt, denim trousers, T-shirt and lingerie. Through evaluation table, a total of 10 professional researchers were distributed a weightage in percentage to each dimension of seam quality in these five apparel products.

In this study, through subjective ranking, there were three critical dimensions for measuring seam quality- seam efficiency, seam puckering and seam boldness. Models of seam efficiency, seam puckering and seam boldness for cotton, cotton-polyester and cotton-spandex woven fabrics were formulated. The result revealed that the logarithmic modelling technique was best fitted for seam efficiency, seam puckering and seam boldness. Through a validation process, the result also found that the proposed model could be effectively applied in various apparel products.

The outcomes of this study could provide in-depth analysis of seam quality through different multiple regression modelling technique. The success of this modelling could help apparel manufacturers to evaluate seam quality more effectively when a particular sewing thread size and stitch density are applied on a particular type of fabric. It would facilitate apparel engineers in the production planning and quality control.

PRESENTATIONS AND PUBLICATIONS

Conference presentations

1. Mandal, S., Ng, F. and Hui, P. Polyester sewing thread selection depends on sewn fabric dimensional properties. *Proceeding of The Fiber Society Spring Conference at South Carolina*, *USA*. 2007, May 23-25.
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3. Mandal, S., Ng, F. and Hui, P. An empirical analysis of seam quality with spun and core-spun sewing threads in woven fabrics. *The 36th Textile Research Symposium at Mt. Fuji*, *Japan*. 2007, August 5-7.
4. Mandal, S., Ng, F. and Hui, P. An empirical analysis on seam quality of cotton woven fabrics for different sewing conditions. *Proceedings of The 6th China International Silk Conference at Suzhou*, *China*. September 13-14.

Journal publications

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

In cut and sewn apparel products, seams are formed when two or more pieces of fabrics are held together by stitches. As the seam is one of the basic requirements in the construction of apparel, seam quality has great significance in apparel products. Consumers evaluate seam quality mainly based on the seam appearance and its durability after wear and care procedures. The quality of seam has to be evaluated by the manufacturers during product development and production.

Manufacturers establish seam quality standards that result in garments of a particular quality level. Not all apparel products need to have the highest seam quality, but the seams should be of the appropriate quality that could provide adequate performance to ensure serviceability in use and to provide a saleable appearance. Thus, carefully planned steps should be employed in apparel manufacturing to ensure the seam quality truly meets the requirements of each type of apparel product.

In general, the seam quality mainly depends on the strength and the appearance of the seam itself. Seam strength and appearance affects both the functional and aesthetic performance of an apparel product and is important to its saleability and durability. A good quality seam must have flexibility and strength with no seaming defects such as puckering or skipped stitches; and the overall appearance of the seam must meet the design requirements of the apparel products. Besides the consideration on the quality level of the apparel product, judgement of seam quality requires consideration of the purposes of the apparel products as well. For some functional garments such as sportswear, the requirements of seam strength may be higher than the need for seam appearance, while for some apparel products such as nightgowns, the appearance of the seam is of higher importance.

There are various factors which can affect the seam strength and seam appearance. Many previous studies (Bhalerao *et al.*, 1997; Behera *et al.*, 1997a; Behera *et al.*, 2000; Mukkhopadhaya *et al.*, 2004) showed that seam appearance and performance depends on the interrelationship of fabrics, threads, the stitch and seam selection, and sewing conditions, which include the needle size, stitch density, the appropriate operation and maintenance of the sewing machines etc. The combination of materials that are assembled with the sewing thread and sewing conditions vary from individual to individual. Selection of sewing thread and sewing condition for a particular type of material is an integral part of producing a quality seam.

The different parameters of sewing thread such as the thread type, size and finish would have a definite effect on seam strength and appearance (Glock and Kunz, 1995; Rengasamy *et al*., 2003; Gribaa *et al*., 2006). The clothing industry tends to use the polyester spun thread with standard finish for most apparel products unless special requirements are demanded. In the apparel industry, after a particular type of seam and stitch is selected for the construction of an apparel product, the apparel designer and/or manufacturer needs to select the thread size and to determine the seam boldness required for seam construction. Seams with different degrees of boldness serve different purposes as design features. Some types of garments such as the jeans prefer a seam with more prominent design, while other garments such as the dress shirt conventionally prefer the seams be sewn more inconspicuously. The seam boldness is an important element of determining the seam appearance, and the size of sewing thread becomes the primary factor for the manufacturers to consider for the required seam quality.

The sewing conditions such as the thread tensions and pressure of pressure foot should be adjusted based on the thread size and the material to be sewn. However, the stitch density may vary at different seam locations. Stitch density was deemed to be an important attribute in seam quality because it assembles the fabric components together. The change of stitch density exerts a great influence on seam strength and appearance.

Basically, seam quality may be examined from two main aspects: functional and aesthetic performance. Most previous studies (Chmielowiec *et al*., 1987; Bhalerao *et al*., 1997; Tarafdar *et al*., 2007) investigated the functional performance of seam mainly in terms of the seam strength and/or seam efficiency. There are also numerous studies (Carr and Latham, 1995; Gupta *et al*., 1992; Tarafdar *et al*., 2005) on the seam quality based on the aesthetic performance. However, these studies focus mainly on the seam defects such as the seam puckering (Gupta *et al*., 1992; Tarafdar *et al*., 2005), seam damage (Carr and Latham, 1995). Furthermore, few studies had been evaluated the seam quality from both aspects of seam: the functional and the aesthetic (Behera *et al*., 1997a; Krasteva and Petrov, 2008). However, in these studies, in order to evaluate the seam quality, the authors did not combine the functional and aesthetic performance of seam. Up to now, very limited work has been done to study the seam quality on functional and aesthetic performance together. This study attempts to analyse the seam quality from the aspects of both functional and aesthetic performance, and to study the effect of thread size, fabric properties and stitch density on seam quality in various types of fabric materials. The success of this study could help apparel manufacturers to evaluate the seam quality more effectively when a particular sewing thread size and stitch density are applied on a particular type of fabric. In turn, this would facilitate apparel engineers in the production planning and quality control.

1.2 Objectives

The main concern of this study is to delineate the seam quality of various apparel products. In this regard different critical dimensions for measuring seam quality are discussed. The effects of sewing thread size, fabric properties and stitch density for each critical dimension are also reckoned through modeling. This research has also identified the best fit model for each critical dimension of seam quality evaluation. The best fit models were integrated together for seam quality of various apparel products.

The principal objectives of the present research study are described as follows:

1) To identify critical dimensions for measuring seam quality.

2) To study the effect of sewing thread size, fabric properties and stitch density on each critical dimension for the evaluation of seam quality for various fabrics by different modeling techniques.

3) To measure the performance of various modeling techniques for each dimension of seam quality evaluation. This will help to identify the best fit model for each critical dimension of seam quality evaluation.

4) To integrate the best fit models of critical dimensions for evaluating seam quality on various apparel products. This part of study provides a solution for evaluating the overall seam quality of a particular apparel product.

1.3 Research methodology

There were five phases for this study. The five phases and their purposes are illustrated in Figure 1.1. The methodologies adopted in each phase are outlined in the following sections.

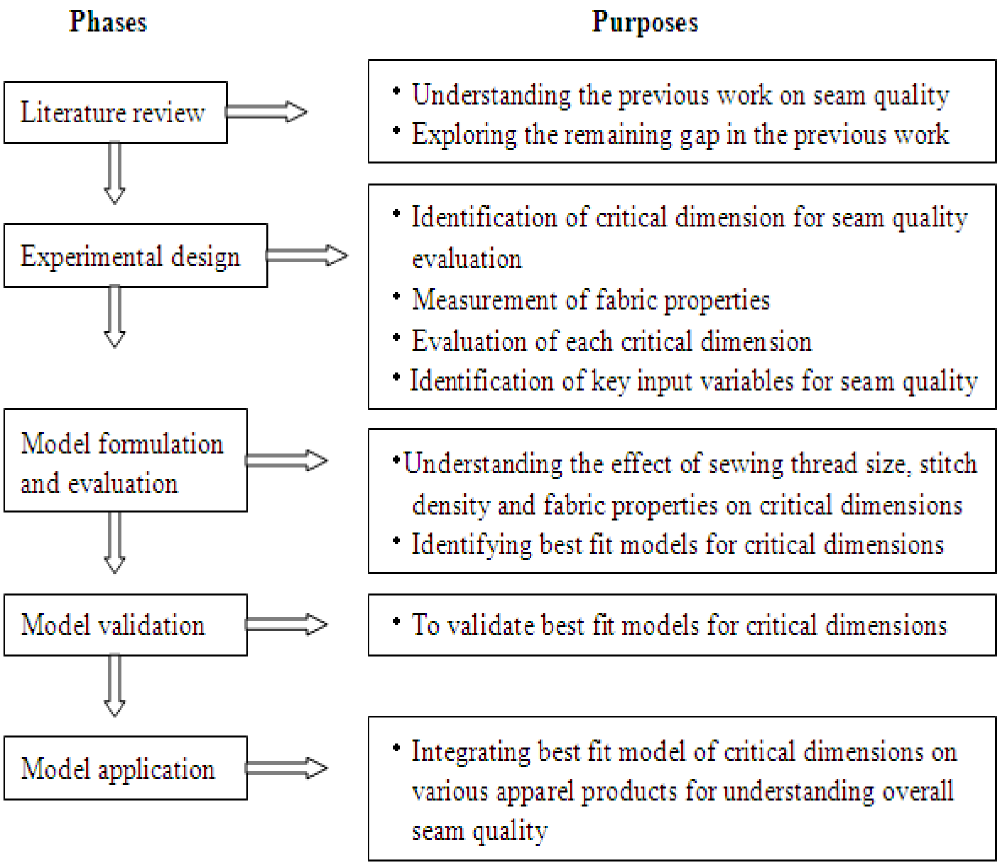


Figure 1.1: Research methodology for this study

1.3.1 Literature review

This was the first step in understanding the previous work on seam quality and remaining issues on it. This is very important for clearly defining the objectives of this study.

For this part of work, journal papers, books and internet publications were searched and studied. All these were essential for seeking information on methods used in evaluating seam quality, factors affecting the seam quality and the problems existing in the previous research in this area.

1.3.2 Experimental design

In order to study the seam quality, at first, critical dimensions for seam quality evaluation were identified from a list of general dimensions appeared in the literatures. A subjective ranking method was applied to identify the most important dimensions for seam quality evaluation. A group of experienced judges were involved in subjective ranking. The three most important dimensions were inferred as critical dimensions for seam quality evaluation.

The different properties of selected fabrics were measured using Kawabata Evaluation System or ASTM method. Each selected fabric was sewn by different sewing thread size at various stitch density. From the prepared seam, each critical dimension was measured by their standard evaluation method. The key input variables for seam quality were identified through covariance analysis, regression analysis and factor analysis.

1.3.3 Model formulation and evaluation

The effects of sewing thread size, stitch density and fabric properties on each critical dimension for seam quality evaluation were evaluated by formulating empirical models. Multiple regression modeling methodology was used to formulate the linear and logarithmic model of each critical dimension. In order to identify the best fit models of each critical dimension for seam quality evaluation, the coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) were calculated to compare the performance between linear and logarithmic model. The effect of input variables (sewing thread size, stitch density and fabric properties) on output variables (each critical dimension for seam quality evaluation) was identified from regression coefficient of individual input variable in the best fit models.

1.3.4 Model validation

Best fit models were validated with new set of experimental data. To verify the validity of best fit models, the predicted values obtained from the best fit model were compared with the experimental values. In order to compare the predicted values with the experimental values, the coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) between experimental values and predicted values were calculated.

1.3.5 Model application

The best fit models of each critical dimension were integrated on various apparel products for providing a solution to evaluate the overall seam quality. Weighing factor approach was adopted to integrate the models of each critical dimension. To begin with, the relative importance of each critical dimension on the overall seam quality of apparel products was calculated through subjective evaluation. The weighing factor of each critical dimension was examined based on the relative importance of each of the dimension.

1.4 Scope of the study

The focus of this research is the analysis of seam quality in woven fabrics. This delimitation can be justified because woven fabric is one of the most dominating fabric types in the apparel industry and commonly sold in the apparel markets. This type of fabric could possess wide range of properties for consumer satisfaction during wear and care of an apparel product (Brown and Patty, 1992).

Furthermore, woven fabrics are suitable for the construction of most of the basic apparel products like as, shirt, trousers etc.

In addition, the present study emphasises on sewing threads size and stitch density for analysing seam quality due to following reasons. The apparel engineers mainly consider sewing thread size and stitch density are the most crucial factors affecting the seam quality; as functional and aesthetic performance of seam is mainly depended on these two factors (Glock and Kunz, 1995; Carr and Latham, 1995). Every apparel engineer must have clear knowledge about the effect of sewing thread size and stitch density on seam to solve the seam quality problems in the apparel industry. Sewing thread size is also important to the apparel designers and/or merchandisers from seam quality point of view. The apparel designer and/or merchandiser consider the sewing thread size as an important element to enhance the boldness of a seam, which is one of the prime seam quality requirements for some apparel like as: denim trousers, jackets etc.

In this research, it is assumed that human factors and environmental factors are all constant. That means, the skill of the operator and the environmental factor such as temperature, humidity etc. will not affect the quality of seam in the study.

1.5 Outline of the thesis

This dissertation contains six chapters. Chapter 1 introduces the research background for this study. The statement of the problem and objectives of the investigation are explained. Research methodologies and scope of this study are also overviewed. A brief outline of the dissertation is introduced.

Background knowledge is provided in Chapter 2, in which the literatures and theories of seam quality are reviewed. The evaluation methods of seam quality are explained. The various affecting factors for seam quality are also explained individually. In addition, problems and limitations of previous studies on seam quality are discussed with reference to the literature.

The critical dimensions for seam quality evaluation are identified in Chapter 3 through subjective ranking.

Research methodologies for this study are discussed in Chapter 4. Experimental design and model formulation methods are introduced in this chapter. Model performance analysis and validation methods are also discussed. Application processes of each best fit model for seam quality of various apparel products are also described.

Chapter 5 determines the key input variables for seam quality through covariance analysis, regression analysis and factor analysis. Empirical models are developed on the three critical dimensions for the evaluation of seam quality. Multiple regression methodology is used for the modeling. Performance of the empirical models of each critical dimension for seam quality evaluation is also evaluated. All the best fit models were validated and integrated together for seam quality of various apparel products.

Finally, Chapter 6 presents the summary and conclusions of the study. Limitations and recommendations for further study based on the present work are also discussed.

CHAPTER 2

LITERATURE REVIEW

An extensive literature review is presented in this chapter regarding the fundamentals of the related topics covered in this dissertation. It starts with an introduction to seam quality and then covers its various evaluation methods. The factors affecting the seam quality are also discussed. Finally, the remaining gap in the previous literatures is also pointed out.

2.1 Seam quality

The cut and sewn apparel product industry converts a two-dimensional fabric into three- dimensional apparel. Many processes are involved during apparel production, till the stage of finished apparel to be seen in a shop-window, on a tailor's dummy, or on a coat hanger is reached. While there are other methods of shaping fabrics into apparel products, stitch seaming is by far the most common method used worldwide (Solinger, 1989; Behera and Sharma, 1998).

For common apparel products, the seam is an essential part of the garment (Lindberg *et al*., 1960). A seam is manufactured employing sewing methods, with the idea that the seam should satisfy all the requirements imposed by a number of end-users of apparel products (Rosenblad and Cednas, 1973; Stylios and Lloyd; 1990). For any apparel product, it is necessary to clearly understand the seam, as it is the basic element of an article of clothing.

In the apparel industry, overall seam quality defined through various functional and aesthetic performances desired for the apparel product during their end use. The functional performance mainly refers to the strength, tenacity, efficiency, elasticity, elongation, flexibility, bending stiffness, abrasion resistance, washing resistance and dry cleaning resistance of the seam under conditions of mechanical stress for a reasonable period of time (Mehta, 1985; Solinger, 1989; Carr and Latham 1995; Glock and Kunz, 1995). Properties like as, strength, tenacity and efficiency is required for determining the serviceability of apparel. Elasticity, elongation, flexibility, and low bending stiffness of seam are needed to easily bend, shift, and fold without damage to the seam or change to the silhouette of the garment. Seam also comes under abrasion with body parts at wear or at the time of washing or dry cleaning. It is expected that seam should have good abrasion and/or washing and/or dry cleaning resistance.

There are also certain aesthetic requirements of a seam to the consumers' body sensory mechanism (hand, eye) (Solinger, 1989; Carr and Latham 1995; Glock and Kunz, 1995; Choudhry, 1995). For proper appearance, seam should not contain any defects including skipped stitches, unbalanced stitches, looseness, seam grin, distortion or unevenness or puckering, unsteadiness, improper drapeability, uneven seam density and yarn severance or damage. A defect free seam is required for consumer satisfaction at the point of sale of apparel and helps to increase the saleability.

Apart from all the above aesthetic mentioned requirements, seam should also meet the design requirement of the consumers for apparel. The different degree of boldness of seam can help to fulfil different purposes as design features and affect the appearance of garment. In the apparel industry, seam boldness is commonly used as a prime dimension for evaluating the design prominence of a seam (Sandow and Hixon, 1999; Ukponamwan *et al*., 2000; Behera *et al*., 1997a).

Therefore, overall quality of a seam depends on the requirements imposed by the consumers. Good overall seam quality is essential for the longevity of an apparel product, which together with consumer satisfaction during wear and care procedures affect its saleability. The apparel industry use different dimensions for the evaluation of seam quality on the basis of the requirements of a seam from consumers' point of views (Kadolph, 1998). The requirements of a seam are more clearly illustrated in Figure 2.1

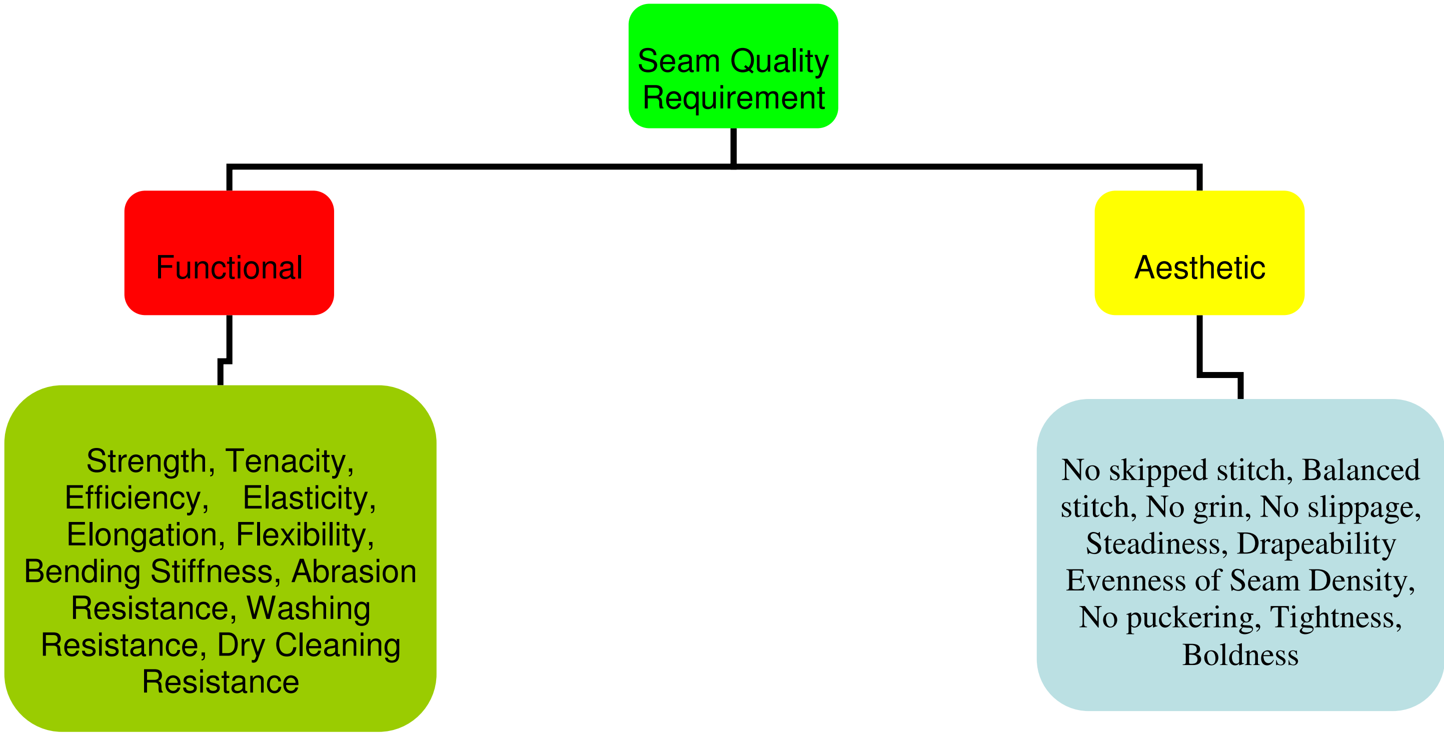


Figure 2.1: Seam quality requirements

The degree of requirement of functional or aesthetic performance of seam also varies, based on the intended use of apparel (Brown, 1992; Glock and Kunz, 1995). For example, a military cloth must provide protection from highly hostile environments. Aesthetic appearance is of comparatively little importance as long as an extensive list of functional needs is required. By contrast, aesthetic performance is of primary importance for bridal wear. For any bride, a high quality gown should possess aesthetic performance- its appearance and design prominence to the wearer are paramount.

In order to understand various seam performances, knowledge of various factors affecting the seam quality is necessary. Seam quality is governed by a broad spectrum of factors including sewing thread type and size, fabric, sewing machine speed, needle kind and size, stitch type and density and operator skills (Salhotra *et al*., 1994; Ito, 1997; Gribaa *et al*., 2006; Krasteva and Petrov, 2008) etc. For better seam quality, it is important to consider the complete harmony of the key fabric properties, sewing thread properties and sewing condition parameters used. The functional and aesthetic performance of the seam line is the result of all these factors.

2.2 Methods used in the previous research for the seam quality evaluation

In the previous research, different methods were used for measuring various dimensions for seam quality evaluation: seam strength, seam efficiency, seam slippage, seam elongation, seam damage, seam puckering and seam boldness. In this section, evaluation methods of these dimensions are discussed in detail.

2.2.1 Seam strength

Seam strength refers to the load required to break a seam. This measure the strength and tenacity of a seam. Two pieces of woven fabric are joined by a seam and if tangential force is applied the seam line, rupture ultimately occurs at or near the seam line. Every seam has two components, fabric and sewing thread. Therefore, seam strength must result from the breakage of either fabric or thread or, in more cases, both simultaneously. Research has revealed that the load required to rupture the seam is usually less than that required to break the unsewn fabric (Behera and Sharma, 1998; Choudhury, 2000).

A large number of studies (Shimazai, 1976; Bhalerao *et al*., 1997; Behera *et al*., 1997a Behera and Sharma, 1998; Choudhury, 2000; Lin, 2004; Mohanta, 2006; Tarafdar *et al*., 2007) have determined the seam strength according to ASTM

1683-04 standards, which express the value of seam strength in terms of maximum force (in Newton (N)) to cause a seam specimen to rupture. This is measured by using the following equation:

$S_s = KS_b$

Where:

S_s = sewn seam strength (N)

K = a constant equal to 1000 for SI units

S_b = observed seam breaking force (N)

The ASTM 1683-04 seam strength standard is worth emphasizing due to its accuracy and ease in processing measurements. Hence, this method is widely used by the apparel industry for the evaluation of seam strength worldwide.

2.2.2 Seam efficiency

Seam efficiency measures the durability along the seam line (Pai *et al*., 1984; Sundaresan *et al*., 1997; Behera, 1997b). Durability is identified as necessary to satisfactory seam's functional performance, and efficient seams are assumed to be more durable than weak ones.

Many studies (Cheng and Poon, 2002; Mohanta, 2006; Tarafdar *et al*., 2007; Gurada, 2008) measured the seam efficiency from the strength tester, based on the pendulum lever principle according to the ASTM 1683-04 standard method. In this method, seam efficiency was measured by using the following equation:

$$\text{Seam efficiency}(\%) = \frac{\text{Seam Tensile Strength}}{\text{Fabric Tensile Strength}} \times 100$$

This ASTM 1683-04 method provides an accurate measure of seam efficiency and thus is widely accepted.

2.2.3 Seam slippage

Seam slippage is expressed as the transverse ratio of seam strength to fabric strength including the ratio of elongation of fabric to the ratio of elongation at the seam (Behera, 1997b; Kothari, 1999). Any movement of the warp and weft yarns away from a seam line under transverse stresses exacerbate the potential slippage.

A lot of scholars (Behera *et al*., 1997a; Behera and Sharma, 1998; Tarafdar *et al*., 2005; Gurada, 2008) have suggested measuring seam slippage according to the ASTM 1683-04 standard for evaluation of seam quality. In this standard, the force required for slippage of 0.6mm of seam has been determined.

The measurement of seam slippage from the ASTM 1683-04 standard is well established as an international standard and most apparel industries follow this method to evaluate seam slippage.

2.2.4 Seam elongation

Seam elongation evaluates the elasticity, flexibility of a seam. Seam elongation is defined as the ratio of the extended length after loading to original length of the seam.

A group of researchers (Kothari, 1999; Rengasamy *et al*., 2002; Chowdhary and Poynor, 2006) evaluated the seam elongation according to the ASTM 1683-04 standard. This standard measures the seam elongation according to the following formula:

$$SE = \frac{EL}{OL} \times 100$$

SE = Seam Elongation (%)

EL= Extended Length

OL= Original Length

The evaluation of seam elongation from ASTM standard is well accepted by the apparel industry because it is an international standard.

2.2.5 Seam damage

Seam damage refers to needle cutting or yarn severance in the fabric during sewing (Sandow, 1990a; Tait, 1997). This is unacceptable in any apparel because it may result in reduced seam strength, poor appearance, or both, due to frayed yarns (Behera *et al*., 1997a; Behera, 1997b). Seam damage is measured by the Needle Cutting Index. To find the Needle Cutting Index, sewing threads are removed from the sewn specimen. The count of the number of fabric yarns and the count of the number of fused yarns in the direction perpendicular to the direction of sewing are used. Behera *et al*., (1997a) measured the seam damage according to its standard formula, which is

$$\text{Needle Cutting Index (\%)} = \frac{\text{No. of yarns cut/unit length}}{\text{No. of yarns in fabric/unit length}} \times 100$$

2.2.6 Seam puckering

Seam puckering in a garment is the uneven appearance of a seam in a smooth fabric. Seam puckering appears along the seam line of garments when the sewing parameters and sewn material properties are not properly selected. This results in a reduction of the aesthetic value of garments. Puckering can occur due to excess fabric and not enough thread in the seam (Lojen and Gersak, 2001; Hennig, 2002; Gersak, 2004; Hu *et al*., 2006).

There are different methods of measuring seam puckering for the evaluation of seam quality. These are the international standard method, laser scanner method, seam length method and thickness strain method. In the following section, these methods are discussed in brief and the best method identified.

2.2.6.1 International standard method (AATCC)

AATCC-88B has been used to measure seam puckering (Gupta *et al*., 1992; Malek *et al*., 1993; Kothari, 1999; Cheng and Poon, 2002; Lin, 2004; Tarfadar *et al*., 2005; Tarafdar *et al*., 2007). This test method is designed to evaluate the puckering of seams after stitching. Evaluation is performed using a standard lighting and viewing area by rating the appearance of the specimen in comparison with an appropriate reference standard provided by AATCC.

The standard AATCC-88B grading method is well accepted but the main limitation of this method is that it is subjective. This causes error and variability between occasions and locations, particularly for fabrics which are patterned and have darker shades. It is also time consuming and involves more people than other methods.

2.2.6.2 Laser scanner method

Another method used for measuring seam puckering is laser scanner. Laser scanner is a useful tool for this purpose (Fan *et al*., 1999; Fan and Liu, 2000; Kang and Lee, 2000; Kang *et al*., 2002; Kim and Kang, 2005), and is used for scanning the picture of the seam. From the scanned picture, asymmetry and pointedness of height distribution of the seam is measured to understand the seam puckering. The logarithm of the average pucker height displacement away from the mean or the logarithm of the variance of the pucker heights can provide an objective measure of seam puckering.

While accurate, the measurement of seam puckering using the laser scanner system is very expensive and complicated. This method is also not applicable to fabrics of a very dark shade. Because it is expensive, complicated and limited in use, it is not generally adopted by apparel engineers for their normal practice.

2.2.6.3 Seam length method

Seam length method can also be used for evaluating seam puckering. A method to measure the seam puckering from seam length has been adopted by previous researchers (Ananthakrishnan and Chengamal, 2005; Dobilaite and Juciene, 2006). The percentage of puckering that occurs in the fabric is calculated as:

$$\text{Seam Puckering}(\%) = \frac{\text{Original length of sample} - \text{Seam length of sample}}{\text{Seam length of sample}} \times 100 .$$

According to Ananthakrishnan and Chengamal (2005) the seam length mainly depends on the sewing thread chosen for a seam. Therefore, the limitation of the seam length method is that it does not pay any attention to the fabric properties for measurement of seam puckering. Moreover, it is very difficult and time consuming to accurately calculate the seam length of a sewn fabric sample. The method to measure the seam puckering from seam length is not used widely because it may not give a clear picture of seam puckering for different fabrics.

2.2.6.4 Thickness strain method

Kothari, 1999 analysed the seam puckering and found that the cause of seam puckering is related to the compressive forces generated on the fabric during sewing from interaction between the sewing thread, fabric and sewing conditions. Seam puckering depends on sewing thread properties, stitch length, thread tension, sewing speed, pressure of pressure foot, needle size, and the fabric's properties and its constituent yarn. However, after analyzing the puckering behaviour of various seamed fabrics in Kothari's study, it has been found that seam puckering depends mainly on the thickness properties of the fabric (Behera, 1997b; Kothari, 1999). As a result, seam puckering should be calculated by measuring the difference in fabric and seam thickness under constant compressive load. Seam puckering is calculated by using the following formula (Behera *et al*., 1997a; Behera, 1997b; Kothari, 1999; Mohanta, 2006):

$$\text{Seam puckering}(\%) = \frac{t_s - 2t}{2t} \times 100$$

[Where, t_s= seam thickness, t= fabric thickness]

has sustainable validity.

This method is widely used for evaluating seam puckering because it is well referred and can give more accurate results than any other method. It is also easy to calculate and is less time consuming than other methods.

2.2.7 Seam boldness

Seam boldness is used to measure the design prominence over seam. Generally, high degree of boldness is required for better ornamentation of apparel (Percy, 2001). The accurate evaluation of seam boldness is essential in the course of garment manufacturing.

The current practice for the assessment of seam boldness is mainly by subjective visual means. Even though there is no international recognised standard for the evaluation of boldness, most apparel manufacturers have set a bench mark for this evaluation based on their past experience. The experienced assessors are required for the subjective evaluation of seam boldness. The evaluation is performed by using a standard lighting and viewing the specimens in five ratings in comparison with the appropriate reference benchmark. Seams are rated in five classes, in which class 5= highest prominence and class 1= no prominence.

2.3 Factors affecting the seam quality

According to many researchers (Chemielowiec *et al*., 1987; Park and Kang, 1999a; Meric and Durmaz, 2005; Tarafdar *et al*., 2007), there are various factors affecting the seam quality. These comprise sewing thread, fabric, sewing condition and others. In this section all the factors will be discussed.

2.3.1 Sewing thread

There are various parameters of sewing thread including type, finish, size, ply and twist, which affect the seam quality (Crook, 1991; West, 1992; West, 1993). These parameters will be discussed in the following sections.

2.3.1.1 Type

Sewing thread types are mainly classified by the type of fibre used in their manufacture and the way the threads are constructed (Ukponamwan *et al*., 2000; Jonaitiene and Stanys, 2005). Sewing threads may be made up of polyester, cotton, viscose, linen etc. In addition, according to method of construction the sewing thread types include are spun, core-spun and filaments etc.

Various types of sewing thread have different levels of properties like shrinkage, strength and elasticity. The high shrinkage and elasticity of sewing thread lead to seam puckering by reducing the thread's length after sewing or during the wash and care procedure of an apparel product (Kithara *et al*., 1964; Munshi *et al*., 1987; Mori and Niwa, 1994; Sandow and Hixon, 1999). However, high strength of sewing thread always gives better seam functional performance, namely seam strength and seam efficiency (Bhatnagar *et al*., 1991; Sundaresan *et al*., 1998).

West (1992, 1993) stated that sewing thread types have considerable effect on seam strength. The author mentioned that there are various types of sewing thread like as- spun polyester, core spun, spun cotton etc. The author compared the seam strength achieved by different sewing thread and concluded that spun polyester sewing thread always gives better seam strength than others. Tarafdar *et al*., (2007) also found that spun polyester can give better seam strength for garment stitched from plain and twill fabrics.

Rengasamy *et al*., (2002) established that sewing thread type has a great influence on seam efficiency. In their study, seam efficiency of sewn fabric stitched with polyester textured threads lies in between those of fabrics stitched with cotton and spun polyester threads, but closer to fabric stitched with spun polyester threads.

Ananthakrishnan and Chengamal (2005) examined the effect of sewing thread type on seam puckering. It was observed that polyester sewing thread generate less pucker than cotton sewing thread in a seam line because these two types of thread have different fibre content. In addition, Yardi (2005) asserted that seam puckering is dependent on sewing thread type which affects the seam's properties like elasticity and flexibility and, in turn lead to seam puckering. Moreover, Dobilaite and Juciene (2006) found that core spun polyester sewing thread leads to higher seam puckering than spun polyester and cotton sewing thread after sewing.

Although there are various types of sewing thread, spun-polyester sewing thread is generally used in the apparel industry due to its good functional and aesthetic performances in the seam during garment use (West, 1993).

2.3.1.2 Finish

Different types of finishes are applied over sewing thread according to the specific end uses of apparel products (Carr and Latham, 1995; Glock and Kunz, 1995). They are lubrication finish, mercerised finish, glazed finish, water resistance finish, soil resistance finish, flame resistance finish etc.

A few researchers (West, 1993; Carr and Latham, 1995) conducted research on the effect of thread finishes on seam quality. They stated that the lubrication finish is used on a sewing thread to assure better seam quality due to its protective nature from needle heat in the course of garment manufacturing. Lubrication finish protects the thread from strength reduction and/or breakage during sewing, which, in turn, produces high seam efficiency and less chance of seam damage (Bhatnagar, 1991; West, 1992).

There are various types of finishes; however, in general the clothing industry tends to use standard lubrication finish for better seam performance in apparel (Ukponamwan *et al*., 2000).

Glock and Kunz (1995) stated that mercerised and glazed cotton thread have higher strength, durability, abrasion resistance than normal soft cotton threads.

Increased strength, durability and abrasion resistance helps to get greater seam efficiency, seam strength and seam slippage. Additionally, they mentioned that other finishes like, water resistance, soil resistance, flame resistance are specific to the end use of the apparel and fabric to be sewn (Ukponamwan *et al*., 2000).

2.3.1.3 Size

The size of sewing thread is denoted by linear density (Tex, cotton count, metric count etc.) or ticket number (equal to three times the metric count of the thread). Tex is the universal system used to represent the sewing thread size (Booth, 1968; Glock and Kunz, 1995).

Various sewing thread sizes have different levels of diameter and strength (Tait, 1997; Robers, 1997). For example, a greater diameter in the sewing thread leads to seam puckering by structural jamming along the seam line (Yardi, 2005; Ananthakrishnan and Chengamal, 2005) and high strength is responsible for good seam efficiency and seam strength etc (Gurarda, 2008).

Pai *et al*., (1984) analysed the impact of different types of cotton sewing thread size on seam efficiency. The authors stated that very coarse sewing thread have more chance to decrease the strength-elongation characteristics during sewing due to friction. Therefore, it always reduces the seam efficiency for any apparel grade fabrics. However, Tait (1997) emphasised that lower sewing thread size is the cause of poor seam efficiency. Generally, lower sewing thread size represents lesser strength than coarser sewing threads, which, in turn reduce the seam efficiency of an apparel product (Mukhopadhya *et al*., 2004; Mohanta, 2006).

Gersak and Knez (1991) showed the impact of sewing thread size on seam strength. Higher sewing thread size was subjected to greater friction during sewing, which ultimately reduced its strength. This consequently led to poor seam strength. On the other hand, Sundaresan *et al*., (1998) found that sewing thread size is one of the important factors affecting seam strength. Generally, higher sewing thread size leads to greater seam strength for any apparel. Lin (2004), Gribaa *et al*., (2006), and Tarafdar *et al*., (2007) also corroborated the fact that higher sewing thread size have strong positive impact on seam strength.

Park and Kang (1999a, 1999b), Kang *et al*., (2002), Lonjen and Gersak (2003) and Kang *et al*., (2005) mentioned that seam puckering appears in garments when sewing thread size is not properly selected. Furthermore, Dobilaite and Juciene (2006) analysed the influence of sewing thread size on seam puckering of lightweight fabrics. It was established that high sewing thread size is responsible for greater seam puckering in the course of garment sewing.

There is a trend in the apparel industry to select the lowest size of thread with the greatest possible strength for making a seam which is less visible and has good seam functional performance (Hennig, 2002; Rengasamy *et al*., 2002). However, in certain cases, greater thread size is required where the seam boldness consideration becomes a decisive dimension for the evaluation of seam quality, denim trousers, blouses, and shirts being typical examples (Behera *et al*., 1997a; Ukponamwan *et al*., 2000).

2.3.1.4 Ply

Kothari (1999) mentioned that number of ply in the sewing thread has considerable effect on seam quality. The author found that more number of ply in a sewing thread ultimately helps to increase the strength of the sewing thread. Increased strength leads to higher seam strength and/or seam efficiency. A chance of seam slippage also becomes lower due to more number of ply in a sewing thread (Ukponamwan *et al*., 2000, Carr and Latham, 1995).

Moreover, West (1993) found that due to more number of ply in a sewing thread the diameter of the thread becomes high. Increased diameter of a sewing thread is the cause of structural jamming along the seam line, which, in turn lead to seam puckering (Glock and Kunz, 1995).

2.3.1.5 Twist

There are generally two types of twist in the sewing thread; Z twist and S twist. Twist is measured in terms of turns per inch or turns per cm.

Ukponamwan *et al*., (2000) concluded that sewing thread twist has significant impact on seam quality. The author stated that if the twist is to low, the yarn may fray and break during sewing, which ultimately reduce the seam strength and/or seam efficiency. On the other hand, if the twist level in a thread is high, the resulting liveliness in the thread may cause snarling, looping, knots or spillage and leads to defects like skipped stitches, broken stitches etc.

Glock and Kunz (1995), Kothari (1999) mentioned that correct and stable twist balance between the needle thread and looper thread is required to prevent the seam defects. If the balance of twist between these two threads is not proper, there is a chance of defects like unbalanced stitches along the seam line.

2.3.2 Fabric properties

Fabric properties which affect the seam quality are discussed by many previous researchers (Chemielowiec *et al*., 1987; Kawabata and Niwa, 1989; Kawabata and

Niwa, 1991; Minazio, 1998; Lin, 2004; Tarafdar *et al.*, 2005). These properties are cover factor, weight, thickness, strength, extensibility, bending rigidity, bending hysterisis, shear rigidity and shear hysterisis. In the following sections these fabric properties are discussed in brief.

2.3.2.1 Cover factor

Cover factor shows the tightness of fabric structure. High cover factor refers to a tighter structure in fabric than low cover factor.

Stylios and Lloyd (1989a), Behera *et al*. (1997a), Tarafdar *et al*. (2005) studied on impact of fabric cover factor on seam puckering. They claimed that due to high cover factor, structural jamming occurs along the seam line during sewing and generates a seam puckering problem (Shiloh, 1971; Schwartz, 1984; Minazio, 1998).

Behera (1997b), Miguel *et al*. (2005), Tarafdar *et al*. (2007) emphasised that fabric cover factor has considerable effect on seam strength and/or seam efficiency. Their study revealed that fabrics with high cover factor have an increased tendency to break the fabric yarns (warp and/or weft) at the time of sewing. The breakage of yarns in fabric ultimately reduces the seam functional performance such as seam strength and seam efficiency (Nergis, 1998; Behera and Sharma, 1998).

2.3.2.2 Weight

The fabric weight is generally calculated in grams per square metre under standard atmospheric conditions.

Stylios and Lloyd (1989b), Behera (1997b), Kang *et al*., 2005 stated that light weight fabrics are more prone to seam puckering than heavy weight ones. Fabrics with a very light weight display less stability, have handling problems in the course of garment manufacturing, and reduce the aesthetic performance of the seam in terms of seam puckering (Kawabata *et al*., 1997; Kawabata and Niwa, 1998).

Chemielowiec (1987), Stjepanovic and Strah (1998), Cheng and Poon (2002), observed that high fabric weight is always the cause of greater fabric strength, which ultimately reduces the seam efficiency of an apparel product. The reason is that seam efficiency is inversely proportional to fabric strength for a given sewing thread (Salter *et al*., 1998; Tarafdar *et al*., 2005).

2.3.2.3 Thickness

Fabric thickness is measured in millimetres (mm) and also has an effect on seam efficiency, seam puckering and seam slippage (Gupta *et al*., 1992; Behera and Sharma, 1998; Mukhopadhyay *et al*., 2004).

According to these researchers, high fabric thickness leads to lower seam efficiency due to high fabric strength and less seam puckering resulting from an increase in in-plane compression resistance at the time of sewing (Stylios and Lloyd, 1989a; Stjepanovic and Strah, 1998; Cheng and Poon, 2002; Tarafdar *et al*., 2005).

Moreover, Behera *et al*. (1997a) and Behera and Sharma (1998) mentioned that resistance of seam slippage increases with the increase in fabric thickness. The reason for this is a higher contact area of sewing thread in a seam for the bulkier mass of fabric.

2.3.2.4 Strength

Fabric strength refers to the load required to break a fabric.

Fabric strength has a significant impact on seam performance, namely seam efficiency and seam puckering (Pai *et al*., 1984; Chemielowiec, 1987; Seiler, 1990; Behera and Sharma, 1998; Kang *et al*., 2002; Lin 2004; Tarafdar *et al*., 2005). These researchers found that high strength of fabric always leads to lower seam efficiency in apparel as the seam efficiency is measured from the ratio of seam strength to fabric strength. In addition, an increase in fabric strength is the cause of less flexibility and cohesiveness of the fabric which leads to a decrease in seam puckering during sewing (Park and Kang, 1999a; Fan and Liu, 2000).

2.3.2.5 Extensibility

Extensibility is one fabric low-stress mechanical property measured in percentage and has an effect on seam quality (Gupta *et al*., 1992; Minazio, 1998; Tarafdar *et al*., 2005).

Kothari (1999) claimed that extensibility is related to the ease of crimp removal of fabric, which, in turn, determines the mobility of threads within the fabric. Mobility of a thread under low load is influenced by seam slippage and/or seam strength and/or seam efficiency. Moreover, highly extensible fabric always tends to return back from stretching after sewing, which generates a seam pucker along the seam line (Sandow, 1990b; Stylios and Sotomi, 1993).

2.3.2.6 Bending rigidity

Bending rigidity is another fabric low stress mechanical property which is measured in terms of gf/cm.

Bending rigidity has a great impact on seam puckering (Stylios and Lloyd, 1989b; Gupta *et al*., 1992; Hes *et al*., 1997; Inui and Yamanka, 1998; Inui *et al*., 2001; Gersak, 2002; Kang *et al*., 2005; Tarafdar *et al*., 2005; Pavlinic *et al*., 2006). These researchers mentioned that fabrics with higher bending rigidity show stronger resistance when bent by external forces encountered during fabric manipulation in sewing. As a result, in-plane compression resistance increases and therefore, the seam pucker value decreases. Furthermore, an increase in bending rigidity causes an increase in fabric strength, which, in turn, decreases the seam efficiency and/or seam slippage (Behera *et al*., 1997a; Behera, 1997b).

2.3.2.7 Bending hysterisis

Bending hysterisis gives a measure of the energy lost by a fabric during bending and has a considerable impact on the quality of seams (Stylios and Lloyd, 1989a; Hes *et al*., 1997). Bending hysterisis is measured in terms of gf.cm/cm.

Taradar *et al* (2005) and Pavlinic *et al* (2006) mentioned that fabrics with lower bending hysterisis ensure better fabric flexibility in the course of sewing. However, too low a value has a detrimental influence on the aesthetic performance of a seam in terms of seam puckering, as fabric cannot compensate for the deformation occurring in the area of a seam.

2.3.2.8 Shear rigidity

Shear rigidity is expressed by gf/cm.deg. In general, easy fabric shear is desirable for yarn mobility and for transfer of local distortion into the bulk of the fabric during sewing.

Shear rigidity also has considerable influence on seam puckering (Stylios and Lloyd, 1989a; Fan and Liu, 2000; Gersak, 2004; Pavlinic *et al*., 2006). These author conclude that if the fabric shear rigidity is high the fabric is stiff enough to resist severe local distortions, during and after sewing, and hence to resist the development of seam puckering. However, Stylios and Lloyd (1989a) also found that in the case of structural jammed fabrics, due to high shear rigidity, they are not strong enough to absorb the local distortion during sewing and seam puckering is developed.

2.3.2.9 Shear hysterisis

Shear hysterisis measured in terms of gf/cm.

According to the previous researchers (Stylios and Lloyd, 1989a; Gersak, 2004) it has been established that low shear hysterisis has a direct impact on seam aesthetic performance. A fabric with low shear hysterisis cannot adopt the deformation in the seam area at the time of sewing. It reflects more or less a puckered seam.

2.3.2.10 Coefficient of friction

Behera and Sharma (1998) found that fabric with different coefficient of friction has significant effect on seam puckering. The authors concluded that fabric with high coefficient of friction is difficult to feed during sewing and generates seam puckering.

Tarafdar *et al*., (2005) corroborated the fact that fabric coefficient of friction has considerable effect on seam quality. In their study fabric with high coefficient of friction showed greater seam puckering along the seam line.

2.3.3 Sewing condition

Bertold and Munden, 1978; Amirbayat and Norton, 1990; Amirbayat and McLauren, 1991; Chemielowiec, 1987; Kang *et al*., 2002; Krasteva and Petrov, 2008 studied that there are various sewing conditions affecting parameters for seam quality. These are stitch type, stitch density, sewing machine speed, needle size, pressure of pressure foot, feed dog, thread tension, needle plate and stitch balance. In the following sections all these parameters are discussed in brief.

2.3.3.1 Stitch type

Solinger (1989), Glock and Kunz (1995), Carr and Latham (1995) stated that stitch configurations vary and there are different reasons behind these configurations. Due to different configurations the amount of thread in a stitch varies as does the interlocking method between two layers of fabric. The amount of thread and various interlocking methods result in different levels of seam efficiency and seam puckering along the seam line (Lin, 2004; Tarafdar *et al*., 2007).

2.3.3.2 Seam type

Chmielowiec (1987) found that double seam shows the greater seam efficiency than plain seam. Mohanta (2006) studied the impact of various seam types on seam quality. It was observed that bound seam showed more strength than plain seam. These authors mentioned that generally, more number of layers of fabric in a seam, the more will be seam efficiency.

2.3.3.3 Stitch density

Stitch density is specified as the number of stitches per inch (spi) and has significant effect on seam quality (Glock and Kunz, 1995; Tarafdar *et al*., 2007; Gurarda, 2008).

Glock and Kunz (1995) studied the effect of stitch density on seam quality. They found that a high stitches per inch (spi) means short stitches; and a low spi means long stitches. Long stitches are usually less durable and considered to be of lower quality because they are subject to abrasion and likely to snag. Shorter stitches produce more subtle, less obvious lines of stitches that are often more visually appealing. Generally, the greater the number of stitches per inch in a seam, the greater the seam efficiency and strength (Mukhpadhaya *et al*., 2004; Tarafdar *et* *al*., 2007; Gurarda, 2008). However, in certain fabric, too many stitches can cause seam damage by cutting the fabric yarn. A high stitch density also has potential to increase seam puckering due to structural jamming along the seam line.

2.3.3.4 Sewing machine speed

Modern sewing machine speed can reach up to 5,500 stitches a minute. Rogale (2003), Tait (1997), Kothari (1999) analysed the fact that in a high speed sewing machine the movement of the sewing needle is higher. Due to the high needle speed, heat generation takes place at the surface of the needle. Excessive heat in and around the surface of the needle may create a seam damage problem by cutting the fabric yarn (Sundaresan *et al*., 1998). This damage is the cause of poor seam efficiency and appearance in a garment (Krasteva and Petrov, 2008).

2.3.3.5 Needle size

The needle size refers to the diameter of the needle. There are different needle size systems in the apparel industry such as the metric system, singer system etc (Carr and Latham, 1995). The metric system is the simplest and most widely used in the apparel industry. A higher the metric count represents a greater needle diameter.

According to Carr and Latham (1995), Tait, 1997, Nergis, 1998, Mohanta, 2006 a higher needle size may be the cause of seam damage because there is more possibility of breaking the fabric yarn when using a needle with greater diameter. However, due to the use of a lower needle size the chance of sewing thread strength loss and/or breakage is high (because of friction between sewing thread and needle eye), which, in turn, reduces the seam strength and/or seam efficiency. The chance of seam slippage also becomes very high (Salhotra *et al*., 1994; Gotlih, 1997; Gurarda, 2008).

2.3.3.6 Pressure of pressure foot

The pressure foot is required to hold the fabric firmly during sewing, thus preventing the fabric from rising and falling with the needle. Inadequate pressure of the pressure foot reduces the aesthetic performance of the seam (Park and Kang, 1999b; Krasteva and Petrov, 2008). Solinger (1989), Glock and Kunz (1995) mentioned that due to low pressure of the pressure foot control of the sewn fabric will be reduced under the needle at the time of sewing. Improper control will displace the fabric from the normal sewing position and reduce the aesthetic performance of the seam due to puckering and/or staggered stitching.

2.3.3.7 Feed dog

The feed dog consists of a toothed surface (Carr and Latham, 1995). The purpose of the feed dog is to move the fabric along by a predetermined amount between successive stitches. The feed dog is selected based on tooth pitch (distance from the peak to the peak of the tooth)

Inappropriate tooth pitch will hinder the fabric's movement along the seam line (Henning, 2002). Carr and Latham (1995) acknowledged that due to improper movement the needle will strike continuously at the same place in the fabric resulting in a high possibility of seam damage. Glock and Kunz (1995) informed that improper selection of feed dog may generate uneven stitch density during sewing. Moreover, improper movement may generate seam puckering in the course of garment manufacturing (Park and Kang, 1999a; Kang and Lee, 2000).

2.3.3.8 Thread tension

At the time of sewing, sewing thread should be guided through tension discs to control the thread tension. Improper thread tension will create seam quality problems (Nergis 1998; Tarafdar *et al*., 2007).

Pai *et al*. (1984), Gersak and Knez (1991) found that due to high thread tension the chance of sewing thread strength loss and/or breakage becomes high, which ultimately reduces the seam strength (Stylios *et al*., 1992). In addition, Park and Kang (1999a) stated that high tension is the cause of stretch in sewing thread. Thus, after sewing, sewing thread tries to come back to its original position and creates seam puckering and/or waviness.

Glock and Kunz (1995) mentioned that if too much tension is placed on the thread the thread will restricts and compress the fabric that it surrounds. A tight thread will also draw a looser thread over the edge of a seam allowance, which causes an unbalanced stitch. They concluded that due to high tension seam pucker, uneven stitches, unbalanced stitches and seam damage problems occurs in the course of garment manufacturing. Additionally, Glock and Kunz also highlighted that too little tension may allow too much thread to be pulled off and cause excessive looping or loose and skipped stitches.

Tarafdar *et al*., 2007 studied the effect of thread tension on seam aesthetic performance. They found that due to high thread tension of the upper thread, after stitch formation the lower thread will be visible on the upper side. Visibility of the lower thread on the upper side will create the problem of unbalanced stitch.

2.3.3.9 Needle plate

The function of the needle plate is to provide a smooth, flat surface over which the fabric passes as successive stitches are formed. It has a hole through which the needle passes as it goes up and down. The needle hole should be only about 30 percent larger than the size of the needle. If the size of the hole is not according to the needle size, a seam quality problem will be created (Krasteva and Petrov, 2008).

Carr and Latham (1995) mentioned that the use of a high needle hole means that fabric can be passed into the hole with each penetration of the needle at sewing. This will reduce the aesthetic performance of the seam by flagging. Furthermore, too low a needle hole will increase the risk of breakage of the needle, resulting in a higher possibility of seam damage.

2.3.4 Others

According to several researchers (Ng and Hui, 2000; Kang *et al*., 2002; Rogale *et al*., 2003) there are two other factors which affect the seam quality. They are the human factor and environmental factor. In the following sections these factors will be discussed in brief.

2.3.4.1 Human factors

The apparel industry is a very labour intensive industry. Considerable labour is required for apparel manufacturing. If the operator is lacking in skill a seam quality problem will be generated during sewing (Ng and Hui, 2000).

Solinger (1989), Carr and Latham (1995) noted that the lack of skill of the operator may create a handling problem of the fabric parts in the course of garment manufacturing. Excessive or improper handling and positioning of the fabric parts during sewing lead to seam puckering. Furthermore, if the operator is unable to handle the sewing machine properly, there is a chance of seam damage due to frequent needle breakage.

2.3.4.2. Environmental factors

Parimalam *et al*. (2006) investigated on the environmental factors of garment industry and its effect. They concluded that congested work area, improper ventilation, dust, unergonomic work station, excessive noise, high temperature and humidity inside the apparel plant are the biggest problems. They also found that all these problems reduce the concentration and skill of the operator to work. Due to poor concentration and reduction of the skill, the operator can not properly handle the garment parts during stitching. Therefore, it generates puckering problem along the seam line (Glock and Kunz, 1995). High humidity and temperature also reduced the strength of sewing thread during sewing. This produced poor seam strength and/or seam efficiency along the seam line.

2.3.5 Conclusions

Based on the discussion in the section 2.3, the following conclusions can be drawn.

There are various factors for seam quality: fabric properties, sewing thread and sewing conditions and others (human factors, environmental factors). Fabric is the basic raw material for the apparel products. Generally, all the fabric properties such as, weight, cover factor, thickness, strength, extensibility, bending rigidity, bending hysterisis, shear rigidity, shear hysterisis and coefficient of friction have considerable effect on seam quality of apparel products.

The different parameters of sewing thread are type, ply, finish, twist and size would have definite effect on functional and aesthetic performance of seam. If there is no special requirement, the apparel industry mainly select the spun-polyester, 3-ply, normal twist and standard finish sewing thread for all types of sewn fabrics (Ukponamwan *et al*., 2000). However, the size of the sewing thread is the most crucial for that seam quality as the improper selection of sewing thread size directly affects the seam quality of apparel products.

There is also a lot of sewing conditions such as stitch type, seam type, stitch density, sewing machine speed, needle size, pressure of pressure foot, feed dog, thread tension and needle plate, which affect the seam quality. Among the above mentioned sewing conditions, stitch density is the only attribute, which can vary at different seam locations and has direct impact on the quality level of apparel products (Gloack and Kunz, 1995; Tarafdar *et al*., 2007). Therefore, stitch density deemed to be a most important sewing condition in the course of garment manufacturing. The remaining sewing conditions are adjusted during the course of apparel manufacturing based on the thread size and/or the material to be sewn. So, these are not considered as important factors for seam quality analysis in the present study.

The human factors and environmental factors are normally kept constant in the apparel industry to maintain the consistent quality level in the apparel products (Parimalam *et al*., 2006).

2.4 Remaining gap in the literatures

Inadequacies in the previous studies are discussed below to identify the remaining gap which the present study attempts to fill.

Chmielowiec's (1987) study highlighted seam quality and, in particular, seam strength and seam efficiency as dimensions for measuring seam quality. He found that evaluation of seam efficiency is more important for apparel because it helps to measure the longevity of the apparel products during heavy laundering. The investigation was carried out on two types of fabrics (2/1 twill and 4/1 twill) using two different sizes sewing thread (8 tex/2 and 9 tex/2) and four different types of stitch density (32, 36, 40 and 44 stitch per 10 cm). Through statistical analysis it was found that seam strength and seam efficiency affected by many factors including sewing thread size, stitch type and stitch density. This study is very useful for analysis of seam quality. However, the limitation of the study is that the author's did not shed any light on seam aesthetic performance. Moreover, this study considered only cotton fabric and two types of sewing thread size for the evaluation of seam quality. The impact of fabric properties on seam quality was not analysed in the study.

Gupta *et al*., (1992) analysed the seam quality of five plain weave fabrics which typically appear in women's casual and business dresses and shirting. These authors contended that seam puckering is the most effective dimension for evaluating seam quality. Their research showed that bending rigidity and shear rigidity of fabric have considerable effect on seam puckering. However, the findings were not analysed statistically. In addition to that they did not consider any dimension of functional performance for evaluating seam quality. Their study also evaluated seam puckering by using AATCC standard, which is subjective. A subjective evaluation may not give the accurate results for the evaluation of seam puckering.

Behera *et al*., (1997a) studied the seam quality of denim fabric. They evaluated seam quality by measuring each of these five dimensions: seam strength, seam efficiency, seam slippage, seam puckering and seam damage. In their study, five different fabrics (6.5, 10, 12.5, 14.5, 15.5 oz/yd^2) and 12 different sizes of sewing thread was used for seam quality evaluation. Regression analysis was carried out to understand the various affecting factors for seam quality. The result revealed that for light weight fabric (6.5 oz/yd^2) seam strength, seam efficiency increased with lower sewing thread size, whereas seam pucker, seam damage and seam slippage decreased. The reverse trend was observed in the case of medium (10, 12.5 oz/yd^2) and high weight (14.5, 15.5 oz/yd^2) fabrics. Although, the authors studied five dimensions for evaluating seam quality, they did not place enough emphasis on seam quality by considering all the dimensions together. Thus, the most obvious limitation of the study lies in fact that it can not provide any knowledge on the overall seam quality. In addition, although the authors highlighted the seam quality of denim fabric, in which seam boldness is a prime dimension for evaluating seam quality, they did not study this.

Bhalerao *et al*., (1997) experimented on seam quality of apparel grade fabrics. Seam strength and seam efficiency were measured to assess seam quality in 2/1 twill fabrics. ASTM standards were used to evaluate the seam quality. The investigation was carried out by using two types of seam (plain and double stitched), sewing thread (70 and 50 ticket no.) and stitch density (12 and 10 stitches per inch). It was found that seam strength and seam efficiency increased with higher stitch density and lower ticket number sewing thread size. Additionally, seam strength and seam efficiency also affected by seam type- plain seam strength and efficiency was less than double stitched seam. The authors put considerable effort in evaluating seam quality. However, the author analysed the seam quality only for functional performance. Their study did not consider seam aesthetic performance for the evaluation of seam quality. Additionally, the sample size for the selected fabric was also very low.

Behera and Sharma (1998) studied seam quality for suiting and shirting fabrics of polyester/viscose, linen, cotton etc. by evaluating seam strength, seam efficiency and seam slippage. Seam was prepared by using 3200 stitches/min machine speed, 16 needle size and 8 stitches/inch. Multiple linear regression modelling methodology was used for the analysis seam quality. It was concluded that seam efficiency decreased with increase in fabric strength, bending rigidity, cover factor and thickness. Furthermore, seam slippage increased with the increase in fabric weight, thickness and cover factor in both suiting and shirting fabrics. Although, the authors made considerable effort, their study focus mainly on the functional performance of a seam, the aesthetic performance is not considered in their study. In their study, the number of seam specimen for seam quality evaluation was also very low.

Cheng and Poon (2002) evaluated seam quality of plain, 2/1 twill, 3/1 twill fabrics using spun polyester sewing thread at 12 stitches per inch. The authors emphasised that the seam quality can evaluated by seam efficiency, and seam slippage. Correlation coefficient was calculated to understand the various factors affecting the seam quality. From their study, factors which affect seam efficiency and seam slippage included fabric weight, thickness and extensibility. They observed that heavier and thicker fabric leads to lower the seam efficiency. In addition, seam efficiency is higher when fabric extensibility is greater. In their study, although the authors studied the correlation coefficient of various factor with seam efficiency and seam slippage, they did not formulate any regression models for seam quality evaluation. Moreover, they neglected seam aesthetic performance in their study for seam quality evaluation.

Lin (2004) analysed the seam quality of polyester, silk, polyester/cotton blend, polyester/rayon blend and cotton fabrics in combination with cotton/polyester sewing thread. The author evaluated seam strength and seam puckering as dimensions for seam quality evaluation. He found that fabric strength, thickness, sewing thread size has positive dependency on seam strength. On the other hand, fabric cover factor has negative correlation with seam puckering. Lin's study evaluates two dimensions – seam strength and seam puckering for analysing seam quality. However, the importance of these two dimensions on overall seam quality was not calculated. There was also no information about the seam quality of different apparel products.

Tarafdar *et al*., (2005) analysed the seam quality of suiting and shirting fabrics. The authors selected polyester, cotton, polyester/cotton, polyester/viscose fabric for the evaluation of seam quality. Sewing was carried out in a singer sewing machine with 3200 stitches/min, at 8 spi with needle size 16 for each seam specimen. Seam efficiency, seam puckering and seam slippage were measured for evaluating seam quality. The authors found that seam efficiency decreased with the increase in fabric strength, bending rigidity and bending hysterisis. In the case of seam pucker, it is increased with the increase of fabric thickness, weight and cover factor of shirting fabric, whereas a decreasing trend was observed when the bending rigidity increased. By contrast for suiting fabric seam pucker decreased with the increase of weight, extensibility, bending rigidity and thickness of the fabric. Although the authors mentioned that fabric properties have an impact on seam quality, any statistical interpretation was missing. Moreover, the author did not study the relative importance of seam efficiency, seam puckering and seam slippage on overall seam quality of the suiting and shirting fabrics.

Mohanta (2006) studied on seam quality of cotton, polyester and cotton-polyester fabric using cotton and polyester sewing thread. Sewing was done on industrial sewing machine using three different needle sizes- 11, 14 and 16. The author measured the seam efficiency for seam quality evaluation. Her study found that seam efficiency is positively correlated with sewing thread size. The author studied seam functional performance elaborately; however, she did not focus on seam aesthetic performance. On the other hand, stitch density and fabric properties are the major contributor for seam efficiency, but there was no information about the effect of these seam quality in her study.

Tarafdar *et al*., (2007) studied on seam quality of garment stitched from plain and twill fabrics. The authors evaluated seam quality in terms of three dimensions – seam strength, seam efficiency and seam slippage. Two types of 100% cotton fabrics of different construction [plain (136×68) and Twill (138×68)] were stitched by six different stitch densities (6, 8, 9, 10, 12 and 13 stitches/inch) for the analysis of seam quality. The authors found that stitch density, thread size adversely affects the seam efficiency, seam strength and seam slippage. They objectively measured seam strength, seam efficiency and seam slippage in different position of the garment. However, they neglected the seam aesthetic performance. Moreover, the authors did not adopt any systematic approach for predicting the seam efficiency, seam strength and seam slippage.

Karsteva and Petrov's (2008) study measured the seam quality of light weight fabrics. Seam strength, seam elongation and seam puckering was evaluated by considering its three affecting factors including straining of the upper thread, needle size and load on the pressure foot. Their formulated model is very helpful for optimisation of seam quality. However, the authors evaluated these dimensions only for the lightweight fabrics. In addition, their formulated models were not validated and applied for the seam quality of apparel products. Therefore, no information provided by the authors regarding the relative importance of seam strength, seam efficiency and seam puckering on overall seam quality. The authors also chose three factors which predominantly affect the seam quality by interview with experts. But, they did not carried out any statistical test like factor analysis, principal component analysis for determining the key factors. In addition, their formulated model did not consider any fabric properties for the evaluation of seam quality.

Gurarda (2008) investigated the seam quality of PET/Nylon-elastane woven fabrics. Plain and twill weave pet/nylon fabrics were stitched by spun-polyester sewing thread of 80 and 140 Ticket number. Gurarda's recent study evaluated seam quality by focusing on three individual dimensions- seam efficiency, seam strength and seam slippage. His study on seam quality of PET/Nylon elastane woven fabrics demonstrated that seam efficiency depended on various factors such as, stitch type, stitch density, fabric properties, sewing thread size, and needle size. Additionally, seam slippage also affected by stitch density and thread size. It has been shown that, at the seams of elastane woven fabric when the thread size increased seam strength and seam efficiency also increased. Moreover, high fabric extensibility and stitch density is the cause of high seam strength, seam efficiency and seam slippage. The author studied all the three dimensions (seam strength, seam efficiency and seam slippage) extensively. However, Gurarda's study focused on the functional performance of the seam only, but the aesthetic aspects is not included. Another limitation of his study is that he evaluated seam quality using only two types of sewing thread size.

Although previous researchers put considerable effort into evaluating the seam quality, the restriction of their studies is that all studied seam quality using an individual dimension either based on functional or aesthetic performance. Moreover, the previous researchers did not carried out any studies on seam boldness, which is one of the important dimensions for evaluating the design prominence of a seam. Thus, their study of seam quality is limited, fragmented and rarely deep enough. Until the present, very limited work has been undertaken on seam quality by considering its seam functional and aesthetic performance together.

A study which considers both functional and aesthetic performance of seam together will definitely contribute to the knowledge of the overall seam quality for apparel products. A knowledge on the overall seam quality will help the apparel engineers to evaluate the quality of apparel products more precisely, when a particular sewing thread size and stitch density are applied on a particular type of fabric. This will facilitate the apparel engineers for proper planning and control of quality during the course of apparel manufacturing.

CHAPTER 3

CRITICAL DIMENSIONS FOR SEAM QUALITY EVALUATION

The previous chapter discussed that there are several functional and aesthetic requirements for a good quality seam. Seam quality is evaluated based on various dimensions: seam efficiency, seam elongation, seam bending stiffness, seam abrasion resistance, seam density, seam slippage, seam puckering, seam tightness, seam boldness and seam damage (Glock and Kunz, 1995). Seam efficiency, seam elongation, seam density, seam slippage, seam bending stiffness and seam abrasion resistance are the dimensions for functional performance of the seam. In contrast, seam puckering, seam tightness, seam boldness and seam damage are mainly evaluated for better aesthetic performance of the seam.

There are several dimensions for seam quality evaluation. In order to simplify the analysis of seam quality, it is essential to choose only most important evaluating dimensions, which can well represent the overall seam quality. This study tried to identify the most important dimensions for the seam quality evaluation through subjective ranking. The three most important dimensions are termed as "critical dimensions for seam quality evaluation".

3.1 Selection of judges

The selection of judges is an important element for the subjective ranking in order to achieve greater reliability and consistency. In this study, there were two criteria for the selection of the judges – 1) working experience in the clothing industry, 2) research experience in the clothing field. It was assumed that a group of judges with industrial experience as well as research experience can maintain reliability and consistency during subjective ranking. The judges were selected from the Institute of Textiles and Clothing (ITC), the Hong Kong Polytechnic University, Hong Kong; as ITC is regarded as a well renowned research institute for textiles and clothing in all over the world. The working experiences of 30 researchers of this institute were collected through personal discussion with each of the researchers. It was found that ten researchers had industrial experiences in the garment field prior to their research work in ITC. They had diverse work experiences in areas such as apparel quality control, apparel design and apparel manufacturing. The particulars of the selected ten judges for the present study were as shown in Table 3.1.

Table 3.1: Judges background

No. of researchers	Research area	Industry experience
2	Apparel Production	More than 7 years (Apparel production)
4	Apparel Design	More than 9 years (Apparel design)
4	Apparel Quality control	More than 10 years (Apparel quality control)

3.2 Subjective ranking

In order to evaluate the most important dimension for the seam quality evaluation, at first, every dimension is given a number. The numbers are showed in Table 3.2.

Table 3.2: Numbering of the dimensions for the evaluation of seam quality

Sr. No	Dimensions for seam quality evaluation
1	Seam efficiency
2	Seam elongation
3	Seam bending stiffness
4	Seam abrasion resistance
5	Seam density
6	Seam slippage
7	Seam puckering
8	Seam tightness
9	Seam boldness
10	Seam damage

Every researcher (identified from A-J) was asked to rank the importance of each dimension in seam quality evaluation on a scale of 1-10. Questionnaire provided to each researchers are shown in Appendix I. The ranking given by different researchers for the dimensions are shown in Table 3.3.

Table 3.3: Rank given by the researchers

Dimensions for seam quality evaluation		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ranking by judges	**A**	10	8	4	9	6	5	10	5	10	6
	B	10	10	10	8	6	10	10	6	10	8
	C	10	8	7	10	7	10	10	9	9	9
	D	10	8	6	8	8	6	10	8	9	7
	E	9	6	7	9	8	9	9	8	10	8
	F	8	5	1	6	8	8	10	4	6	3
	G	10	10	5	8	3	5	10	6	10	6
	H	8	8	7	8	6	8	9	8	7	3
	I	8	7	5	7	6	6	9	7	6	6
	J	10	5	8	7	4	10	10	5	9	4
Rank total		93	75	60	80	62	77	97	66	86	60

If all the researchers were in complete agreement on rank, the rank total would be

10 (1+2+3+4+5+6+7+8+9+10)

$= 10 \times 55$

= 550.

Moreover, if all the researchers had shown no ability in ranking the dimensions, the ranking number would be at random. Therefore, the rank total would be equal and be one tenth of the total 550, equal to 55. The actual rank totals are now compared (Table 3.4) with 55 to calculate the coefficient of concordance (W).

Table 3.4: Rank comparison

Dimensions for seam quality evaluation	**Rank total (R.T)**	**Difference (d) $\lvert 55 - R.T \rvert$**	**(Difference)^2 d^2**
1	93	38	1444
2	75	20	400
3	60	5	25
4	80	25	625
5	62	7	49
6	77	22	484
7	97	42	1764
8	66	11	121
9	86	31	961
10	60	5	25
			5898 (Sum of d^2= S)

Let, S= the sum of the squares of the difference = 5898

m = the number of judges = 10

n = the number of seam quality evaluating dimensions = 10

The measure of the degree of agreement among the researchers is given by the coefficient of concordance (W),

$$W = \frac{S}{[m^2(n^3 - n)]/12}$$

In this example,

$$W = \frac{5898}{[10^2(10^3 - 10)]/12}$$

$= 0.71$

Thus, the ten researchers in this case exhibited a high degree of agreement on the ranking of the dimensions for the evaluation of seam quality.

The significance of the concordance may be tested by reference to the F tables. In order to do so first, the value of W is modified by changing it numerator and denominator.

1) Subtracted 1 from S
2) Added 2 to the divisor [$m^2(n^3\text{-}n)]/12$

Thus, S = 5898 – 1= 5897

The divisor = 8250 + 2= 8252

Hence, W = 5897/ 8252= 0.71 approx.

$\therefore$ Two estimates of the degree of freedom:

The greater estimate = $(n-1)-\dfrac{2}{m}$ = 9 – 2/10 = 8.8

The lesser estimate = $(m-1)[(n-1)-\dfrac{2}{m}]$ = 9 $\times$ 8.8 = 79.2

The value for F is then calculated:

$$F=\frac{(m-1)W}{(1-W)}=\frac{9\times 0.71}{1-0.71}=22.03$$

The calculated value of F, 22.03, is well above the 1 per cent level of F, 2.82, for degrees of freedom of 8 and 79.

Therefore, from the coefficient of concordance of value 0.71, it can be concluded that the ten researchers are in close agreement. This closeness is not due to chance because the F-value (22.03) is well above the 1% level of F (for degrees of freedom 8 and 79). The final ranking may now be made by considering the rank totals and given in Table 3.5.

Table 3.5: Final rank

Dimensions for seam quality evaluation	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Rank total	93	75	60	80	62	77	97	66	86	60
Final Rank	2	6	9	4	8	5	1	7	3	9

It is clear from the Table 3.5 that seam puckering, seam efficiency and seam boldness are the three critical dimensions for the evaluation of seam quality based on experts' viewpoints. The seam efficiency is used to evaluate the functional performance of seam in terms of durability (Kothari, 1999; Mohanta, 2006). Seam puckering and seam boldness are the two dimensions for the evaluation of seam aesthetic performance. Seam puckering used to measure the appearance along the seam line (Ananthakrishnan and Chengamal, 2005). Seam boldness is the dimension for evaluating the design prominence of the seam (Technical Bulletin, 2006).

CHAPTER 4

RESEARCH METHODOLOGY

This study was carried out in four steps. They were: experimental design, model formulation and evaluation, model validation and model application. The research framework of this study is illustrated in Figure 4.1.

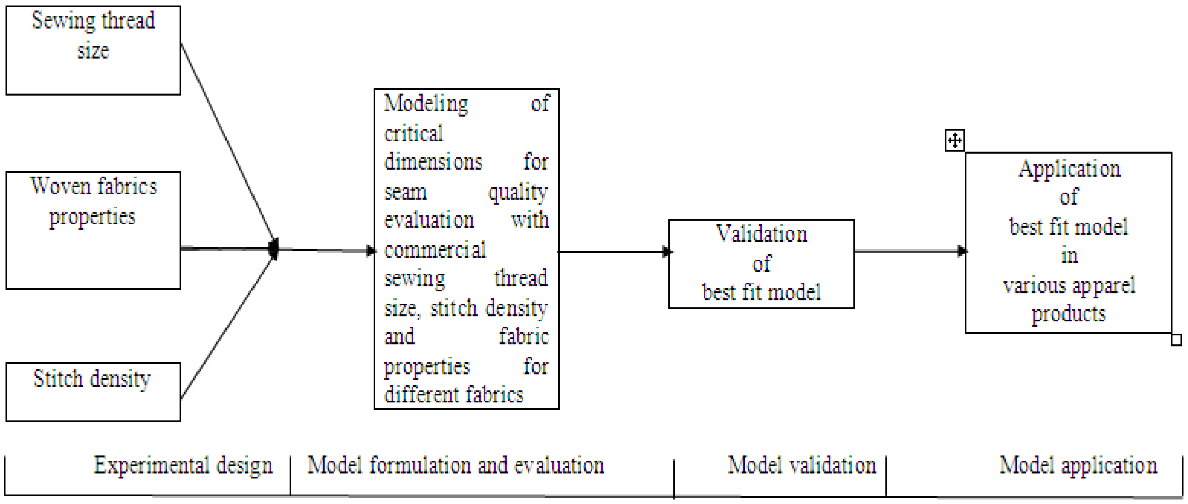


Figure 4.1: Research framework

4.1 Experimental design

In order to analyze the seam quality, at first, sewing thread and fabrics were selected. Then the selected fabrics were sewn by various sizes of sewing thread using different types of stitch density. Critical dimensions for seam quality evaluation: seam efficiency, seam puckering and seam boldness were measured from the prepared seam specimen. The properties of the selected fabrics were also measured by Kawabata Evaluation System or ASTM method. Finally, the key input variables for seam quality were identified by covariance analysis, regression analysis and factor analysis for multiple regressions modeling on seam efficiency, seam puckering and seam boldness.

4.1.1 Selection of sewing threads samples

Commercially available sewing threads, supplied by "Gunzental Limited, Hong Kong"- were employed in this study. In order to investigate the effect of sewing thread size on seam quality, 100% spun polyester sewing threads of seven different sizes were selected to prepare the seam specimens.

The seven sewing thread sizes: 18 Tex, 21 Tex, 30 Tex, 35 Tex, 45 Tex, 60 Tex and 90 Tex, were selected for this study. The selected seven sewing thread sizes are commonly used in apparel industry for different types of apparel products, depending on fabric properties. The details of the sewing thread samples are given in Table 4.1.

Table 4.1: Sewing threads samples

Sewing Thread Sample	Composition	Construction	Ticket number	Linear density (Tex)
1	Polyester	Spun	180	18
2	Polyester	Spun	140	21
3	Polyester	Spun	120	30
4	Polyester	Spun	100	35
5	Polyester	Spun	75	45
6	Polyester	Spun	50	60
7	Polyester	Spun	30	90

(Number of ply =3; Twist = 18 Twist per inch; Finish = Lubrication finish)

Spun polyester sewing threads dominate the apparel industry because they provide durable and stable seams with good sewing performance. Their versatile nature makes them appropriate for the manufacturing of normal apparel products (West, 1992; Reinsch, 1997). These were the reasons for choosing spun polyester sewing thread in the present study of seam quality.

4.1.2 Selection of fabric samples

Cotton, cotton-polyester and cotton-spandex fabrics of different constructions were used to investigate the effects of fabric properties on seam quality. Fifty typical commercially available woven fabrics were selected for the study. Among these fabric samples there were – 20 cotton fabrics, 15 cotton-polyester fabrics (65% cotton and 35% polyester) and 15 cotton-spandex fabrics (97 % cotton and 3% spandex). The lists of fabric samples, along with their constructional details, are given in Table 4.2.

Table 4.2: Fabric samples

Fabric Sample	Weave	Material	Ends/inch	Picks/inch
1	Plain	Cotton	32	18
2	Plain	Cotton	24	13
3	Plain	Cotton	39	26
4	Plain	Cotton	46	28
5	Plain	Cotton	72	40
6	Plain	Cotton	94	48
7	Plain	Cotton	104	53
8	Plain	Cotton	90	50
9	Plain	Cotton	128	70
10	Plain	Cotton	60	44
11	Plain	Cotton	136	62
12	Plain	Cotton	60	60
13	Plain	Cotton	130	70
14	Plain	Cotton	104	53
15	Plain	Cotton	160	78
16	Plain	Cotton	136	62
17	Plain	Cotton	164	62

18	Plain	Cotton	130	70
19	Plain	Cotton	104	53
20	Plain	Cotton	160	78
21	Plain	Cotton -Polyester	136	62
22	Plain	Cotton -Polyester	164	62
23	Plain	Cotton - Polyester	130	80
24	Plain	Cotton - Polyester	72	72
25	Plain	Cotton -Polyester	60	60
26	Plain	Cotton - Polyester	172	70
27	Plain	Cotton- Polyester	170	120
28	Plain	Cotton - Polyester	110	53
29	Plain	Cotton - Polyester	56	54
30	Plain	Cotton - Polyester	150	80
31	Plain	Cotton - Polyester	190	60
32	Plain	Cotton - Polyester	110	76
33	Plain	Cotton - Polyester	51	47
34	Plain	Cotton - Polyester	156	60
35	Plain	Cotton - Polyester	196	92
36	Plain	Cotton - Spandex	164	78
37	Plain	Cotton - Spandex	124	44
38	Plain	Cotton - Spandex	126	58
39	Plain	Cotton - Spandex	156	50

40	Plain	Cotton - Spandex	66	40
41	Plain	Cotton - Spandex	132	58
42	Plain	Cotton - Spandex	150	76
43	Plain	Cotton - Spandex	94	46
44	Plain	Cotton - Spandex	100	60
45	Plain	Cotton - Spandex	92	52
46	Plain	Cotton - Spandex	132	58
47	Plain	Cotton - Spandex	66	52
48	Plain	Cotton - Spandex	64	48
49	Plain	Cotton - Spandex	190	60
50	Plain	Cotton - Spandex	96	56

Cotton, cotton-polyester (65% cotton and 35% polyester) and cotton-spandex (97 % cotton and 3% spandex) are the most popular fabrics in apparel manufacturing industry. These fabrics generally give better quality and overall performance including comfort- the criteria welcomed by customers today.

4.1.3 Specimen preparation

To prepare each seam specimen for the study of seam quality the selected fabric samples (see section 4.1.2) were sewn by seven sewing thread sizes (see section

4.1.1). The most conventional plain seam type (ISO 1.01.01) was selected to sew all the fabrics. All fabric samples were sewn in single needle lockstitch (ISO 301) in the warp direction. The lockstitch and plain seam is most frequently used in the apparel industry.

The whole sewing process in this study was carried in The Hong Kong Polytechnic University, Institute of Textiles and Clothing garment workshop. It was performed on an industrial sewing machine at a speed of 3000 stiches/minute which is commercially used in apparel manufacturing. Three different stitch densities commonly used for the sewing of woven fabrics were selected for the study; they were 6 stitches per inch, 10 stitches per inch, and 14 stitches per inch. For all the stitches- needle thread tension, bobbin thread tension and pressure of pressure foot was constant.

The sizes of sewing needle were selected to match the size of sewing thread employed (section 4.1.1). Two different needle sizes were used according to the sewing thread size: a needle size 11 was used for sewing thread sizes 18 Tex, 21 Tex, 30 Tex and 35 Tex. For sewing thread sizes 45 Tex, 60 Tex and 90 Tex- a needle size 14 was used.

To measure the critical dimensions of seam quality evaluation, five seam specimens (2 for seam efficiency, 2 for seam puckering and 1 for seam boldness) were prepared for each fabric sample. As stated earlier, there were altogether 50 fabric samples and seven sewing thread sizes in this study and for each sewing thread size there were two samples. In total, for three types of stitch density, 10,500 seam specimens were prepared for this study. The number of specimens used for seam efficiency, seam puckering and seam boldness measurements were 4200, 4200 and 2100 respectively.

Different methods were used to prepare the sewn samples for seam efficiency, seam puckering and seam boldness. The specimen for seam efficiency was prepared according to the ASTM D 1683 standards. The diagram of the seam specimen for seam efficiency is shown in Appendix II. For seam puckering and seam boldness, $20cm \times 20cm$ of each fabric sample were cut parallel to the length and width. The seam specimens were prepared in such a way that the existing seams ran through the middle of each specimen. Any wrinkled fabrics were ironed before preparation of the seam specimen.

4.1.4 Measurement of fabric properties

Different fabric properties which primarily affect the seam quality were measured to carry out the present study. These properties were: cover factor, weight, strength, shear rigidity, shear hysterisis, extensibility, bending rigidity, bending hysterisis, thickness and coefficient of friction. The measurement procedures for all these properties are briefly discussed below.

4.1.4.1 Cover factor

The cloth cover factor was calculated using the following formula (Booth, 1968).

Cloth cover factor $K_c = K_1 + K_2 - \frac{K_1 + K_2}{28}$

Warp cover factor (K_1) = $\frac{n_1}{\sqrt{N_1}}$; Weft cover factor (K_2) = $\frac{n_2}{\sqrt{N_2}}$

[Where, n_1 = Ends/inch, n_2 = Picks/inch, N_1 = Warp count, N_2 = Weft count]

To determine the cover factor, ends/inch and picks/inch of the fabrics were counted by pick glass. ASTM-D1059-01 standards were used to measure the warp and weft count. This test method determines the count of all types of fabrics in which the yarns are intact and can be removed in measurable length. The counts of the warp and weft were calculated from the mass and the measured length of the yarn in terms of “mass per unit length”.

4.1.4.2 Weight

Measurement of the fabric weight was conducted according to the ASTM 3776-96 standards. This test method gives the measurement of fabric mass per unit area (weight) and is applicable to most fabrics.

A 100 sq.cm area of fabric was cut by a die cutter (Figure 4.2) and then the fabric is weighed on an electronic balance. From the measured weight in grams, the gram per square meter of the fabric was calculated.

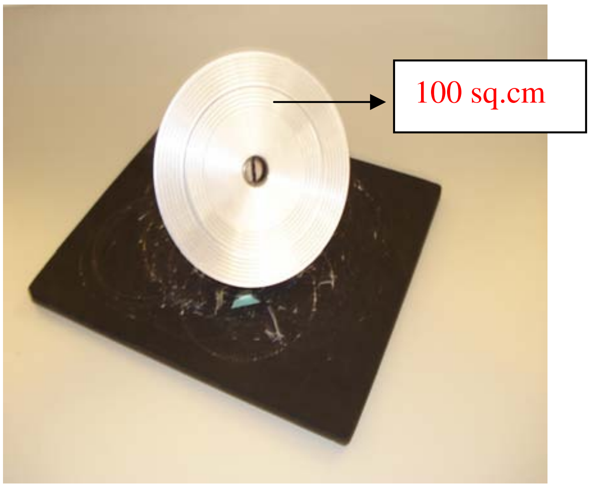


Figure 4.2: Die cutter

4.1.4.3 Strength

The tensile strength of the fabric was tested on an Instron Tensile Tester, model 4411 (Figure 4.3) by the grab test method. The ASTM D 5034 test method was used to measure the strength of the fabric. This test method uses the grab test procedure to measure the breaking strength of textile fabrics.

A 4 inch wide fabric specimen was used for the grab test. The test length was 6 inch between the jaws. The specimen was mounted securely in the jaws to prevent slipping. The jaws were aligned and made parallel so that the load could be applied uniformly across the width of the fabric sample.

Figure 4.3: Instron tensile tester (Model 4411)

4.1.4.4 Shear rigidity and shear hysterisis

The Kawabata Evaluation System-1(KES-FB1) instrument (Figure 4.4) was used to measure the shear rigidity and shear hysterisis of the fabric samples. Figure 4.5 shows the schematic diagram (KES-FB1). The following conditions were maintained for shear testing (Table 4.3).

Table 4.3: Standard conditions for shear rigidity and shear hysterisis testing

Parameters	**Shear**
Sensitivity	2×5 (2-lowest and 5-highest)
Clamp interval	5 cm
Maximum shear angle	+8.0 to -8.0
Shear tension	10gf/cm
Sample width	20 cm

Figure 4.4: KES-FB1

Figure 4.5: Schematic diagram of KES-FB1 (Kothari, 1999)

The fabric sample was clamped between the two jaws with an effective test area of ($20cm \times 20cm$), and subjected to a constant tension of 10 gf/cm by means of a weight attached to the drum on which one of the jaws was mounted. Constant tension was maintained by removing a clutch before shear deformation hence allowing the drum to rotate freely at a constant rate to a pre-set shear angle. The recovery cycle was then automatically started. The shear rigidity and shear values were recorded from a computer connected to the KES-FB1.

4.1.4.5 Extensibility

Extensibility was also measured using the Kawabata Evaluation System-1(Figure 4.4). Extensibility in the fabric was detected by engaging the free drum rotation and a torque detector connected to the drum. Fabric was extended at a constant strain rate by moving the other jaw assembly until a pre-set load was reached before staring the recovery cycle. The conditions for extensibility testing were employed are shown in Table 4.4.

Table 4.4: Standard conditions for extensibility testing

Parameters	**Extensibility**
Sensitivity	2×5 (2-lowest and 5-highest)
Clamp interval	5 cm
Maximum shear angle	-
Shear tension	-
Velocity	0.2 mm/sec
Sample width	20 cm
Clamp interval Elongation sensitivity	25mm/10V
Maximum load	50gf/cm

4.1.4.6 Bending rigidity and bending hysterisis

The Kawabata Evaluation System-2 (KES-FB2) (Figure 4.6) was used to measure the bending rigidity and bending hysterisis of the fabric samples. Figure 4.7 shows the schematic diagram of the KES-FB2. The test was carried out under the following conditions (Table 4.5).

Table 4.5: Standard conditions for bending rigidity and bending hysterisis testing

Parameters	Bending rigidity
Sensitivity	2×5 (2-lowest and -5 highest)
Sample width	20 cm

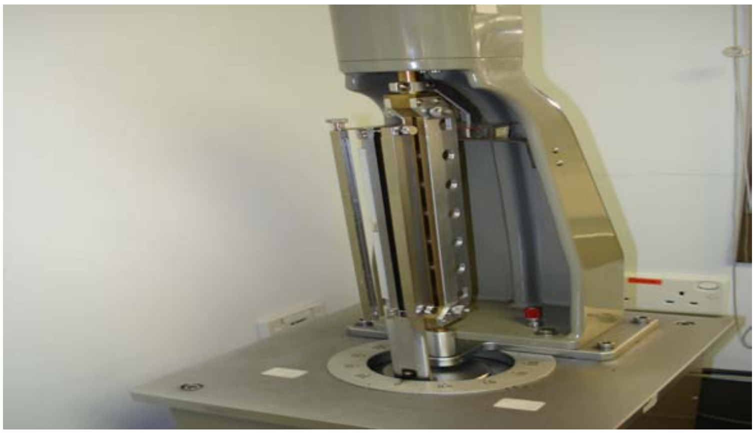


Figure 4.6: Front view of KES-FB2

Figure 4.7: Schematic diagram of KES-FB2 (Kothari, 1999)

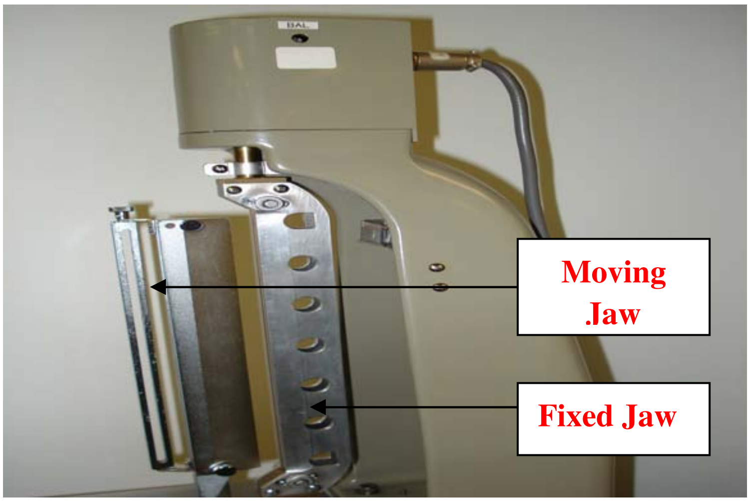


Figure 4.8: Side view of KES-FB2

The fixed jaw of the KES-FB2 held one edge of the fabric sample ($20cm \times 20cm$) and the movable jaw (at a distance of 1cm) held the other (Figure 4.8). The moving jaw followed a fixed orbit turning its head so that the fabric curvature increased at a constant rate till the required curvature was reached. The bending rigidity and bending hysterisis data was acquired from a computer connected to the KES-FB2.

4.1.4.7 Thickness

The Kawabata Evaluation System-3 (KES-FB3) instrument (Figure 4.9) was used to measure the thickness of the fabric samples. Figure 4.10 represents the schematic diagram of the KES-FB3. The testing conditions for thickness were standard and are shown in Table 4.6.

Table 4.6: Standard conditions for thickness testing

Parameters	**Compressional property**
Sensitivity	2×5
Velocity	50mm/sec
Compress area	2 cm^2
Stroke	5mm/10V
Max load	50gf/ cm^2

Figure 4.9: KES-FB3

Figure 4.10: Schematic diagram of KES-FB3 (Kothari, 1999)

The fabric sample ($20cm \times 20cm$) was placed on the bottom plate of the instrument. A plunger of $2cm^2$ compressed the fabric at a constant rate. The fabric was compressed till a pre-set pressure was reached before starting the recovery cycle at the same constant rate. The thickness was noted from a computer connected to the KES-FB3.

4.1.4.8 Coefficient of friction

The Kawabata Evaluation System-4 (KES-FB4) instrument (Figure 4.11) was used to measure the coefficient of friction of the fabric samples. Figure 4.12 represents the schematic diagram of the KES-FB4. The testing conditions are shown in Table 4.7.

Table 4.7: Standard conditions for coefficient of friction testing

Parameters	**Coefficient of friction**
Rate of traverse	1 mm/s
Tension on sample	$20 gf/cm^2$
Normal force	50gf/cm
Distance moved	3 cm

Figure 4.11: KES-FB4

Figure 4.12: Schematic diagram of KES-FB4 (Kothari, 1999)

The one end of the fabric sample ($20cm \times 20cm$) was fixed on the winding drum and the other end was held by a weight to apply a constant tension on the fabric. The winding drum turned to displace the fabric at a constant speed by 2-3 cm on a smooth plate place horizontally. Surface friction was measured by a sensor which is placed on the surface of the fabric with 50 gf compressional load. The coefficient of friction was noted from a computer connected to the KES-FB4.

4.1.5 Measurement of critical dimensions for the evaluation of seam quality

As noted in Chapter 3, there are three critical dimensions for the evaluation of seam quality. They are seam efficiency, seam puckering and seam boldness. The measurement procedures for each critical dimension are discussed below.

4.1.5.1 Measurement of seam efficiency

Seam efficiency was measured according to the method discussed in the section 2.2.2 of the literature review chapter.

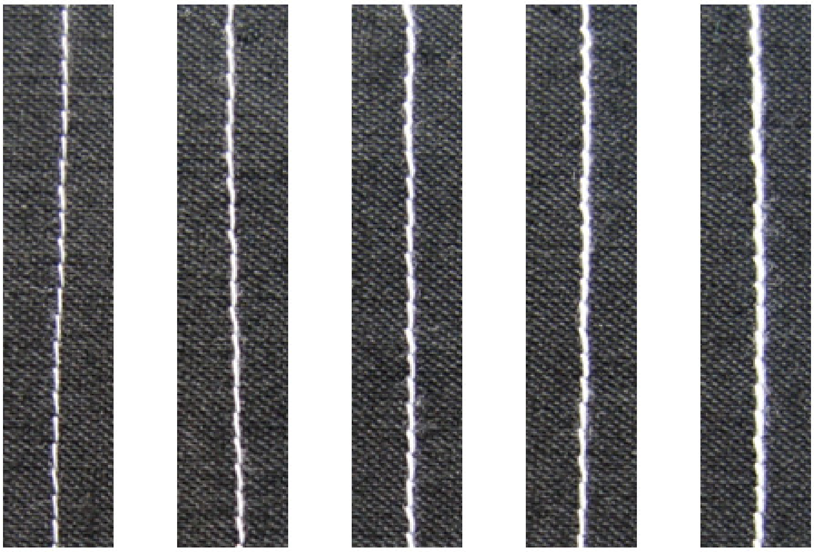
4.1.5.2 Measurement of seam puckering

Seam puckering was measured according to the method discussed in the section 2.2.6.4 of the literature review chapter.

4.1.5.3 Measurement of seam Boldness

The current practice for the assessment of seam boldness is mainly by subjective visual means. Even though there is no international recognised standard for the evaluation of boldness, most apparel manufacturers have set a bench mark for this evaluation based on their past experience.

The benchmarks for evaluating seam boldness of five big apparel manufacturers in Hong Kong were collected from quality control personnel. The five bench marks for the visual assessment of seam Boldness (SB) were selected for this study and are shown in Figure 4.14. These benchmarks are regularly used by five large scale apparel manufacturers in Hong Kong. SB 5 is the bench mark for seam boldness of the highest prominence, whereas SB 1 is the bench mark for seam boldness of the lowest prominence.



SB 1 SB 2 SB 3 SB 4 SB 5

Figure 4.14 Five benchmark for visual assessment of seam boldness

The evaluation of seam boldness was performed by distributing the stitched fabric sample to a group of 10 researchers, who were involved for subjective ranking of dimensions for seam quality evaluation (see chapter 3, section 3.1). These researchers had industrial experience as well as research experience; thereby gave best grading for the evaluation of seam boldness. The boldness of seam was subjectively rated by the assessors by comparing the samples with reference benchmarks. In order to reduce the unwanted effect to seam boldness, all the seams were placed properly on a table before conducting the visual assessment process. All the seams were placed under relaxation. The reference benchmarks and the seam specimens were positioned in the same visual level for assessment under the standard light. The assessors assigned the numerical grades of seam boldness with bench mark independently.

Before the assessment, each of the judges was given a clear instruction as well as the grading sheet (Appendix III). In the grading sheet, there is an emphasis for the judges to ignore the effect of colour in fabric and sewing thread while comparing the seam specimen with benchmarks. The seam boldness assessment was based on the comparison of the specimens and the benchmark of seam boldness.

The scale of grading is given in Table 4.8.

Table 4.8: Scale of ratings

Seam boldness	**Grading**
Highest prominence	5
Slightly prominence	4
Average prominence	3
Below average prominence	2
No prominence	1

It was found that the assessors have good degree of agreement in ranking as the coefficient of concordance was 0.81.

4.1.6 Analysis and identification of key input variables for seam quality

In this section, methods for selecting the key input variables for seam quality are described. Covariance analysis, regression analysis and factor analysis were carried out to develop the empirical model with reduced number of mutually independent input variables without significant loss of the predictability for outputs. The input variables were sewing thread size, stitch density and various fabric properties and each critical dimension for the seam quality evaluation was considered as output variables. SYSTAT12 software (Developed by Systat Software Inc (SSI), San Jose, California, USA) was used to carry out the covariance analysis, regression analysis and factor analysis.

Covariance analysis was conducted for identification of mutually dependent input variables for seam quality. The high covariance between two input variables represent as mutually dependent variables.

Regression analysis was used to eliminate the input variables, which are least contributing to the output and mutually dependent. Input variables with low absolute value of regression coefficient to the output were regarded as the least contributing input variables. These input variables were eliminated for seam quality analysis of the three selected fabrics- cotton, cotton-spandex and cotton-polyester. Among the mutually dependent input variables, those having low absolute value of regression coefficient were also eliminated.

Factor analysis results confirm that seam quality could be effectively explained using the rest of the input variables after elimination. In this analysis, the cumulative percentage of variance which is 99 was the critical in the selection of key input variables. It was considered that if cumulative percentage of variance value became less than 99, there would be a significant loss of predictability in the output. So, factor analysis aids in determining the number of key input variables required for effective seam quality evaluation.

4.2 Model formulation and evaluation

This research, aims to determine the effect of influencing factors such as sewing thread size, stitch density and fabric properties on critical dimensions for seam quality evaluation; which are seam efficiency, seam puckering and seam boldness. In order to evaluate the effect of the influencing factors, empirical models based on multiple regression were developed. As multiple regression model is an effective tool to understand the relationship between input and output variables

(Barnes, 1994; Sprinthall, 2003), this type of model was selected to analyze the effect of various parameters on critical dimensions.

4.2.1 Multiple regression models

Multiple regression model relate the dependent output variable with the independent input variables. In this study, multiple regression modeling methodology was applied for evaluating the seam quality in terms of sewing thread size, stitch density and fabric properties. The multiple regression models were formulated for seam quality evaluation of three types of fabrics: cotton-polyester, cotton-spandex and cotton. The three critical dimensions (seam efficiency, seam puckering and seam boldness) for seam quality evaluation were considered as output variables and sewing thread size, stitch density and fabric properties were selected as input variables.

Two types of multiple regression models: linear regression and logarithmic regression, were formulated for this study. SYSTAT12 software (Developed by Systat Software Inc (SSI), San Jose, California, USA) was used to formulate the linear regression and logarithmic regression models with a constant. In general, linear and logarithmic regression equations are expressed in the following form (David, 2005; Gunst and Mason, 1985):

$$Y = a + b_1 X_1 + b_2 X_2 + \ldots\ldots\ldots\ldots\ldots + b_p X_p \quad \text{(Multiple linear regression form)}$$

$$Y = a + b_1 \log X_1 + b_2 \log X_2 + \ldots\ldots\ldots + b_p \log X_p \quad \text{(Multiple log regression form)}$$

Where,

a = constant,

$b_1, b_2, \ldots\ldots$ bp = regression coefficient,

$X_1, X_2, \ldots\ldots\ldots\ldots$ Xp = input variables,

Y = output variable.

The effect of the input variables, sewing thread size, stitch density and fabric properties to the output variables, seam efficiency, seam puckering and seam boldness was identified from the regression coefficients of the individual input variable in the formulated model. For example; an input variable, with a positive regression coefficient was considered having a positive effect on the output variables; but with a negative regression coefficient, it was considered having a negative effect on the output variables.

The coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) were calculated to measure the performance of both models (linear and logarithmic).

Coefficient of determination (R^2)

Statistically, the coefficient of determination (R^2) is the proportion of variability in a data set that is accounted for a mathematical model. It is given as follows:

$$R^2 = \frac{SS_R}{SS_T}$$

SS_R = regression sum of squares,

SS_T = total sum of squares.

For the regression model, the coefficient of determination (R^2) is a statistical measure to express how well the regression line approximates the real data points. An R^2 of 1.0 indicates that the regression line perfectly fits the data.

Standard Error (SE)

The standard error of a mathematical model is the estimated standard deviation of the error in that method. Namely, it is the standard deviation of the difference between the measured or estimated values and true values. The standard error of the mean of a sample from a population is the standard deviation of the sampling distribution of the mean and is estimated by the formula:

$$S_E = \frac{\sigma}{\sqrt{n}}$$

Where,

σ is an estimate of the standard deviation of the population,

n= is the size (number of items) of the sample.

Mean Square Error (MSE)

The Mean Square Error of an estimator is the expected value of the square of the "error". The error is the amount by which the estimator differs from the quantity to be estimated. The Mean Square Error is calculated by using the following formula:

$$MSE = \left[\frac{\sum_{i=1}^{n} (Y_i - Y_{i,\,real})^2}{n} \right]$$

Where:

y_i = predicted values from the model,

$y_{i,\,real}$ = actual values from the model,

n = number of samples.

Coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) were selected as the parameters to compare the performance between the formulated linear and logarithmic model of each critical dimension for seam quality evaluation. The highest coefficient of determination (R^2), lowest Standard Error (SE) and lowest Mean Square Error (MSE) values at 95% confidence level provide a better performance for the formulated model. Better performance models were considered as a best fit model for each critical dimension for the seam quality evaluation.

4.3 Model Validation

The best fit models were validated with a new set of experimental data. The purpose of this validation is to measure the accuracy of the best fit model. To verify the validity of best fit models for seam efficiency, seam puckering and seam boldness of three types of fabrics (cotton-polyester, cotton-spandex and cotton), the predicted values obtained from the best fit model were compared with the new set of experimental values. For example; in the case of cotton-polyester fabric, 44 new seam specimens were prepared for each critical dimension of seam quality evaluation (seam efficiency, seam puckering and seam boldness). Then seam efficiency, seam puckering and seam boldness were measured and calculated. They were also predicted from the obtained best fit models. In order to identify the validity of the best fit model, the coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) between experimental values and predicted values were calculated. The model with high coefficient of determination (R^2), low Standard Error (SE) and low Mean Square Error (MSE) inferred that the best fit model could suitably predict the new experimental data in general.

4.4 Model application

The three respective best fit models of each critical dimensions for seam quality evaluation (seam efficiency, seam puckering and seam boldness) were integrated to provide a solution for evaluating the overall seam quality of a particular apparel product. Five different apparel products were chosen to provide a solution for evauating the overall seam quality. They were: Blouse, Shirt, Denim trousers, T-shirt and Lingerie. Weighing factor approach was the simplest method to integrate the best fit models for providing a solution to evaluate the overall seam quality of apparel products. The principle of the integration of the best fit models to provide a solution for evaluating the overall seam quality of apparel products are shown in Figure 4.15.

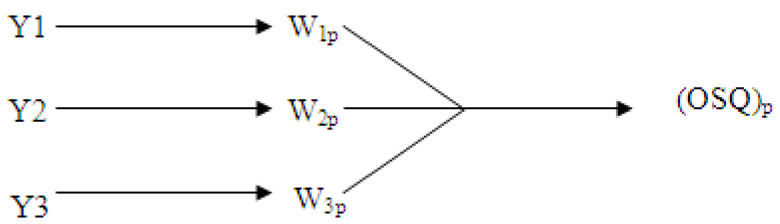


Figure 4.15: Principle for integration of the best fit model

Where,

Y1 = Best fit model of seam efficiency,

Y2 = Best fit model of seam puckering,

Y3 = Best fit model of seam boldness,

OSQ = Overall Seam Quality,

p= Apparel product,

W_{1p}, W_{2p}, and W_{3p} = Weighing factor of seam efficiency, seam puckering and seam boldness on the overall seam quality for a particular apparel product.

4.4.1 Subjective assessment for the evaluation of relative importance

In order to calculate the weighing factor of seam efficiency, seam puckering and seam boldness, it was essential to calculate their relative importance on the overall seam quality of the five apparel products. A subjective evaluation was carried out to understand the relative importance of seam efficiency, seam puckering and seam boldness on the overall seam quality of a particular apparel product. It was rated by a group of 10 professional researchers in the textile and apparel field, who were involved in the identification of critical dimensions for the seam quality evaluation in the present study (see chapter 3, section 3.1). They were experts in the quality of apparel products; thereby gave the best rating on each critical dimension for seam quality evaluation (seam efficiency, seam puckering and seam boldness) of apparel products according to consumer desires.

The selected 10 researchers were asked to complete the Table 4.9. They were asked to assign a number in percentage to each critical dimension based on the relative importance of each dimension on the overall seam quality. This was done for the five apparel products: Blouse, Shirt, Denim trousers, T-shirt, Lingerie.

Table 4.9: Relative importance evaluation table

Product	**Distribution percentage of the relative importance of critical dimensions on the overall seam quality**			**Summation of Y1+Y2+Y3**
	Seam efficiency (Y1)	**Seam puckering (Y2)**	**Seam boldness (Y3)**	
Blouse				100%
Shirt				100%
Denim trousers				100%
T-shirt				100%
Lingerie				100%

4.4.2 Weighing factor calculation

An average of the percentages of relative importance for each critical dimension assigned by all the experts was calculated for the five selected apparel products. Then the average of each dimension was normalized with respect to the lowest value as explained below.

Let us say, the average values of seam efficiency, seam puckering and seam boldness were I_1, I_2, and I_3 and I_2 is the lowest value in this example. So, the average values I_1, I_2 and I_3 are normalized with respect to I_2. Then the ratio of relative importance is $\frac{I_1}{I_2}:\frac{I_2}{I_2}:\frac{I_3}{I_2}$. The ratio of relative importance of each critical dimension for the five apparel products was used as weighing factor. In this example,

$W_{1p} = \frac{I_1}{I_2}$ = Weighing factor of seam efficiency,

$W_{2p} = \frac{I_2}{I_2} = 1$ = Weighing factor of seam puckering,

$W_{3p} = \frac{I_3}{I_2}$ = Weighing factor of seam boldness.

4.4.3 Overall seam quality of various apparel products

Weighing factors for each critical dimension were different for the five chosen apparel products. As a result, the solution to evaluate the overall seam quality for an apparel product may be represented in the following way:

$$(SQ)p = \begin{cases} +W_{1p}Y1 \\ -W_{2p}Y2 \\ \pm W_{3p}Y3 \end{cases} \tag{1}$$

Where,

SQ = Seam Quality,

p= Apparel product,

W_{1p}, W_{2p}, and W_{3p} = the weighing factors of seam efficiency, seam puckering and seam boldness on the overall seam quality respectively for a particular apparel product.

Here,

Y1 = Best fit model of seam efficiency,

Y2 = Best fit model of seam puckering,

Y3 = Best fit model of seam boldness.

The reason for the selection of signs in the Equation (1) is given below.

Seam efficiency is a measure of the durability of apparel products. A high percentage of seam efficiency always represents good seam quality. Seam efficiency has a positive impact on the overall seam quality of the five apparel products. Therefore, Y1 is positive in the Equation (1).

In contrast, a greater seam puckering always leads to poor seam quality. As a result, seam puckering always has a negative impact on the overall seam quality. So, Y2 has negative sign in the Equation (1).

Furthermore, the acceptability of seam boldness depends on the each apparel product. As seam boldness relates to the prominence of design, the degree of requirement for design of seam is different for various apparel products. Seam boldness (Y3) may have a positive or a negative influence on the overall seam quality depending on the apparel products. Therefore Y3 has positive or negative sign in the Equation (1).

CHAPTER 5

RESULTS AND DISCUSSION

This chapter aims to provide a solution for evaluating the overall seam quality of apparel products. To begin with, key input variables are identified for the multiple regressions modeling of each critical dimension for seam quality evaluation. Identification of key input variables are carried out through covariance analysis, regression analysis and factor analysis.

Linear and logarithmic regression models are formulated for each critical dimension for seam quality evaluation. The formulated linear and logarithmic models of each critical dimension for seam quality evaluation are compared through statistical analysis to identify best fit models. Effects of key input variables on each critical dimension for seam quality evaluation are inferred from the best fit models.

Distinguished best fit models of each critical dimension for the seam quality evaluation in each fabric are validated by statistical analysis. Finally, a method is proposed to provide a solution for evaluating the overall seam quality of particular apparel products such as, Blouse, Shirt, Denim trousers, T-shirt and Lingerie by integrating the respective best fit models of each critical dimension for seam quality evaluation.

5.1 Analysis and identification of key input variables for modeling

Based on the literature review in chapter 2, it has been found that there are different factors affecting the seam quality. They are considered as input variables for empirical modeling of seam quality. The input variables are: sewing thread size (X1), cover factor (X2), weight (X3), thickness (X4), strength (X5), extensibility (X6), bending rigidity (X7), shear rigidity (X8), stitch density (X9), shear hysterisis (X10), bending hysterisis (X11) and coefficient of friction (X12). In this research, these input variables are measured in the laboratory for seam quality evaluation of three types of fabric: cotton-polyester, cotton-spandex and cotton. The values of the input variables (X1-X12) obtained from the experiments for seam quality evaluation of cotton-polyester, cotton-spandex and cotton fabrics are given in Appendices IV, V and VI respectively.

In the Chapter 3, it has been found that there are three critical dimensions for seam quality evaluation. These critical dimensions for seam quality evaluation are considered as output variables for modeling. The output variables are: seam efficiency (Y1), seam puckering (Y2) and seam boldness (Y3). These are measured in the laboratory for the three fabrics: cotton-polyester, cotton-spandex and cotton. The values of output variables (Y1, Y2 and Y3) obtained from the experiments for three types of fabrics are given in Appendices VII, VIII and IX.

The aim of this section is to select key variables among the 12 input variables (X1-X12) for multiple regressions modeling of Y1, Y2 and Y3. Among the 12 input variables (X1-X12), the mutually dependent input variables are identified through covariance analysis. The least contributing to the outputs and mutually dependent input variables are eliminated through regression analysis. Factor analysis is carried out to confirm that after the elimination of these input variables, there will be no significant loss in predictability of the outputs. The least number of mutually independent variables that predominantly contribute to the output variables are considered as the key input variables.

5.1.1 Covariance analysis

The covariance between each pair of input variables is calculated. If the covariance value of above 0.05, it is assumed that such pair of variables are mutually dependent.

The covariance matrixes of all the 12 input variables (X1-X12) for the seam quality evaluation of the three types of fabric specimen are shown in Tables 5.1, 5.2 and 5.3.

Table- 5.1: Covariance matrix of the input variables for seam quality evaluation of cotton-polyester fabrics

	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**	**X12**
X1	0.086	0.000	0.021	0.034	0.000	0.012	0.022	0.013	0.015	0.032	0.031	0.000
X2	0.000	0.078	0.027	-0.015	0.029	-0.003	0.034	0.016	0.000	0.007	0.020	-0.000
X3	0.021	0.027	0.062	-0.010	0.027	-0.020	0.032	0.036	0.034	0.040	0.040	0.000
X4	0.034	-0.015	-0.010	0.070	0.025	-0.011	-0.030	-0.016	0.000	-0.021	-0.020	0.002
X5	0.000	0.029	0.027	0.025	0.045	-0.017	0.016	0.011	0.032	-0.002	0.017	-0.000
X6	0.012	-0.003	-0.020	-0.011	-0.017	0.063	-0.009	-0.010	0.000	0.003	-0.010	-0.000
X7	0.022	0.034	0.032	-0.030	0.016	-0.009	0.080	0.037	0.000	0.033	***0.065***	-0.000
X8	0.013	0.016	0.036	-0.016	0.011	-0.010	0.037	0.067	0.000	***0.053***	0.034	0.001
X9	0.015	0.000	0.034	0.000	0.032	0.000	0.000	0.000	0.135	0.000	0.000	0.000
X10	0.032	0.007	0.040	-0.021	-0.002	0.003	0.033	***0.053***	0.000	0.063	0.035	0.000
X11	0.031	0.020	0.040	-0.020	0.017	-0.010	***0.065***	0.034	0.000	0.035	0.073	0.000
X12	0.000	-0.000	0.000	0.002	-0.000	-0.000	-0.000	0.001	0.000	0.000	0.000	0.061

Table- 5.2: Covariance matrix of the input variables for seam quality evaluation of cotton-spandex fabrics

	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**	**X12**
X1	0.086	0.015	0.000	0.000	0.032	0.000	0.033	0.034	0.023	0.012	0.000	0.000
X2	0.015	0.089	0.033	0.035	0.035	-0.005	0.039	0.038	0.000	0.029	0.031	-0.000
X3	0.000	0.033	0.088	0.030	0.036	0.008	0.038	0.024	0.034	0.037	0.035	-0.000
X4	0.000	0.035	0.030	0.089	0.039	0.011	0.031	0.042	0.032	0.032	0.039	-0.000
X5	0.032	0.035	0.036	0.039	0.080	-0.008	0.035	0.039	0.000	0.032	0.024	-0.000
X6	0.000	-0.005	0.008	0.011	-0.008	0.051	-0.010	-0.016	0.000	-0.011	-0.010	-0.000
X7	0.033	0.039	0.038	0.031	0.035	-0.010	0.093	0.031	0.011	0.031	***0.089***	-0.000
X8	0.034	0.038	0.024	0.042	0.039	-0.016	0.031	0.075	0.000	***0.065***	0.036	0.003
X9	0.023	0.000	0.034	0.032	0.000	0.000	0.011	0.000	0.135	0.000	0.000	0.000
X10	0.012	0.029	0.037	0.032	0.032	-0.011	0.031	***0.065***	0.000	0.070	0.030	0.006
X11	0.000	0.031	0.035	0.039	0.024	-0.010	***0.089***	0.038	0.000	0.030	0.106	-0.000
X12	0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.003	0.000	0.006	-0.000	0.128

Table- 5.3: Covariance matrix of the input variables for seam quality evaluation of cotton fabrics

	X1	**X2**	**X3**	**X4**	**X5**	**X6**	**X7**	**X8**	**X9**	**X10**	**X11**	**X12**
X1	0.086	0.021	0	0.023	0	0.028	0	0	0.012	0	0	0
X2	0.021	0.037	-0.003	0.004	0.012	-0.002	0.004	0.009	0	0.008	0.006	0.001
X3	0	-0.003	0.06	0.027	0.020	-0.029	0.028	0.026	0.131	0.025	0.019	0
X4	0.023	0.004	0.027	0.075	0.027	-0.021	0.026	0.019	0.022	0.025	0.029	0
X5	0	0.012	0.020	0.027	0.047	-0.028	0.029	0.014	0	0.017	0.023	0
X6	0.028	-0.002	-0.029	-0.021	-0.028	0.092	-0.028	-0.039	0.021	-0.027	-0.021	-0.001
X7	0	0.004	0.028	0.026	0.029	-0.028	0.071	0.031	0	0.001	***0.068***	0.003
X8	0	0.009	0.026	0.019	0.014	-0.039	0.04	0.090	0.031	***0.082***	0.039	0.001
X9	0.012	0	0.131	0.022	0	0.021	0	0.031	0.135	0	0.041	0
X10	0	0.008	0.025	0.025	0.017	-0.027	0.001	***0.082***	0	0.086	0.037	0
X11	0	0.006	0.019	0.029	0.023	-0.021	***0.068***	0.039	0.041	0.037	0.078	0
X12	0	0.001	0	0	0	-0.001	0	0.001	0	0	0	0.07

From Tables 5.1, 5.2 and 5.3, it is observed that covariances between the bending rigidity (X7) and bending hysterisis (X11) are 0.065, 0.089 and 0.068 for the three types of fabrics: cotton-polyester, cotton-spandex and cotton fabrics respectively. Additionally, covariances between the shear rigidity (X8) and shear hysterisis (X10) are 0.053, 0.065 and 0.082 for the three types of fabrics. These two pairs of input variables: bending rigidity (X7) and bending hysterisis (X11) as well as shear rigidity (X8) and shear hysterisis (X10) are identified as mutually dependent due to their covariances are all above 0.05.

5.1.2 Regression analysis

From the covariance analysis in previous section, two pairs of mutually dependent variable are found: bending rigidity (X7) and bending hysterisis (X11) as well as shear rigidity (X8) and shear hysterisis (X10). The least dominating input variables between bending rigidity (X7) and bending hysterisis (X11) as well as between shear rigidity (X8) and shear hysterisis (X10) could be eliminated based on the regression analysis. In addition, the least contributing input variables to the outputs (Y1, Y2 and Y3) are also eliminated by regression analysis.

The least dominating input variables can be inferred by observing the absolute values of regression coefficients of the input variables to the outputs (Y1, Y2 and Y3). The regression coefficients of 12 input variables (X1-X12) for the seam efficiency (Y1), seam puckering (Y2) and seam boldness (Y3) are shown in

Tables 5.4, 5.5 and 5.6, for cotton polyester, cotton-spandex and cotton fabric respectively.

Table 5.4: Regression coefficients of the input variables for Y1, Y2 and Y3 (cotton-polyester fabrics)

Input Variables	Regression Coefficients		
	Seam efficiency (Y1)	**Seam puckering (Y2)**	**Seam boldness (Y3)**
Sewing Thread Size (X1)	0.506	0.602	0.892
Cover Factor (X2)	0.069	0.092	0.041
Weight (X3)	-0.088	-0.134	0.119
Thickness (X4)	0.346	-0.05	0.039
Strength (X5)	-0.163	0.092	-0.07
Extensibility (X6)	0.436	0.082	0.048
Bending Rigidity (X7)	***0.183***	***0.17***	***-0.046***
Shear Rigidity (X8)	***-0.585***	***-0.034***	***-0.219***
Stitch Density (X9)	0.263	0.068	0.124
Shear Hysterisis (X10)	***-0.026***	***-0.019***	***0.13***
Bending Hysterisis (X11)	***0.042***	-0.078	***0.034***
Coefficient of Friction (X12)	***0.001***	**0.003**	***0.006***

Table 5.5: Regression coefficients of the input variables for Y1, Y2 and Y3 (cotton-spandex fabrics)

Input Variables	Regression Coefficients		
	Seam efficiency (Y1)	**Seam puckering (Y2)**	**Seam boldness (Y3)**
Sewing Thread Size (X1)	0.512	0.712	0.912
Cover Factor (X2)	0.092	0.192	0.143
Weight (X3)	0.081	-0.168	0.210
Thickness (X4)	0.249	-0.13	0.119
Strength (X5)	-0.174	0.192	0.069
Extensibility (X6)	0.589	0.382	0.081
Bending Rigidity (X7)	***0.201***	***0.128***	***0.123***
Shear Rigidity (X8)	***0.612***	***-0.228***	***0.319***
Stitch Density (X9)	0.273	0.189	0.212
Shear Hysterisis (X10)	***0.012***	***-0.01***	***0.10***
Bending Hysterisis (X11)	***0.089***	***0.02***	***0.03***
Coefficient of Friction (X12)	***0.01***	***0.005***	***0.007***

Table 5.6: Regression coefficients of the input variables for Y1, Y2 and Y3 (cotton fabrics)

Input Variables	Regression Coefficients		
	Seam efficiency (Y1)	**Seam puckering (Y2)**	**Seam boldness (Y3)**
Sewing Thread Size (X1)	0.413	0.513	0.712
Cover Factor (X2)	0.129	-0.129	0.031
Weight (X3)	0.121	0.213	0.33
Thickness (X4)	0.089	0.5	0.129
Strength (X5)	0.173	0.132	0.23
Extensibility (X6)	0.389	0.089	0.108
Bending Rigidity (X7)	***0.289***	***-0.231***	***0.268***
Shear Rigidity (X8)	***0.413***	***0.314***	***0.211***
Stitch Density (X9)	0.312	0.128	0.21
Shear Hysterisis (X10)	***0.039***	***0.02***	***0.12***
Bending Hysterisis (X11)	***0.062***	***0.06***	***0.12***
Coefficient of Friction (X12)	***0.002***	***0.008***	***0.009***

From Tables 5.4 , 5.5 and 5.6 , it is clear that the absolute values of regression coefficient of bending rigidity (X7) is higher than bending hysterisis (X11) for the seam efficiency (Y1), seam puckering (Y2) and seam boldness (Y3) in all the three fabrics. For example, in the case of cotton-polyester fabric, the absolute values of regression coefficient of bending rigidity (X7) for Y1, Y2 and Y3 are 0.183, 0.17 and 0.046 respectively, whereas, the absolute values of regression coefficient of bending hysterisis (X11) for Y1, Y2 and Y3 are 0.042, 0.078 and 0.034 respectively. It helps to interpret that the bending rigidity is more dominant for the outputs than the bending hysterisis. Therefore, bending rigidity is considered for modeling of the outputs instead of bending hysterisis.

Similarly, it is clear that for Y1, Y2 and Y3 in all three types of fabric, shear rigidity (X8) is always dominant over shear hysterisis (X10) in Tables 5.4, 5.5 and 5.6. For example, in the case of cotton fabric, the absolute values of regression coefficient of the shear rigidity (X8) for Y1, Y2 and Y3 are 0.413, 0.314 and 0.211 respectively. In contrast, the absolute values of regression coefficient of the shear hysterisis (X10) for Y1, Y2 and Y3 are 0.039, 0.02 and 0.12 respectively. So, the shear rigidity is considered as the prime input variables over the shear hysterisis for seam quality evaluation of the three fabrics.

Furthermore, it is obvious from Tables 5.4-5.6 that the absolute value of regression coefficient of coefficient of friction (X12) is the smallest for the outputs (Y1, Y2 and Y3) in all the three fabrics. For example, in the case of cotton-polyester fabric, the absolute values of regression coefficient of coefficient of friction (X12) for Y1, Y2 and Y3 are 0.001, 0.003 and 0.006 respectively. Therefore, the coefficient of friction (X12) is not considered for the seam quality evaluation as it is the least contributing variables for the outputs (Y1, Y2 and Y3) in all the three fabrics.

The result of this part of study showed that shear hysterisis (X10), bending hysterisis (X11) and coefficient of friction (X11) are redundant input variables and could be eliminated.

5.1.3 Factor analysis

In this section, factor analysis is carried out to confirm that by considering only X1-X9 and eliminating X10-X12, there is no significant loss of predictability of the outputs (Y1-Y3).

The ability of a model to predict the output with high accuracy is measured by the value of the cumulative percentages of variance for the inputs used in the model. A percentage of minimum 99 for cumulative percentages of variance are generally accepted to reflect high accuracy.

In order to calculate the cumulative percentages of variance, the Factor Analysis (FA) of the input variables (X1-X12) for the seam quality evaluation of cotton-polyester, cotton-spandex and cotton fabrics are carried out. The results of factor analysis are shown in Tables 5.7, 5.8 and 5.9.

Table 5.7: Explained variance of the input variable for the seam quality evaluation of cotton-polyester fabric

Explained Variance (Eigenvalues)

Value	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Eigenvalue	0.279	0.237	0.135	0.117	0.101	0.051	0.044	0.031	0.016	0.014	0.006	0.003
% of Var.	26.934	22.931	13.080	11.327	9.708	4.959	4.207	2.989	1.520	1.397	0.543	0.287
Cum. %	26.934	49.865	62.944	74.271	83.979	88.938	93.145	97.134	99.001	99.532	99.754	100.000

Table 5.8: Explained variance of the input variables for the seam quality evaluation of cotton-spandex fabrics

Explained Variance (Eigenvalues)

Value	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Eigenvalue	0.530	0.237	0.159	0.135	0.071	0.047	0.020	0.014	0.011	0.005	0.002	0.001
% of Var.	42.956	19.228	12.857	10.967	5.731	3.799	1.654	1.171	0.878	0.436	0.201	0.096
Cum. %	42.956	62.183	75.040	86.008	91.739	95.538	97.191	98.363	99.241	99.677	99.878	100.000

Table 5.9: Explained variance of the input variables for the seam quality evaluation of cotton fabrics

Explained Variance (Eigenvalues)

Value	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12
Eigenvalue	0.318	0.237	0.135	0.077	0.062	0.046	0.033	0.014	0.010	0.004	0.002	0.001
% of Var.	33.775	25.206	14.378	8.179	6.630	4.932	3.515	1.536	1.063	0.439	0.237	0.087
Cum. %	33.775	58.982	73.359	81.538	88.168	93.100	96.616	98.151	99.214	99.654	99.890	100.000

According to Tables 5.7, 5.8 and 5.9, the cumulative percentage of variances for the input variables X1-X9 are 99.001, 99.241 and 99.214 in the three types of fabric: cotton-polyester, cotton-spandex and cotton fabric respectively. This cumulative percentage of variances being greater than 99 causes no significant loss in the predictability of the outputs (Y1, Y2 and Y3). As there is no significant loss in predictability, the output variables can be well modeled with just 9 input variables (X1-X9).

5.1.4 Summary

The key input variables for the seam quality analysis are identified from a list of variables. Among the 12 preliminary input variables (X1-X12), it is found that coefficient of friction (X12) is the least contributing input variable to the output variables. Therefore, X12 is eliminated for the multiple regression modeling of Y1, Y2 and Y3. It is also observed that bending rigidity (X7) and shear rigidity (X8) are mutually dependent with bending hysterisis (X11) and shear hysterisis (X10) respectively. From regression analysis, it is found that bending rigidity (X7) and shear rigidity (X8) are dominant over shear hysterisis (X10) and bending hysterisis (X11) respectively. Hence, shear hysterisis (X10) and bending hysterisis (X11) are eliminated from the modeling. The factor analysis showed that by considering only X1-X9 and eliminating X10-X12, there is no significant loss of predictability of the outputs (Y1-Y3). Hence, X1-X9 could be considered as key input variables for better performance of the multiple regression models in the analysis of seam quality.

5.2 Model formulation and evaluation

Multiple regression models are formulated for each critical dimension of seam quality evaluation in three types of fabric: cotton-polyester, cotton-spandex and cotton. For each critical dimension, two types of model: linear regression and logarithmic regression are formulated. There are nine key input variables (X1-X9) for multiple regressions modeling of each critical dimension for seam quality evaluation. The three critical dimensions for seam quality evaluation: seam efficiency (Y1), seam puckering (Y2) and seam boldness (Y3), are considered as output variables for multiple regression modeling in each fabric.

Statistical results of linear and logarithmic regression models of each critical dimension for seam quality evaluation are discussed exclusively to identify the best fit models. The effect of sewing thread size, stitch density and fabric properties on each critical dimension for seam quality evaluation are assessed based on the regression coefficients of the input variables (X1-X9) in the best fit models.

5.2.1 Linear regression model

The values obtained from laboratory experiments for inputs (X1-X9) and outputs (Y1-Y3) variables (see Appendices IV-IX) are used for linear regression model formulation. SYSTAT 12 software is used to calculate the linear regression coefficient of the input variables to each output. Based on the regression coefficient of the input variables to each output, the linear regression model between inputs and output are formulated. The formulated linear regression models of predicted seam efficiency (Yp1), predicted seam puckering (Yp2) and predicted seam boldness (Yp3) for selected three fabrics are listed in Table 5.10.

Table 5.10: Linear regression models for seam efficiency, seam puckering and seam boldness in three types of fabric

Critical Dimensions	**Fabrics** Materials	**Linear Models**
Seam Efficiency	Cotton-polyester	$Yp1 = 24.416 + 0.588X1 - 0.2818X2 - 0.0368X3 + 0.0416X4 - 0.0488X5 + 0.2989X6 + 15.458X7 + 0.692X8 + 2.8815X9$
	Cotton-spandex	$Yp1 = 37.1296 + 0.5717X1 - 0.0415X2 + 0.1257X3 - 67.168X4 - 0.1074X5 + 0.6927X6 + 12.9866X7 + 1.7976X8 + 2.7334X9$
	Cotton	$Yp1 = -0.437 + 0.5905X1 - 0.1257X2 + 0.0272X3 + 21.7738X4 - 0.0655X5 + 0.9854X6 + 12.8054X7 - 1.5872X8 + 3.4207X9$
Seam Puckering	Cotton-polyester	$Yp2 = -7.5629 + 0.635X1 - 0.2053X2 - 0.0732X3 - 0.0861X4 + 0.0171X5 + 1.1386X6 + 1.4052X7 - 2.7092X8 + 0.7209X9$
	Cotton-spandex	$Yp2 = 13.4665 + 0.7187X1 + 0.6277X2 - 0.0721X3 - 126.21X4 - 0.01X5 + 0.6536X6 + 31.7257X7 + 1.5777X8 + 1.3943X9$
	Cotton	$Yp2 = 10.324 + 0.4936X1 + 0.3061X2 + 0.0056X3 - 43.0855X4 - 0.0056X5 - 0.2265X6 + 1.1677X7 - 0.5767X8 + 0.3874X9$
Seam Boldness	Cotton-polyester	$Yp3 = 0.5643 + 0.0444X1 + 0.0015X2 + 0.0022X3 + 0.0026X4 - 0.0004X5 + 0.0126X6 - 0.4586X7 - 0.038X8 - 0.007X9$
	Cotton-spandex	$Yp3 = 1.1849 + 0.0444X1 + 0.007X2 - 0.0008X3 - 0.0622X4 - 0.001X5 + 0.0129X6 + 1.6003X7 - 0.0077X8 - 0.0274X9$
	Cotton	$Yp3 = 1.3998 + 0.0444X1 - 0.0007X2 + 0.0013X3 - 0.8297X4 - 0.0003X5 - 0.0117X6 + 0.142X7 + 0.0208X8 - 0.0911X9$

5.2.2 Logarithmic regression model

The values obtained from laboratory experiments for inputs (X1-X9) and outputs (Y1-Y3) variables (see Appendices IV-IX) are used for logarithmic regression model formulation. SYSTAT 12 software is used to calculate the logarithmic regression coefficient of the input variable to each output. Based on the regression coefficient of the input variables to each output, the logarithmic regression model between inputs and output are formulated. The formulated logarithmic regression models of predicted seam efficiency (Yp1), predicted seam puckering (Yp2) and predicted seam boldness (Yp3) for selected three fabrics are listed in Table 5.11.

Table 5.11: Logarithmic regression models for seam efficiency, seam puckering and seam boldness in three types of fabric

Critical dimensions	**Fabric** Materials	**Logarithmic Models**
Seam Efficiency	Cotton-polyester	$Yp1 = 54.1545 + 27.1251 \log X1 - 6.0421 \log X2 - 9.4917 \log X3 - 0.3094 \log X4 - 17.9707 \log X5 + 4.805 \log X6 + 0.1257 \log X7 + 4.4008 \log X8 + 27.3261 \log X9$
	Cotton-spandex	$Yp1 = 115.7685 + 25.8417 \log X1 - 6.2164 \log X2 + 4.3024 \log X3 - 6.4905 \log X4 - 36.1454 \log X5 + 0.2078 \log X6 + 5.4029 \log X7 - 0.5224 \log X8 + 25.9973 \log X9$
	Cotton	$Yp1 = 48.4152 + 27.2749 \log X1 - 7.564 \log X2 + 1.2284 \log X3 + 14.882 \log X4 - 24.2169 \log X5 + 5.7315 \log X6 + 1.5285 \log X7 - 4.0016 \log X8 + 32.1752 \log X9$
Seam Puckering	Cotton-polyester	$Yp2 = -39.3751 + 27.6427 \log X1 - 8.6538 \log X2 - 11.8953 \log X3 - 0.4798 \log X4 + 4.7309 \log X5 + 7.1193 \log X6 + 0.9123 \log X7 + 4.5755 \log X8 + 6.7215 \log X9$
	Cotton-spandex	$Yp2 = -135.819 + 25.4918 \log X1 + 7.4067 \log X2 - 5.1508 \log X3 - 30.7717 \log X4 - 1.3297 \log X5 - 0.4419 \log X6 + 2.4242 \log X7 + 1.8045 \log X8 + 5.9170 \log X9$
	Cotton	$Yp2 = -64.6687 + 20.9912 \log X1 + 1.8572 \log X2 - 6.4876 \log X3 - 13.639 \log X4 + 2.849 \log X5 - 0.5511 \log X6 - 1.7428 \log X7 - 2.5251 \log X8 + 3.5326 \log X9$
Seam Boldness	Cotton-polyester	$Yp3 = -6.5362 + 2.0475 \log X1 + 0.048 \log X2 + 0.4007 \log X3 + 0.0225 \log X4 - 0.1292 \log X5 - 0.1109 \log X6 + 0.0972 \log X7 - 0.0375 \log X8 - 0.3452 \log X9$
	Cotton-spandex	$Yp3 = -0.3018 + 2.0125 \log X1 + 0.1245 \log X2 - 0.4248 \log X3 + 0.2764 \log X4 - 0.2566 \log X5 - 0.0213 \log X6 + 0.1533 \log X7 + 0.0436 \log X8 - 0.239 \log X9$
	Cotton	$Yp3 = -3.8415 + 1.9903 \log X1 - 0.2232 \log X2 + 0.1006 \log X3 + 0.2274 \log X4 - 0.1484 \log X5 - 0.0413 \log X6 + 0.0492 \log X7 - 0.0145 \log X8 - 0.8388 \log X9$

5.2.3 Comparison between linear and logarithmic model

Coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) of the linear and logarithmic models are calculated. Coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) depict the ability of a model to accurately predict the output. These are calculated to compare the performance of both linear and logarithmic models of each critical dimension for seam quality evaluation. The purpose of this comparison is to identify the best fit models of each critical dimension for seam quality evaluation. In comparison, models with high coefficient of determination, low standard error and low mean square error are considered as best fit models.

The coefficient of determination, standard error and mean square error of the formulated linear and logarithmic models are summarized in Table 5.12.

Table 5.12: Summary of the coefficient of determination, standard error and mean square error of the linear and logarithmic models of each critical dimension for seam quality evaluation

Critical dimensions for seam quality evaluation	**Fabric materials**	**Types of model**	**Model Statistics**		
			Coefficient of determination (R^2)	**Standard Error (SE)**	**Mean Square Error (MSE)**
Seam Efficiency (Y1)	Cotton-polyester	Linear	0.809	9.334	78.231
		Logarithmic	0.854	8.157	66.536
	Cotton-spandex	Linear	0.882	8.37	70.054
		Logarithmic	0.922	6.804	46.296
	Cotton	Linear	0.855	9.534	90.898
		Logarithmic	0.861	9.231	89.707
Seam Puckering (Y2)	Cotton-polyester	Linear	0.874	5.815	59.484
		Logarithmic	0.907	4.99	33.818
	Cotton-spandex	Linear	0.872	7.713	53.941
		Logarithmic	0.885	7.304	53.351
	Cotton	Linear	0.724	9.139	24.121
		Logarithmic	0.711	9.349	24.903
Seam Boldness (Y3)	Cotton-polyester	Linear	0.747	0.617	0.349
		Logarithmic	0.806	0.539	0.291
	Cotton-spandex	Linear	0.802	0.592	0.283
		Logarithmic	0.812	0.589	0.239
	Cotton	Linear	0.738	0.66	0.435
		Logarithmic	0.742	0.654	0.428

5.2.3.1 Comparison between linear and logarithmic models for the evaluation of seam efficiency

In this section, the comparison between linear and logarithmic models of seam efficiency is carried out for each fabric to identify the best fit models for the evaluation of seam efficiency.

According to Table 5.12, in the linear model of cotton-polyester fabric, the coefficient of determination is 0.809, whereas, in the logarithmic model, it is 0.854. It means that the accuracy of the logarithmic model to predict the seam efficiency is 85.4% and that of the linear model is 80.9%. From this it can be concluded that the logarithmic model has a higher accuracy of prediction compared to the linear model. Again, in the linear model, the standard error and mean square error are 9.334 and 78.231 respectively, whereas, in the logarithmic model, the standard error and mean square error are 8.157 and 66.536 respectively. The model with high standard error and mean square error implies that prediction error of the model is high. Therefore, the prediction error of the logarithmic model is lower than that of linear model. In conclusion, the logarithmic model is the best fit model for seam efficiency in the case of cotton-polyester fabric for the reason described above. For cotton-spandex fabric, the experimental results show the same phenomenon.

However, for the cotton fabric, in the linear model, the coefficient of determination is 0.855, while, in the logarithmic model, it is 0.861. It means that the accuracy of the logarithmic model to predict the seam efficiency is 86.1% and that of linear model is 85.5%. From this it can be concluded that the accuracy of prediction of the logarithmic model is close to that of the linear model. Again, in the linear model, the standard error and the mean square error are 9.534 and 90.898 respectively, whereas, in the logarithmic model, the standard error and the mean square error are 9.231 and 89.707 respectively. From the standard error and mean square error values of both models, it is clear that the prediction errors of the linear model are close to that of the logarithmic model. Therefore, both models are fit for the evaluation of seam efficiency.

5.2.3.2 Comparison between linear and logarithmic models for the evaluation of seam puckering

In this section, the comparison between linear and logarithmic models of seam puckering is carried out for each fabric to identify the best fit models for the evaluation of seam puckering.

According to Table 5.12, in the linear model of cotton-polyester fabric, the coefficient of determination is 0.874, whereas, in the logarithmic model, it is 0.907. It means that the accuracy of the logarithmic model to predict the seam puckering is 90.7% and that of the linear model is 87.4%. From this it can be concluded that the logarithmic model has a higher accuracy of prediction compared to the linear model. Again, in the linear model, the standard error and mean square error are 5.815 and 59.484 respectively, whereas, in the logarithmic model, the standard error and mean square error are 4.99 and 33.818 respectively. The model with high standard error and mean square error implies that prediction error of the model is high. Therefore, the prediction error of the logarithmic model is lower than that of linear model. In conclusion, the logarithmic model is the best fit model for seam puckering in the case of cotton-polyester fabric for the reason described above.

However, for the cotton-spandex fabric, in the linear model, the coefficient of determination is 0.872, while, in the logarithmic model, it is 0.885. It means that the accuracy of the logarithmic model to predict the seam puckering is 88.5% and that of linear model is 87.2%. From this it can be concluded that the accuracy of prediction of the logarithmic model is close to that of the linear model. Again, in the linear model, the standard error and the mean square error are 7.713 and 53.941 respectively, whereas, in the logarithmic model, the standard error and the mean square error are 7.304 and 53.351 respectively. From the standard error and mean square error values of both models, it is clear that the prediction errors of the linear model are close to that of the logarithmic model. Therefore, both models are fit for the evaluation of seam puckering. This applies to cotton fabric as well.

5.2.3.3 Comparison between linear and logarithmic models for the evaluation of seam boldness

In this section, the comparison between linear and logarithmic models of seam boldness is carried out in each fabric to identify the best fit models for the evaluation of seam boldness.

According to Table 5.12, in the linear model of cotton-polyester fabric, the coefficient of determination is 0.747, whereas, in the logarithmic model, it is 0.806. It means that the accuracy of the logarithmic model to predict the seam boldness is 80.6% and that of the linear model is 74.7%. From this it can be concluded that the logarithmic model has a higher accuracy of prediction compared to the linear model. Again, in the linear model, the standard error and mean square error are 0.617 and 0.349 respectively, whereas, in the logarithmic model, the standard error and mean square error are 0.539 and 0.291 respectively. The model with high standard error and mean square error implies that prediction error of the model is high. Therefore, the prediction error of the logarithmic model is lower than that of linear model. In conclusion, the logarithmic model is the best fit model for seam boldness in the case of cotton-polyester fabric for the reason described above.

However, for the cotton-spandex fabric, in the linear model, the coefficient of determination is 0.802, while, in the logarithmic model, it is 0.812. It means that the accuracy of the logarithmic model to predict the seam boldness is 81.2% and that of linear model is 80.2%. From this it can be concluded that the accuracy of prediction of the logarithmic model is close to that of the linear model. Again, in the linear model, the standard error and the mean square error are 0.592 and 0.283

respectively, whereas, in the logarithmic model, the standard error and the mean square error are 0.589 and 0.239 respectively. From the standard error and mean square error values of both models, it is clear that the prediction errors of the linear model are close to that of the logarithmic model. Therefore, both models are fit for the evaluation of seam boldness. This applies to cotton fabric as well.

5.2.3.4 Summary

In this section, the obtained best fit model for seam efficiency, seam puckering and seam boldness are summarized in Table 5.13.

Table 5.13: Best fit models of each critical dimension for seam quality evaluation in three types of fabric

Fabric materials	**Best fit models**		
	Seam efficiency	**Seam puckering**	**Seam boldness**
Cotton-polyester	Logarithmic model	Logarithmic model	Logarithmic model
Cotton-spandex	Logarithmic model	Linear / logarithmic model	Linear / logarithmic model
Cotton	Linear / logarithmic model	Linear / logarithmic model	Linear / logarithmic model

According to Table 5.13, it can be concluded that generally logarithmic models are the best fit for seam efficiency, seam puckering and seam boldness in all the three types of fabric.

5.2.4 Effect of sewing thread size, stitch density and fabric properties on seam quality

In this section, the effects of sewing thread size, stitch density and fabric properties on seam efficiency, seam puckering and seam boldness are identified through the regression coefficients of input variables in best fit models. Generally, the logarithmic regression models have been found to be best fit for seam efficiency, seam puckering and seam boldness in the three types of fabrics. In order to understand the effect of sewing thread size, stitch density and fabric properties, the regression coefficients of input variables in the logarithmic regression models (see section 5.2.2) are summarized in Table 5.14. An input variable with positive regression coefficient has a positive effect on the output. On the other hand, an input variable with negative regression coefficient has a negative effect on the output. The obtained effects of sewing thread size, stitch density and fabric properties on seam efficiency, seam puckering and seam boldness are discussed in the following sections.

Table 5.14: Regression coefficient of the input variables in the best fit models (logarithmic regression models) of seam efficiency, seam puckering and seam boldness in three types of fabric

Input Variables	Seam efficiency			Seam Puckering			Seam Boldness		
	Cotton-polyester	Cotton-spandex	Cotton	Cotton-polyester	Cotton-spandex	Cotton	Cotton-polyester	Cotton-spandex	Cotton
Sewing Thread Size (X1)	27.1251	25.8417	27.2749	27.6427	25.4918	20.9912	2.0475	2.0125	1.9903
Cover Factor (X2)	-6.0421	-6.2164	-7.564	-8.6538	7.4067	1.8572	0.048	0.1245	-0.2232
Weight (X3)	-9.4917	4.3024	1.2284	-11.8953	-5.1508	-6.4876	0.4007	-0.4248	0.1006
Thickness (X4)	-0.3094	-6.4905	14.882	-0.4798	-30.7717	-13.639	0.0225	0.2764	0.2274
Strength (X5)	-17.9707	-36.1454	-24.2169	4.7309	-1.3297	2.849	-0.1292	-0.2566	-0.1484
Extensibility (X6)	4.805	0.2078	5.7315	7.1193	-0.4419	-0.5511	-0.1109	-0.0213	-0.0413
Bending Rigidity (X7)	0.1257	5.4029	1.5285	0.9123	2.4242	-1.7428	0.0972	0.1533	0.0492
Shear Rigidity (X8)	4.4008	-0.5224	-4.0016	4.5755	1.8045	-2.5251	-0.0375	0.0436	-0.0145
Stitch Density (X9)	27.3261	25.9973	32.1759	6.7215	5.9170	3.5326	-0.3452	-0.239	-0.8388

5.2.4.1 Effect of sewing thread size, stitch density and fabric properties on seam efficiency

In order to understand the effect of sewing thread size, stitch density and fabric properties on seam efficiency, a comparison of best fit seam efficiency models (logarithmic regression models) among the three types of fabric is carried out. For comparison, the regression coefficients of the input variables for the seam efficiency in Table 5.14 are graphically represented in Figure 5.1.

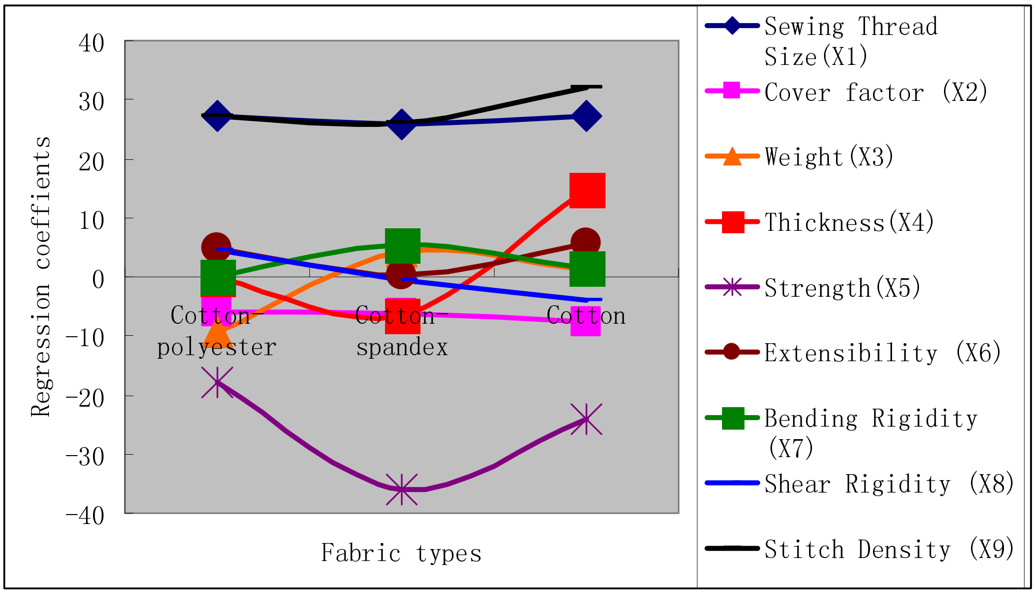


Figure 5.1: Comparison of best fit seam efficiency models (logarithmic regression models) among the three types of fabric.

According to Figure 5.1, the regression coefficients of sewing thread size (X1), cover factor (X2), stitch density (X9) is fairly constant in all the three types of tested fabric. From this it can be concluded that, sewing thread size, stitch density and cover factor have a regular impact on the seam efficiency regardless of the fabric types. Other variables such as, weight (X3), thickness (X4), strength (X5), extensibility (X6), bending rigidity (X7) and shear rigidity (X8) show a great variation of regression coefficients in the three types of fabrics. This variation implies that seam efficiency is affected by the type of fabric.

Furthermore, the regression coefficients of sewing thread size (X1), extensibility (X6), bending rigidity (X7) and stitch density (X9) is positive on seam efficiency in the three types of fabrics. Therefore, these four variables have a positive impact on the seam efficiency. However, cover factor (X2) and strength (X5) have negative regression coefficients and hence these two variables are said to have a negative impact on the seam efficiency.

5.2.4.2 Effect of sewing thread size, stitch density and fabric properties on seam puckering

In order to understand the effect of sewing thread size, stitch density and fabric properties on seam puckering, a comparison of best fit seam puckering models (logarithmic regression models) among the three types of fabric is carried out. For comparison, the regression coefficients of the input variables for the seam puckering from Table 5.14 are graphically represented in Figure 5.2.

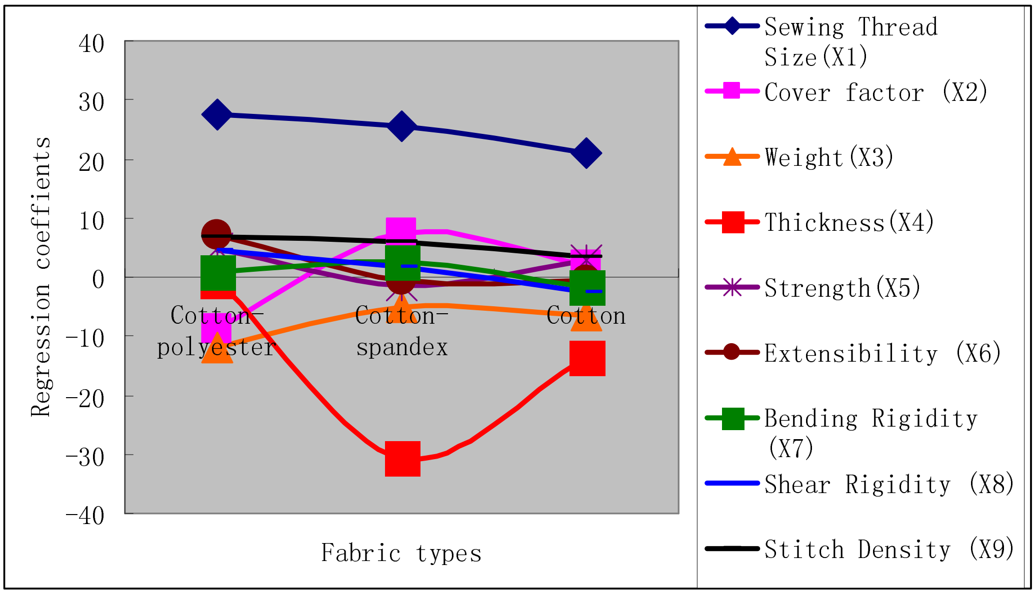


Figure 5.2: Comparison of best fit seam puckering models (logarithmic regression models) among the three types of fabric.

Figure 5.2 shows that the regression coefficients of sewing thread size (X1), weight (X3) and stitch density (X9) are fairly constant in all the three types of tested fabrics. From this it can be concluded that sewing thread size, weight and stitch density have a regular impact on seam puckering regardless of the fabric types. Other variables such as, cover factor (X2), thickness (X4), strength (X5), extensibility (X6), bending rigidity (X7) and shear rigidity (X8) show a great variation of the regression coefficients in the three types of fabric. This variation implies that change of fabric types would greatly affect the seam puckering.

Furthermore, the regression coefficient of sewing thread size (X1), and stitch density (X9) is positive on seam puckering in the three types of fabrics. Therefore, these two variables are said to have a positive impact on the seam puckering. On the other hand, weight (X3) and thickness (X4) have negative regression coefficients in the fabrics and hence these two variables have a negative impact on the seam puckering.

5.2.4.3 Effect of sewing thread size, stitch density and fabric properties on seam boldness

In order to understand the effect of sewing thread size, stitch density and fabric properties on seam boldness, a comparison of best fit seam boldness models (logarithmic regression models) among the three types of fabric is carried out. For comparison, the regression coefficients of the input variables for seam boldness in Table 5.14 are graphically represented in Figure 5.3.

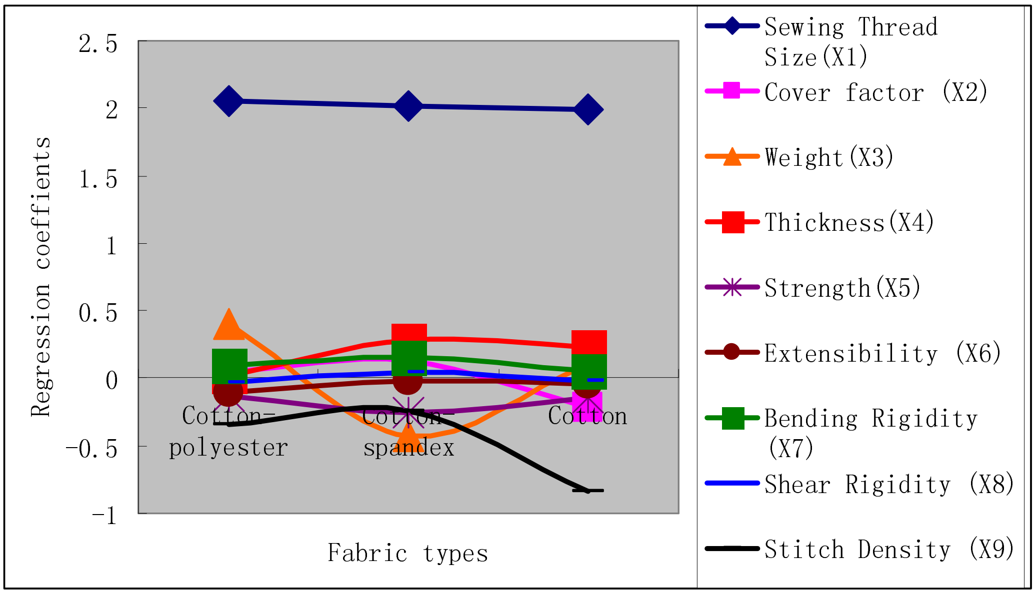


Figure 5.3: Comparison of best fit seam boldness models (logarithmic regression models) among the three types of fabric.

According to Figure 5.3, the regression coefficient of input variables, sewing thread size (X1), thickness (X4), strength (X5), extensibility (X6) and bending rigidity (X7) is fairly constant among the three types of tested fabric. It helps to conclude that the sewing thread size, thickness, strength, extensibility and bending rigidity have a regular impact on the seam boldness regardless of the fabric types.

Moreover, the regression coefficient of sewing thread size (X1), thickness (X4) and bending rigidity (X7) is positive on seam boldness in three types of fabric. It means these three variables have a positive impact on the seam boldness. However, strength (X5), extensibility (X6) and stitch density (X9) have negative regression coefficient. So, these three input variables have a negative impact on the seam boldness.

5.3 Model validation

In this section, the best fit models (logarithmic regression models) of each critical dimension for seam quality evaluation in Table 5.13 are validated through statistical analysis. The purpose of this validation is to measure the prediction accuracy of the best fit models.

In the validation process, at first, each critical dimension for seam quality evaluation is measured from experiments with a new set of prepared seam. The critical dimensions for seam quality evaluation are also predicted from the obtained best fit models. The obtained values from the experiments and values predicted from the model are given in Appendices X-XV.

To verify the validity of best fit models (logarithmic regression models) for seam efficiency, seam puckering and seam boldness of three types of fabrics, the predicted values obtained from the best fit model are compared with the new set of experimental values. The coefficient of determination (R^2), Standard Error (SE) and Mean Square Error (MSE) between experimental values and predicted values are calculated. High coefficient of determination (R^2), low Standard Error (SE) and low Mean Square Error (MSE) of best fit models infers, the models could suitably predict the new experimental data in general.

5.3.1 Validation of the best fit models for seam efficiency

In this section, in order to verify the validity of the best fit models (logarithmic regression models) for seam efficiency, the obtained predicted values of seam efficiency from the best fit models are compared with the new set of experimental values of seam efficiency.

The relationships between the predicted seam efficiency and the experimental seam efficiency in cotton-polyester, cottons-spandex and cotton fabrics are represented in Figure 5.4, 5.5 and 5.6, respectively.

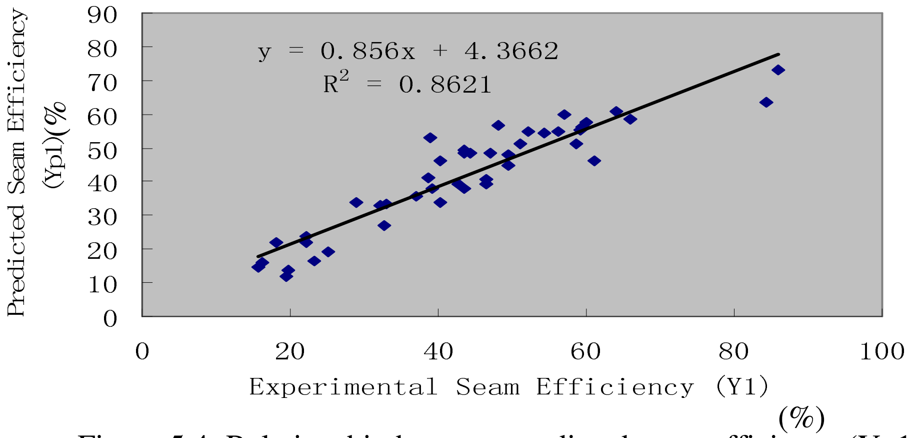


Figure 5.4: Relationship between predicted seam efficiency (Yp1) and experimental seam efficiency (Y1) in cotton-polyester fabric

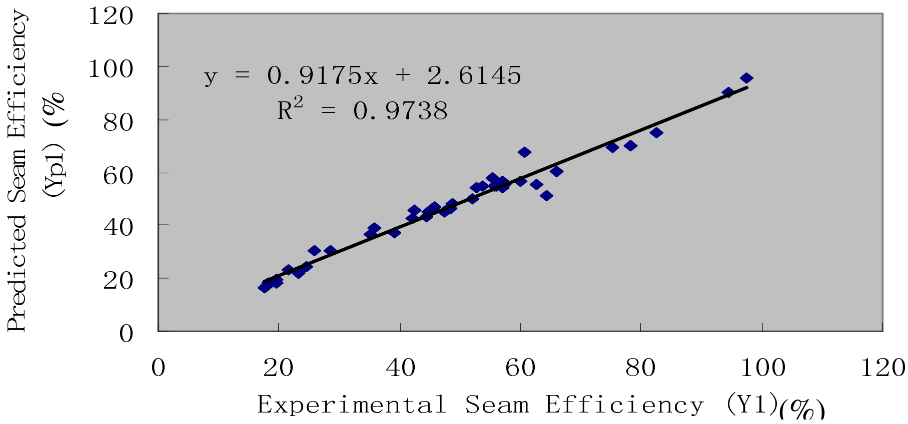


Figure 5.5: Relationship between predicted seam efficiency (Yp1) and experimental seam efficiency (Y1) in cotton-spandex fabric

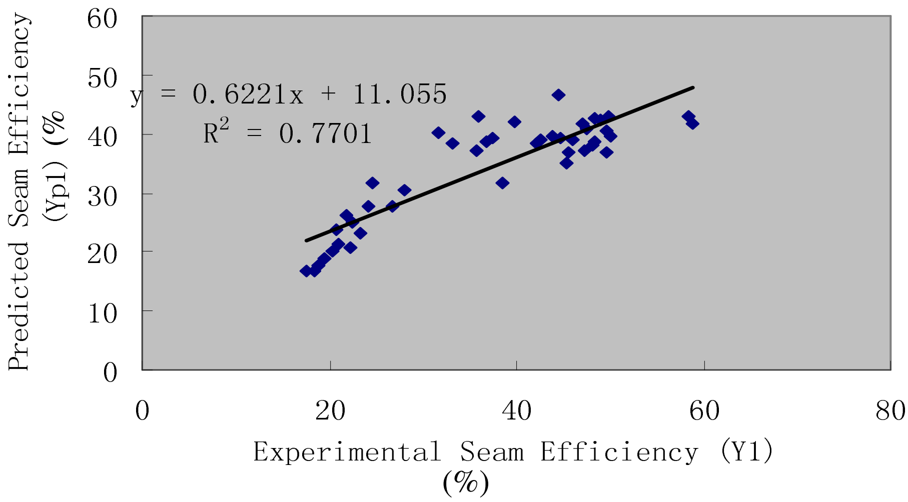


Figure 5.6: Relationship between predicted seam efficiency (Yp1) and experimental seam efficiency (Y1) in cotton fabric

Figures 5.4, 5.5 and 5.6 show that the coefficient of determination (R^2) between the predicted values and the experimental values of the best fit seam efficiency models for cotton-polyester, cotton-spandex and cotton fabrics are 0.8621, 0.9738 and 0.7701 respectively. From the coefficient of determination, it is clear that the accuracy of the best fit models to predict seam efficiency for cotton-polyester, cotton-spandex and cotton fabrics are 86.21%, 97.38% and 77.01% respectively. The Standard Error (SE) and the Mean Square Error (MSE) between the predicted values and the experimental values are also estimated. The Standard Error (SE) between the predicted values and the experimental values for cotton-polyester, cotton-spandex and cotton fabric are 0.9832, 0.5418 and 0.9386 respectively. The Mean Square Error (MSE) between the predicted values and the experimental values for cotton-polyester, cotton-spandex and cotton fabric are 41.4857, 13.1970 and 1.0261 respectively. The standard error and mean square error values show that the prediction error of the best fit models is very less. Therefore, the models can accurately predict the seam efficiency.

5.3.2 Validation of the best fit models for seam puckering

In this section, in order to verify the validity of the best fit models (logarithmic regression models) for seam puckering, the obtained predicted values of seam puckering from the best fit models are compared with the new set of experimental values of seam puckering.

The relationships between the predicted seam puckering and the experimental seam puckering in cotton-polyester, cottons-spandex and cotton fabrics are represented in Figure 5.7, 5.8 and 5.9, respectively.

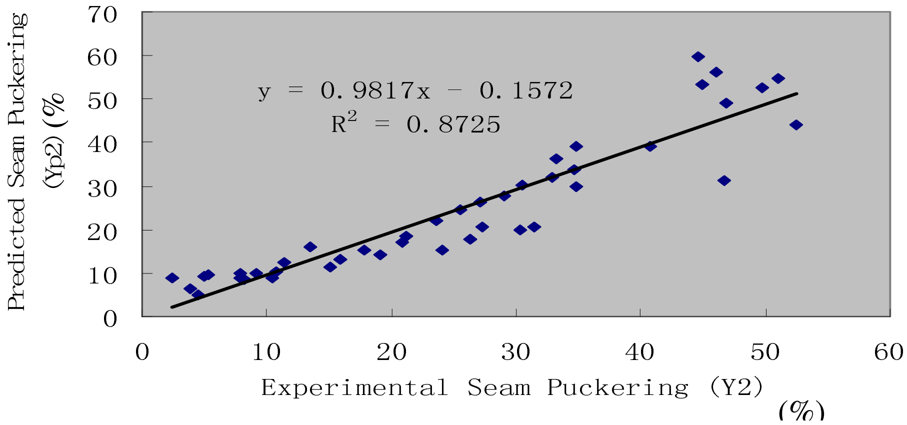


Figure 5.7: Relationship between predicted seam puckering (Yp2) and experimental seam puckering (Y2) in cotton-polyester fabric

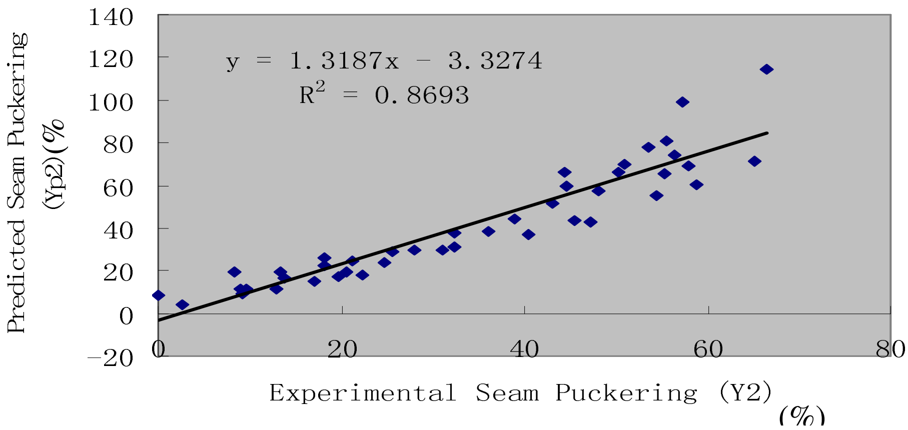


Figure 5.8: Relationship between predicted seam puckering (Yp2) and experimental seam puckering (Y2) in cotton-spandex fabric

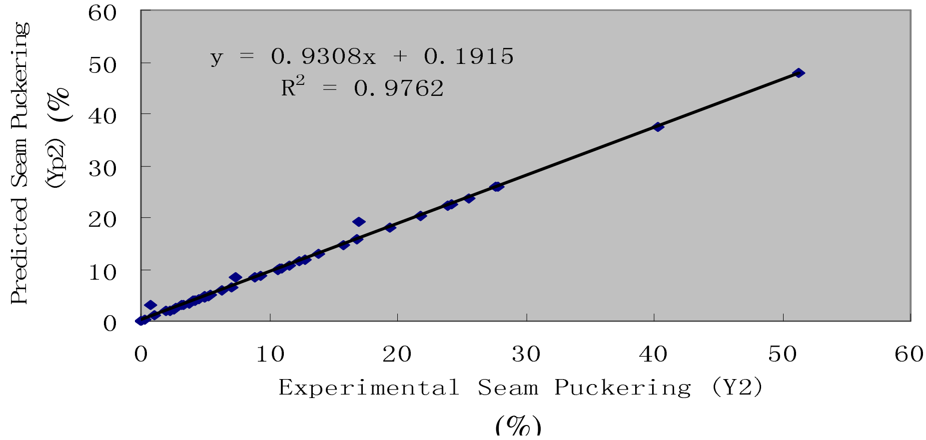


Figure 5.9: Relationship between predicted seam puckering (Yp2) and experimental seam puckering (Y2) in cotton fabric

Figures 5.7, 5.8 and 5.9 show that the coefficient of determination (R^2) between the predicted values and the experimental values of the best fit seam puckering models for cotton-polyester, cotton-spandex and cotton fabrics are 0.8725, 0.8693 and 0.9762 respectively. From the coefficient of determination, it is clear that the accuracy of the best fit models to predict seam puckering for cotton-polyester, cotton-spandex and cotton fabrics are 87.25%, 86.93% and 97.62% respectively. The Standard Error (SE) and the Mean Square Error (MSE) between the predicted values and the experimental values are also estimated. The Standard Error (SE) between the predicted values and the experimental values for cotton-polyester, cotton-spandex and cotton fabric are 1.4775, 1.7362 and 0.1110 respectively. The Mean Square Error (MSE) between the predicted values and the experimental values for cotton-polyester, cotton-spandex and cotton fabric are 101.1424, 182.7743 and 0.1576 respectively. The standard error and mean square error values show that prediction error of the best fit models is very less. Therefore, the models can accurately predict the seam puckering.

5.3.3 Validation of the best fit models for seam boldness

In this section, in order to verify the validity of the best fit models (logarithmic regression models) for seam boldness, the obtained predicted values of seam boldness from the best fit models are compared with the new set of experimental values of seam boldness.

The relationships between the predicted seam boldness and the experimental seam boldness in cotton-polyester, cottons-spandex and cotton fabrics are represented in Figure 5.10, 5.11 and 5.12 respectively.

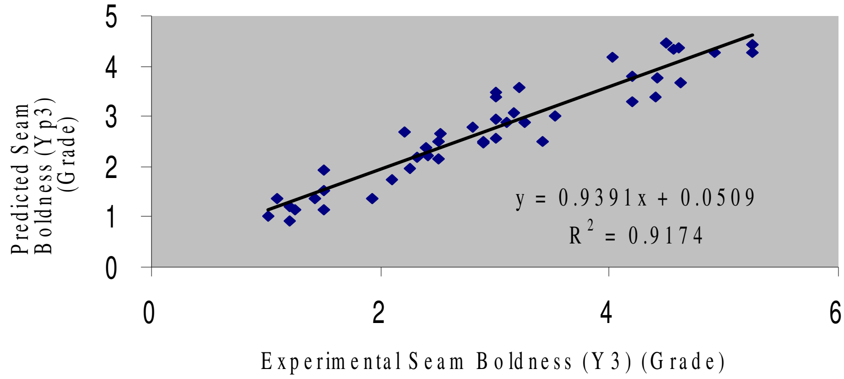


Figure 5.10: Relationship between predicted seam boldness (Yp3) and experimental seam boldness (Y3) in cotton-polyester fabric

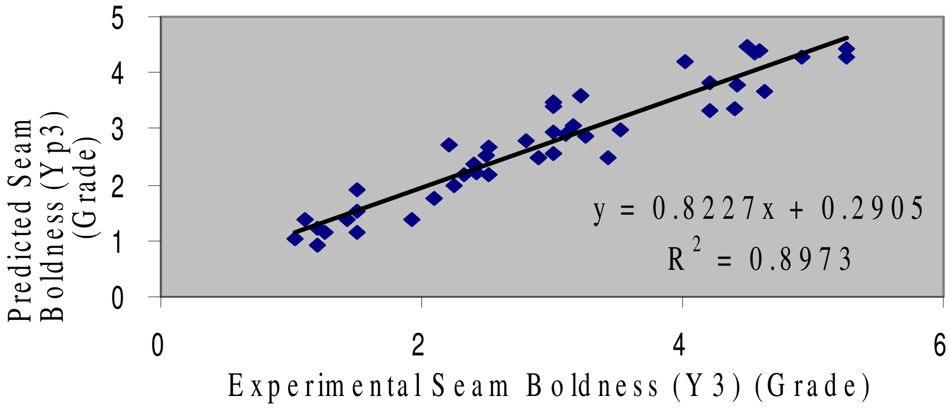


Figure 5.11: Relationship between predicted seam boldness (Yp3) and experimental seam boldness (Y3) in cotton-spandex fabric

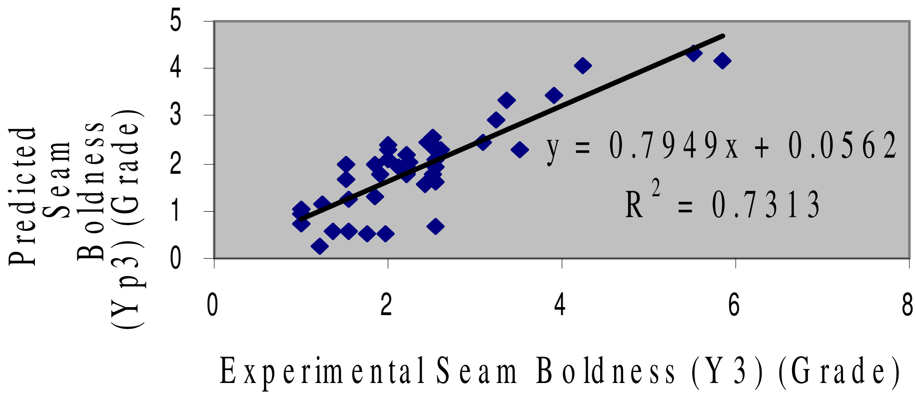


Figure 5.12: Relationship between predicted seam boldness (Yp3) and experimental seam boldness (Y3) in cotton fabric

Figures 5.10, 5.11 and 5.12 show that the coefficient of determination (R^2) between the predicted values and the experimental values of the best fit seam boldness models for cotton-polyester, cotton-spandex and cotton fabrics are 0.9174, 0.8973 and 0.7313 respectively. From the coefficient of determination, it is clear that the accuracy of the best fit models to predict seam boldness for cotton-polyester, cotton-spandex and cotton fabrics are 91.74%, 89.73% and

73.13% respectively. The Standard Error (SE) and the Mean Square Error (MSE) between the predicted values and the experimental values are also estimated. The Standard Error (SE) between the predicted values and the experimental values in cotton-polyester, cotton-spandex and cotton fabric are 0.9456, 0.0825 and 0.0700 respectively. The Mean Square Error (MSE) between the predicted values and the experimental values for cotton-polyester, cotton-spandex and cotton fabric are 33.2314, 0.3030 and 0.1211 respectively. The standard error and mean square error values show that the prediction error of the best fit models is very less. Therefore, the models can accurately predict the seam boldness.

5.4 Application of the best fit models on various apparel products

In this section, the best fit models of each critical dimension (seam efficiency, seam puckering and seam boldness) for seam quality evaluation are integrated to provide a solution for evaluating the overall seam quality of each particular apparel product: Blouse, Shirt, Denim trousers, T-shirt and Lingerie. The requirements of each critical dimension for seam quality evaluation on the overall seam quality vary in accordance with the intended use of apparel products. Therefore, it is essential to calculate the weighing factors of each critical dimension for seam quality evaluation.

A subjective evaluation was carried out to obtain the relative importance of each critical dimension for seam quality evaluation in percentage according to the requirements of each dimension on the overall seam quality for each apparel product. From the relative importance, the weighing factors of each critical dimension for seam quality evaluation on the overall seam quality of each apparel product are calculated.

Moreover, the application of best fit models is dependent on the fabric material used. This is confirmed in Table 5.13, where the three types of fabric having generally logarithmic best fit models for seam efficiency, seam puckering and seam boldness. In order to provide a solution for evaluating the overall seam quality, the best fit models are selected based on the fabric material used in the apparel products.

5.4.1 Relative importance of each critical dimension for seam quality evaluation on the overall seam quality of apparel products

A total of 10 professional researchers were selected for the subjective evaluation in this study. They were requested to assign a number in percentage to each critical dimension of seam quality evaluation for assessing the relative importance according to the requirements of each dimension on the overall seam quality of five apparel products: Blouse, Shirt, Denim trousers, T-shirt and Lingerie. The numbers in percentage, in the researchers view, reflect the importance of the respective critical dimension for seam quality evaluation on the overall seam quality of the apparel products. The average percentages of the relative importance for each critical dimension of seam quality evaluation given by the ten researchers are presented in Table 5.15.

Table 5.15: Percentages of the relative importance of each critical dimension for seam quality evaluation

Product(p)	**Seam Efficiency** (%)	**Seam Puckering** (%)	**Seam Boldness** (%)
Blouse	42.5	39.5	18.0
Shirt	41.5	40.0	18.5
Denim trousers	40.0	17.5	42.5
T-shirt	46.5	37.5	16.0
Lingerie	49.0	35.8	15.2

It can be seen from Table 5.15 that the relative importance of the seam efficiency is the highest among the three critical dimensions for seam quality evaluation for the five apparel products. Seam puckering also has a relatively moderate importance on the blouse, shirt, T-shirt and lingerie but fairly poor on denim trousers. Seam boldness has the highest relative importance on the denim trousers but its influence on blouse, shirt, T-shirt and lingerie is not significant.

5.4.2 Weighing factors of each critical dimension for seam quality evaluation on the overall seam quality of apparel products

The weighing factors of each critical dimension for seam quality evaluation are calculated from the percentages of relative importance for each dimension presented in Table 5.15. The weighing factors are calculated by normalizing the percentages of each critical dimension for seam quality evaluation for a particular apparel product. The normalization is carried out with respect to the lowest value of the relative importance. The weighing factors are shown in Table 5.16.

Table 5.16: Weighing factors of each critical dimension for seam quality evaluation on the overall seam quality of apparel products

Product(p)	**Weighing factor of seam efficiency (W_{1p})**	**Weighing factor of seam puckering (W_{2p})**	**Weighing factor of seam boldness (W_{3p})**
Blouse	2	2	1
Shirt	2	2	1
Denim trousers	2	1	2
T-shirt	2	2	1
Lingerie	2	2	1

Table 5.16 provides information about the weighing factor of each critical dimension for seam quality evaluation on the overall seam quality for five apparel products. The ratio of weighing factors of the seam efficiency, the seam puckering and the seam boldness for blouse, shirt, denim trousers, T-shirt and lingerie are 2:2:1, 2:2:1, 2:1:2, 2:2:1 and 2:2:1 respectively. The seam efficiency registered a weighing factor of 2 for the five apparel products, whereas seam puckering registered a weighing factor of 2 for all the apparel products except denim trousers. In contrast, seam boldness registered a weighing factor of just 1 for four of the apparel products, except for the denim trousers.

5.4.3 Proposed solution for evaluating the overall seam quality for apparel products

In this section, a solution to evaluate the overall seam quality is derived for the five apparel products. The weighing factor of each critical dimension for seam quality evaluation is different for each apparel product. Seam efficiency is directly proportional to good seam quality and always has a positive effect on the overall seam quality of apparel products. Therefore, seam efficiency bears a positive value in the overall seam quality of apparel products. On the other hand, seam puckering is inversely correlated with good seam quality, hence, it has a negative value.

In the case of seam boldness, the positive or negative value depends on the apparel products. In some apparels, seam boldness requirement is reasonably high. For those apparel products, seam boldness is directly proportional to the good seam quality and it has a positive effect on the overall seam quality. Therefore, seam boldness bears positive value to the overall seam quality in the case of such apparels, which have high weighing factors for seam boldness in the overall seam quality. In the present study, the seam boldness has a positive value on the overall seam quality of denim trousers because it gives a weighing factor of 2. However, the seam boldness has a negative value on the overall seam quality for blouse, shirt, T-shirt and lingerie as the weighing factor is 1 for all these apparel products.

The solution for evaluating the overall seam quality of blouse, shirt, T-shirt and lingerie is given in Equation (1):

$$(OSQ)p = \begin{cases} 2Y1 \\ -2Y2 \\ -Y3 \end{cases} \tag{1}$$

And,

The solution for evaluating the overall seam quality of denim trousers is represented in Equation (2):

$$(OSQ)p = \begin{cases} 2Y1 \\ -Y2 \\ 2Y3 \end{cases} \tag{2}$$

Here,

p= Blouse, shirt, T-shirt and denim trousers for Equation (1); Denim trousers for Equation (2),

Y1 = Best fit model of seam efficiency,

Y2 = Best fit model of seam puckering,

Y3 = Best fit model of seam boldness,

OSQ = Overall Seam Quality.

The integration of best fit models on selected apparel products are represented in Table 5.17.

Table 5.17: Integration of best fit models on selected apparel products

Fabric Types	Apparel Products	Integrated models for seam quality
Cotton -polyester	Blouse, T-shirt, Lingerie Shirt	$\left\{\begin{array}{l} 2[54.1545+27.1251\log X1-6.0421\log X2-9.4917\log X3-0.3094\log X4-17.9707\log X5+4.805\log X6+0.1257\log X7+4.4008\log X8+27.3261\log X9] \\ -2[-39.3751+27.6427\log X1-8.6538\log X2-11.8953\log X3-0.4798\log X4+4.7309\log X5+7.1193\log X6+0.9123\log X7+4.5755\log X8+6.7215\log X9] \\ -[-6.5362+2.0475\log X1+0.048\log X2+0.4007\log X3+0.0225\log X4-0.1292\log X5-0.1109\log X6+0.0972\log X7-0.0375\log X8-0.3452\log X9] \end{array}\right.$
	Denim-Trousers	$\left\{\begin{array}{l} 2[54.1545+27.1251\log X1-6.0421\log X2-9.4917\log X3-0.3094\log X4-17.9707\log X5+4.805\log X6+0.1257\log X7+4.4008\log X8+27.3261\log X9] \\ -[-39.3751+27.6427\log X1-8.6538\log X2-11.8953\log X3-0.4798\log X4+4.7309\log X5+7.1193\log X6+0.9123\log X7+4.5755\log X8+6.7215\log X9] \\ 2[-6.5362+2.0475\log X1+0.048\log X2+0.4007\log X3+0.0225\log X4-0.1292\log X5-0.1109\log X6+0.0972\log X7-0.0375\log X8-0.3452\log X9] \end{array}\right.$
Cotton -spandex	Blouse, T-shirt, Lingerie Shirt	$\left\{\begin{array}{l} 2[115.7685+25.8417\log X1-6.2164\log X2+4.3024\log X3-6.4905\log X4-36.1454\log X5+0.2078\log X6+5.4029\log X7-0.5224\log X8+25.9973\log X9] \\ -2[-135.819+25.4918\log X1+7.4067\log X2-5.1508\log X3-30.7717\log X4-1.3297\log X5-0.4419\log X6+2.4242\log X7+1.8045\log X8+5.9170\log X9] \\ -[-0.3018+2.0125\log X1+0.1245\log X2-0.4248\log X3+0.2764\log X4-0.2566\log X5-0.0213\log X6+0.1533\log X7+0.0436\log X8-0.239\log X9] \end{array}\right.$
	Denim-Trousers	$\left\{\begin{array}{l} 2[115.7685+25.8417\log X1-6.2164\log X2+4.3024\log X3-6.4905\log X4-36.1454\log X5+0.2078\log X6+5.4029\log X7-0.5224\log X8+25.9973\log X9] \\ -[-135.819+25.4918\log X1+7.4067\log X2-5.1508\log X3-30.7717\log X4-1.3297\log X5-0.4419\log X6+2.4242\log X7+1.8045\log X8+5.9170\log X9] \\ 2[-0.3018+2.0125\log X1+0.1245\log X2-0.4248\log X3+0.2764\log X4-0.2566\log X5-0.0213\log X6+0.1533\log X7+0.0436\log X8-0.239\log X9] \end{array}\right.$
Cotton	Blouse, T-shirt, Lingerie Shirt	$\left\{\begin{array}{l} 2[48.4152+27.2749\log X1-7.564\log X2+1.2284\log X3+14.882\log X4-24.2169\log X5+5.7315\log X6+1.5285\log X7-4.0016\log X8+32.1752\log X9] \\ -2[-64.6687+20.9912\log X1+1.8572\log X2-6.4876\log X3-13.639\log X4+2.849\log X5-0.5511\log X6-1.7428\log X7-2.5251\log X8+3.5326\log X9] \\ -[-3.8415+1.9903\log X1-0.2232\log X2+0.1006\log X3+0.2274\log X4-0.1484\log X5-0.0413\log X6+0.0492\log X7-0.0145\log X8-0.8388\log X9] \end{array}\right.$
	Denim trousers	$\left\{\begin{array}{l} 2[48.4152+27.2749\log X1-7.564\log X2+1.2284\log X3+14.882\log X4-24.2169\log X5+5.7315\log X6+1.5285\log X7-4.0016\log X8+32.1752\log X9] \\ -[-64.6687+20.9912\log X1+1.8572\log X2-6.4876\log X3-13.639\log X4+2.849\log X5-0.5511\log X6-1.7428\log X7-2.5251\log X8+3.5326\log X9] \\ 2[-3.8415+1.9903\log X1-0.2232\log X2+0.1006\log X3+0.2274\log X4-0.1484\log X5-0.0413\log X6+0.0492\log X7-0.0145\log X8-0.8388\log X9] \end{array}\right.$

CHAPTER 6

CONCLUSIONS

6.1 Summary and conclusions

A fabric cannot be used directly to manufacture cut and sewn apparel products without seam. As the seam is one of the basic requirements in the construction of apparel, seam quality has great significance in the overall quality of apparel products.

There are many factors affecting the seam quality. However, apparel engineers and/or designers mainly consider sewing thread size, stitch density and fabric properties such as weight, cover factor, bending rigidity etc...

In apparel industries, the overall seam quality is defined through various functional and aesthetic performances desired in the apparel product during its use. For the evaluation of seam quality, apparel engineers use different dimensions such as seam efficiency, seam elongation, seam bending stiffness etc...

The requirements of functional and aesthetic performance also vary with the intended use of the apparel. For example, in a military garment the requirements of functional performances are high. On the other hand, in a bridal wear the requirements of aesthetic performances are high. This means that different garments have different requirements of functional and aesthetic performances in the overall seam quality.

Previous researchers have provided evidences to understand seam quality from two major aspects: the functional and the aesthetic performance of seam. Most of the studies evaluated the seam quality using an individual dimension either based on functional and aesthetic aspects. Till to date, there is very little research available on seam quality combining both functional and aesthetic performances.

Furthermore, there are numerous studies on seam quality based on the aesthetic performance. These studies focus mainly on the seam defects such as the seam puckering, seam damage etc... Although a defect free seam in apparel is a prime requirement for proper appearance, the overall appearance of the seam also depends on the design requirements of the consumers for apparel. Different degrees of boldness of seam can help to fulfil different purposes as design features and affect the appearance of garment. In apparel industries, seam boldness is commonly used as a prime dimension for evaluating the design prominence of a seam especially at the early stage of product development. This dimension is crucial for the designer and/or apparel manufacturer to decide when they select the fabric material, sewing thread size and stitch density for making up of a seam of any apparel product. However, previous researchers have not carried out any studies on seam boldness.

A study which considers functional and aesthetic performance of seam together will definitely contribute to the knowledge of the overall seam quality for apparel products. A knowledge of the overall seam quality will help the apparel engineers to evaluate the quality of apparel products more precisely, when a particular sewing thread size and stitch density are applied on a particular type of fabric.

Hence the purpose of this study is to examine seam quality from the aspects of both functional and aesthetic performances and to study the effect of sewing thread size, and stitch density on seam quality in various types of fabric materials. In this study, seam quality has been evaluated for three types of fabrics: cotton-polyester, cotton-spandex and cotton. The study has provided a solution for evaluating the overall seam quality of five apparel products: blouse, T-shirt, shirt, denim trousers and lingerie by considering the functional and aesthetic performances of the seam together.

6.1.1 Critical dimensions for seam quality evaluation

There are so many dimensions that could be used for evaluating seam quality. In order to simplify the analysis of overall seam quality, it is essential to choose only the most important dimensions in the evaluation of seam quality. This study tries to identify the most important dimensions for the evaluation of seam quality through subjective ranking by professional personnel in apparel field.

The result of subjective ranking provides three critical dimensions for the evaluation of seam quality. They are, seam efficiency, seam puckering and seam boldness. Seam efficiency is the dimension for the evaluation of the seam's functional performance. Seam puckering is the dimension for evaluating the seam's aesthetic performance in terms of seam appearance. Seam boldness is the dimension to measure the design prominence along the seam line. These three critical dimensions can well represent both the functional and aesthetic aspects of seam quality.

6.1.2 Model formulation

In order to explain the relationship between each critical dimension for seam quality evaluation and factors affecting the seam quality such as, sewing thread size, fabric properties and stitch density, empirical models are formulated using multiple regression method. Sewing thread size, fabric properties and stitch density are considered as input variables for modelling and critical dimensions for seam quality evaluation are considered as output variables.

For empirical modelling, the different properties of selected fabrics are measured using Kawabata Evaluation System or ASTM method. Each selected fabric is sewn by different sewing thread sizes at various stitch densities. From the prepared seam, each critical dimension for seam quality evaluation is measured by their standard evaluation method. These experimental values are used for model formulation.

In order to reduce the number of input variables so as to simplify the empirical model, the identification of key input variables is carried out through covariance analysis, regression analysis and factor analysis. Based on the literature review, 12 input variables for seam quality can be identified. From these 12 variables, only nine key input variables: sewing thread size, weight, cover factor, thickness, strength, extensibility, bending rigidity, shear rigidity and stitch density are selected for model formulation.

To identify the most effective model for seam quality evaluation, linear and logarithmic regression models are formulated for each critical dimension of seam quality evaluation in the three selected fabrics.

6.1.3 Model effectiveness

For the determination of the most effective model for seam quality evaluation, the formulated linear and logarithmic models of each critical dimension for seam quality evaluation are compared through statistical analysis.

The coefficient of determination, Standard Error and Mean Square Error are calculated to measure the performance of both models. Coefficient of determination, Standard Error and Mean Square Error depict the ability of a model to accurately predict the each critical dimension for seam quality evaluation.

A model with high coefficient of determination, low standard error and low mean square error are considered as most effective and termed as 'best fit model'.

It has been found that generally logarithmic model is the best fit for the evaluation of seam efficiency, seam puckering and seam boldness in the three selected fabrics. However, in some cases linear model can perform as effectively as logarithmic model. For example, both the models are fit for the evaluation of seam puckering in the cotton-spandex and cotton fabrics.

It can be concluded that the logarithmic model can effectively evaluate the seam quality. So, it is recommended that apparel engineers may use the logarithmic models for objective measurement of seam efficiency, seam puckering and seam boldness. An objective measurement will help apparel engineers achieve the desired quality level without cumbersome processes.

6.1.4 Model evaluation

In order to identify the effect of sewing thread size, stitch density and fabric properties on seam efficiency, seam puckering and seam boldness, the obtained best fit models (logarithmic models) are evaluated based on the regression coefficient of the input variables in the model.

From the regression models, it is evident that seam efficiency varies according to the types of fabrics. Seam efficiency increases with the increase in sewing thread size and stitch density for all the three fabrics. Apparel engineers can refer to the models and may select the high sewing thread size and high stitch density for greater seam efficiency in apparels. These sewn fabrics having high extensibility and bending rigidity will also help to achieve greater seam efficiency. On the other hand, fabrics of high cover factor and high strength will reduce the efficiency of a seam assembly. Apparel engineers may carefully select the fabric properties such as, extensibility, bending rigidity, cover factor and strength, in order to achieve desired seam efficiency.

According to the findings from the regression models, seam puckering is affected by the type of sewn fabrics. Seam puckering increases with the increase in sewing thread size and stitch density in any of the three fabrics. Apparel engineers may select a lower sewing thread size and a lower stitch density, in order to reduce the puckering along the seam line. In all the three types of fabric, thickness and weight of the fabrics is important in the course of garment manufacturing. These fabrics having high thickness and high weight will reduce seam puckering in apparel during seam formation, which will ultimately improve the quality of the apparel.

Based on the findings from the regression models, seam boldness enhances with increase in sewing thread size, whereas, seam boldness diminishes with the increase in stitch density along the seam line. In order to achieve high seam boldness, apparel engineers may select a high sewing thread size. The three selected fabrics having high thickness and high bending rigidity will also help to achieve high seam boldness along the seam line. Apparel engineers can select the sewn fabrics having high thickness and high bending rigidity, if the requirement for seam boldness is high in any apparel. On the other hand, it is recommended that apparel engineers may select the fabrics having high strength, high extensibility to reduce the seam boldness along the seam line.

In general, the findings from the regression models will help the apparel engineers easily resolve problems regarding seam quality, which are encountered in the course of apparel manufacturing. An understanding of the impact of the crucial factors such as, sewing thread size, stitch density and fabric properties on seam quality will help apparel engineers meet the desired quality levels.

6.1.5 Model validation

The best fit models (logarithmic models) of each critical dimension for seam quality evaluation in each fabric are validated to measure the accuracy of the models to predict each dimension. For this, the predicted values obtained from the best fit models are statistically compared with a new set of values obtained from laboratory experiments. It is found that all the best fit models have a high coefficient of determination, a low standard error and a low mean square error between the predicted and experimental values. It helps conclude that the derived best fit models have a good accuracy to predict the outputs. Therefore, these models could be used in the apparel industry for accurate prediction of seam quality of the three types of fabric.

6.1.6 Model application

The best fit models of each critical dimension for seam quality evaluation are integrated to provide a solution for evaluating the overall seam quality of each of the five apparel products: blouse, shirt, denim trousers, T-shirt and lingerie. The requirements of each critical dimension for seam quality evaluation on the overall seam quality vary in accordance with the intended use of the apparel. In order to integrate the best fit models, the weighing factors of each critical dimension for seam quality evaluation on the overall seam quality of the apparel products are calculated by subjective analysis.

Through subjective analysis it is found that seam efficiency registered a weighing factor of 2 for five apparel products, whereas, seam puckering registered a weighing factor of 2 for all the apparel products except denim trousers. In contrast, seam boldness registered a weighing factor of just 1 for four of the apparel products, except for denim trousers.

From the obtained weighing factors of each critical dimension for seam quality evaluation, it can be concluded that the requirement of seam efficiency on the overall seam quality is same for all the five apparel products. Seam puckering also has same requirement on the overall seam quality of blouse, shirt, T-shirt and lingerie but comparatively less on the overall seam quality of denim trousers. Seam boldness has same requirements on the overall seam quality of blouse, shirt, T-shirt and lingerie but has relatively high requirement on the overall seam quality of denim trousers.

Based on the respective weighing factors of each critical dimension for seam quality evaluation, the best fit models of seam efficiency, seam puckering and seam boldness are integrated to provide a solution for evaluating the overall seam quality of each apparel products. Since there are different best fit model for different types of fabric, the best fit models are selected based on the type of fabric material used on particular type of apparel product.

In the provided solution, seam efficiency has a positive value on the overall seam quality of five apparel products as a high percentage of seam efficiency always represents good seam efficiency. In contrast, seam puckering always has a negative value on the overall seam quality of the five apparel products because a greater seam puckering always leads to poor seam quality. Seam boldness may have a positive or negative value on the overall seam quality depending on the apparel. Seam boldness always has a positive value on the overall seam quality of denim trousers because in this apparel greater seam boldness always leads to good seam quality. In the rest of the apparel: blouse, shirt, T-shirt and lingerie, seam boldness has a negative value on the overall seam quality.

From the provided solution for evaluating the overall seam quality, apparel engineers can understand the requirements of each critical dimension for seam quality evaluation on the overall seam quality of the apparel. This understanding will help in proper planning and control of the quality of apparel products at the time of sewing.

6.2 Future research

Although the proposed objectives have been completed in this project, it is worth noting that there is a scope for further research work in the area of seam quality.

Owing to limited time, this research has provided a solution for evaluating the overall seam quality only for five apparel products. However, the methodology developed in this study to provide solution can be applied for other types of apparel products.

The fabrics used in the solution for evaluating the overall seam quality are cotton-polyester, cotton-spandex and cotton. Different fabrics can be included in future study to establish best fit models for each critical dimension for seam quality evaluation incorporating the sewing thread size, stitch density and fabric properties.

Finally, the present investigation only provides a solution for evaluating the overall seam quality by integrating each critical dimension for seam quality evaluation. In this study, each critical dimension for seam quality evaluation are measured under different scale that makes a simple mathematical expression not yet could be formulated. In the near future, a normalisation process can be used to solve the scaling problem. The success of development of an integrated mathematical model will help to measure the overall seam quality of the apparel products objectively and accurately.

Appendix I

Critical Dimensions for Seam Quality Evaluation – Questionnaire

Purpose: Identification of Critical dimensions for seam quality evaluation

Name of Judges………………… Occupation…………………………

Year of Experience ……………………… Date…………………………..

Guideline: Judge should provide ranking on dimension according to its importance for seam quality evaluation. The Ranking Scale is 1-10 (Rank 1- least important; Rank 10- Most important). The definition of each dimension is given below.

Seam Efficiency: Seam efficiency define as the ratio of seam strength to fabric strength. It measures the strength, durability, tenacity along the seam line.

Seam elongation: Seam elongation is defined as the ratio of the extended length after loading to original length of the seam. Seam elongation evaluates the elasticity and recovery of a seam.

Seam bending stiffness: Seam bending stiffness measures the flexibility and drapeability along the seam line.

Seam abrasion resistance: It is the amount of rubbing action needed to wear away stitches in the seam.

Seam density: It measures the regularity in the formation and stitching of the seam.

Seam slippage is expressed as the transverse ratio of seam strength to fabric strength including the ratio of elongation of fabric to the ratio of elongation at the seam.

Seam puckering: Seam puckering is the degree of wrinkle appearance along the seam line.

Seam tightness: Seam tightness is the degree of tightness or closeness of the stitches along the seam line.

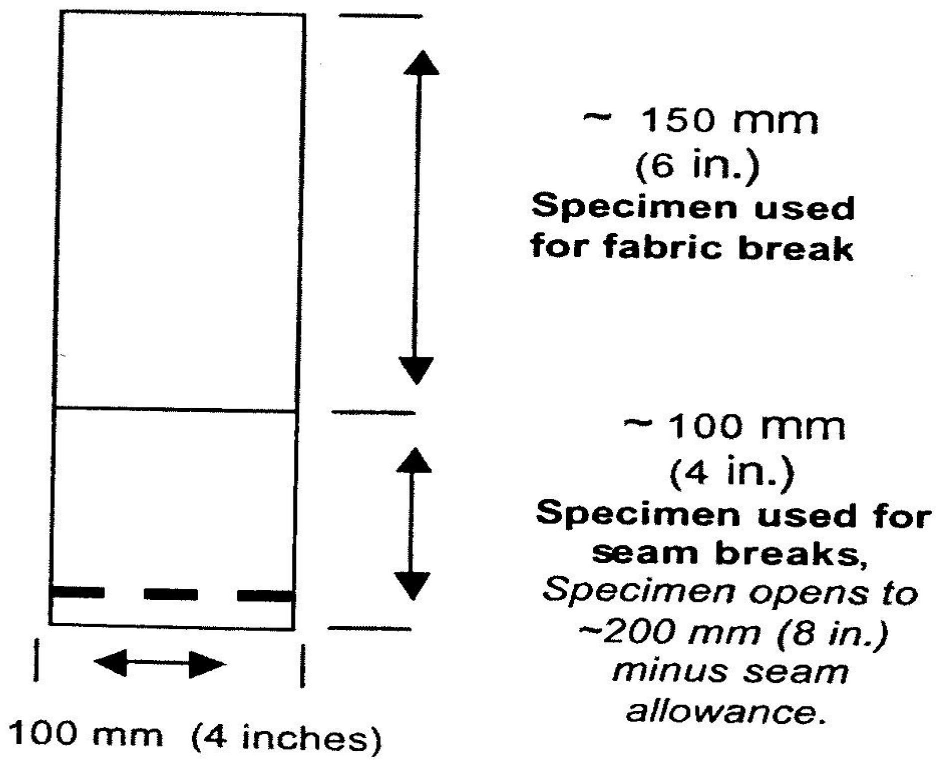
Seam boldness: It measures the design prominence along the seam line. Greater linear projection of the sewing thread from the seam surface is the cause of more seam boldness.

Seam damage: Seam damage measures the yarn severance percentage along the seam line.

Sr. No	Dimensions for seam quality evaluation	Rank
1	Seam efficiency	
2	Seam elongation	
3	Seam bending stiffness	
4	Seam abrasion resistance	
5	Seam density	
6	Seam slippage	
7	Seam puckering	
8	Seam tightness	
9	Seam boldness	
10	Seam damage	

Appendix II

Diagram of the seam specimen for seam efficiency



Appendix III

Seam boldness Evaluation – Grading sheet

Purpose: Evaluation of seam boldness

Name of Judges …………………… Occupation…………………………

Year of Experience ……………………… Date…………………………..

Guideline: Judge should provide grading based on their experience for the evaluation of each seam according to the scale below. It is emphasized that the judges to ignore the effect of color in fabric and sewing thread while comparing the seam specimen with benchmarks. The definition of seam boldness is given below.

Seam boldness: It measures the design prominence along the seam line. Greater linear projection of the sewing thread from the seam surface is the cause of more seam boldness.

Grading scale for seam boldness assessment:

Seam boldness	**Grading**
Highest prominence	5
Slightly prominence	4
Average prominence	3
Below average prominence	2
No prominence	1

Sample No	**Material**	**Sewing Thread size(Tex)**						
		18	**21**	**30**	**35**	**45**	**60**	**90**
1	Cotton							
2	Cotton							
3	Cotton							
4	Cotton							
5	Cotton							
6	Cotton							
7	Cotton							
8	Cotton							
9	Cotton							
10	Cotton							
11	Cotton							
12	Cotton							

13	Cotton							
14	Cotton							
15	Cotton							
16	Cotton							
17	Cotton							
18	Cotton							
19	Cotton							
20	Cotton							
21	Cotton-polyester							
22	Cotton-polyester							
23	Cotton-polyester							
24	Cotton-polyester							
25	Cotton-polyester							
26	Cotton-polyester							
27	Cotton-polyester							
28	Cotton-polyester							
29	Cotton-polyester							
30	Cotton-polyester							
31	Cotton-polyester							
32	Cotton-polyester							
33	Cotton-polyester							
34	Cotton-polyester							
35	Cotton-polyester							
36	Cotton-spandex							
37	Cotton-spandex							
38	Cotton-spandex							
39	Cotton-spandex							
40	Cotton-spandex							
41	Cotton-spandex							
42	Cotton-spandex							
43	Cotton-spandex							
44	Cotton-spandex							
45	Cotton-spandex							
46	Cotton-spandex							
47	Cotton-spandex							
48	Cotton-spandex							
49	Cotton-spandex							
50	Cotton-spandex							

Appendix IV

Values of input variables obtained from experiments for seam quality evaluation of cotton polyester fabric

Sr. No	Sewing thread Size (X1) (Tex)	Cover factor (X2)	Weight (X3) (GSM)	Thickness (X4) (mm)	Strength (X5) (N)	Extensibility (X6) (%)	Bending rigidity (X7) (gf/cm)	Shear rigidity (X8) (gf/cm.deg)	Stitch density (X9) (spi)	Shear hysterisis (X10) (gf/cm)	Bending hysterisis (X11) (gf.cm/cm)	Coefficient of friction (X12)
1	18	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12
2	18	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
3	18	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
4	18	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
5	18	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
6	18	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
7	18	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09
8	18	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
9	18	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
10	18	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07
11	18	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
12	18	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
13	18	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17
14	18	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
15	18	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
16	21	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12

17	21	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
18	21	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
19	21	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
20	21	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
21	21	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
22	21	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09
23	21	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
24	21	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
25	21	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07
26	21	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
27	21	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
28	21	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17
29	21	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
30	21	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
31	30	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12
32	30	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
33	30	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
34	30	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
35	30	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
36	30	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
37	30	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09
38	30	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
39	30	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
40	30	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07
41	30	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
42	30	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
43	30	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17

44	30	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
45	30	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
46	35	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12
47	35	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
48	35	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
49	35	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
50	35	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
51	35	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
52	35	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09
53	35	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
54	35	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
55	35	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07
56	35	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
57	35	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
58	35	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17
59	35	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
60	35	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
61	45	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12
62	45	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
63	45	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
64	45	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
65	45	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
66	45	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
67	45	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09
68	45	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
69	45	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
70	45	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07

71	45	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
72	45	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
73	45	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17
74	45	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
75	45	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
76	60	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12
77	60	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
78	60	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
79	60	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
80	60	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
81	60	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
82	60	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09
83	60	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
84	60	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
85	60	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07
86	60	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
87	60	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
88	60	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17
89	60	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
90	60	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
91	90	32.08	250	0.55	803.1	3.82	0.11	2.1	6	3.21	0.09	3.12
92	90	39.55	130	0.39	410.6	9.1	0.07	1.55	6	2.75	0.02	2.13
93	90	34.52	183	0.54	426.56	7.26	0.05	1.1	6	3.12	0.01	1.11
94	90	27.04	150	0.45	204.39	8.2	0.13	2.33	6	4.24	0.1	4.33
95	90	42.17	206	0.51	479.47	8.65	0.14	1.26	6	3.25	0.06	1.76
96	90	46.83	255	0.56	510.23	6.2	0.25	3.15	6	5.34	0.11	2.98
97	90	32.79	185	0.34	440.12	5.83	0.27	2.78	6	4.12	0.17	3.09

98	90	26.79	199	0.4	170.45	5.76	0.2	1.48	6	3.76	0.1	2.22
99	90	48.12	278	0.56	520.31	5.71	0.38	3.32	6	6.45	0.21	1.98
100	90	42.15	216	0.48	498.22	5.87	0.29	2.58	6	4.44	0.15	2.07
101	90	36.44	198	0.32	475.63	6.81	0.2	2.59	6	3.23	0.1	3.76
102	90	40.5	260	0.5	363.76	4.47	0.08	3.12	6	4.15	0.06	3.97
103	90	50.17	193	0.39	532.87	7.1	0.19	1.57	6	2.32	0.1	2.17
104	90	47.89	288	0.56	663.83	5.73	0.38	2.89	6	3.65	0.27	1.86
105	90	36.28	311	0.6	492.81	9.54	0.3	3.98	6	6.75	0.21	2.99
106	18	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12
107	18	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
108	18	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
109	18	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33
110	18	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
111	18	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
112	18	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
113	18	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
114	18	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
115	18	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07
116	18	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
117	18	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
118	18	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17
119	18	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
120	18	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
121	21	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12
122	21	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
123	21	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
124	21	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33

125	21	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
126	21	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
127	21	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
128	21	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
129	21	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
130	21	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07
131	21	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
132	21	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
133	21	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17
134	21	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
135	21	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
136	30	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12
137	30	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
138	30	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
139	30	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33
140	30	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
141	30	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
142	30	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
143	30	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
144	30	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
145	30	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07
146	30	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
147	30	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
148	30	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17
149	30	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
150	30	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
151	35	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12

152	35	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
153	35	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
154	35	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33
155	35	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
156	35	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
157	35	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
158	35	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
159	35	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
160	35	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07
161	35	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
162	35	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
163	35	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17
164	35	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
165	35	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
166	45	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12
167	45	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
168	45	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
169	45	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33
170	45	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
171	45	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
172	45	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
173	45	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
174	45	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
175	45	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07
176	45	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
177	45	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
178	45	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17

179	45	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
180	45	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
181	60	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12
182	60	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
183	60	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
184	60	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33
185	60	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
186	60	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
187	60	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
188	60	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
189	60	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
190	60	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07
191	60	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
192	60	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
193	60	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17
194	60	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
195	60	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
196	90	32.08	250	0.55	803.1	3.82	0.11	2.1	10	3.21	0.09	3.12
197	90	39.55	130	0.39	410.6	9.1	0.07	1.55	10	2.75	0.02	2.13
198	90	34.52	183	0.54	426.56	7.26	0.05	1.1	10	3.12	0.01	1.11
199	90	27.04	150	0.45	204.39	8.2	0.13	2.33	10	4.24	0.1	4.33
200	90	42.17	206	0.51	479.47	8.65	0.14	1.26	10	3.25	0.06	1.76
201	90	46.83	255	0.56	510.23	6.2	0.25	3.15	10	5.34	0.11	2.98
202	90	32.79	185	0.34	440.12	5.83	0.27	2.78	10	4.12	0.17	3.09
203	90	26.79	199	0.4	170.45	5.76	0.2	1.48	10	3.76	0.1	2.22
204	90	48.12	278	0.56	520.31	5.71	0.38	3.32	10	6.45	0.21	1.98
205	90	42.15	216	0.48	498.22	5.87	0.29	2.58	10	4.44	0.15	2.07

206	90	36.44	198	0.32	475.63	6.81	0.2	2.59	10	3.23	0.1	3.76
207	90	40.5	260	0.5	363.76	4.47	0.08	3.12	10	4.15	0.06	3.97
208	90	50.17	193	0.39	532.87	7.1	0.19	1.57	10	2.32	0.1	2.17
209	90	47.89	288	0.56	663.83	5.73	0.38	2.89	10	3.65	0.27	1.86
210	90	36.28	311	0.6	492.81	9.54	0.3	3.98	10	6.75	0.21	2.99
211	18	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12
212	18	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
213	18	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
214	18	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33
215	18	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
216	18	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
217	18	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09
218	18	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
219	18	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
220	18	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
221	18	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
222	18	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
223	18	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17
224	18	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
225	18	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99
226	21	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12
227	21	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
228	21	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
229	21	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33
230	21	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
231	21	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
232	21	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09

233	21	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
234	21	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
235	21	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
236	21	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
237	21	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
238	21	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17
239	21	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
240	21	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99
241	30	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12
242	30	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
243	30	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
244	30	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33
245	30	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
246	30	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
247	30	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09
248	30	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
249	30	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
250	30	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
251	30	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
252	30	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
253	30	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17
254	30	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
255	30	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99
256	35	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12
257	35	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
258	35	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
259	35	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33

260	35	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
261	35	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
262	35	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09
263	35	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
264	35	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
265	35	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
266	35	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
267	35	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
268	35	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17
269	35	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
270	35	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99
271	45	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12
272	45	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
273	45	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
274	45	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33
275	45	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
276	45	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
277	45	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09
278	45	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
279	45	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
280	45	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
281	45	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
282	45	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
283	45	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17
284	45	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
285	45	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99
286	60	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12

287	60	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
288	60	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
289	60	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33
290	60	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
291	60	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
292	60	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09
293	60	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
294	60	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
295	60	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
296	60	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
297	60	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
298	60	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17
299	60	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
300	60	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99
301	90	32.08	250	0.55	803.1	3.82	0.11	2.1	14	3.21	0.09	3.12
302	90	39.55	130	0.39	410.6	9.1	0.07	1.55	14	2.75	0.02	2.13
303	90	34.52	183	0.54	426.56	7.26	0.05	1.1	14	3.12	0.01	1.11
304	90	27.04	150	0.45	204.39	8.2	0.13	2.33	14	4.24	0.1	4.33
305	90	42.17	206	0.51	479.47	8.65	0.14	1.26	14	3.25	0.06	1.76
306	90	46.83	255	0.56	510.23	6.2	0.25	3.15	14	5.34	0.11	2.98
307	90	32.79	185	0.34	440.12	5.83	0.27	2.78	14	4.12	0.17	3.09
308	90	26.79	199	0.4	170.45	5.76	0.2	1.48	14	3.76	0.1	2.22
309	90	48.12	278	0.56	520.31	5.71	0.38	3.32	14	6.45	0.21	1.98
310	90	42.15	216	0.48	498.22	5.87	0.29	2.58	14	4.44	0.15	2.07
311	90	36.44	198	0.32	475.63	6.81	0.2	2.59	14	3.23	0.1	3.76
312	90	40.5	260	0.5	363.76	4.47	0.08	3.12	14	4.15	0.06	3.97
313	90	50.17	193	0.39	532.87	7.1	0.19	1.57	14	2.32	0.1	2.17

314	90	47.89	288	0.56	663.83	5.73	0.38	2.89	14	3.65	0.27	1.86
315	90	36.28	311	0.6	492.81	9.54	0.3	3.98	14	6.75	0.21	2.99

Appendix V

Values of input variables obtained from experiments for seam quality evaluation of cotton-spandex fabric

Sr. No	Sewing thread Size (X1) (Tex)	Cover factor (X2)	Weight (X3) (GSM)	Thickness (X4) (mm)	Strength (X5) (N)	Extensibility (X6) (%)	Bending rigidity (X7) (gf/cm)	Shear rigidity (X8) (gf/cm.deg)	Stitch density (X9) (spi)	Shear hysterisis (X10) (gf/cm)	Bending hysterisis (X11) (gf.cm/cm)	Coefficient of friction (X12)
1	18	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
2	18	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
3	18	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
4	18	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
5	18	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22
6	18	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
7	18	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
8	18	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
9	18	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
10	18	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76
11	18	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
12	18	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
13	18	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
14	18	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
15	18	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76

16	21	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
17	21	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
18	21	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
19	21	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
20	21	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22
21	21	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
22	21	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
23	21	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
24	21	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
25	21	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76
26	21	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
27	21	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
28	21	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
29	21	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
30	21	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76
31	30	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
32	30	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
33	30	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
34	30	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
35	30	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22
36	30	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
37	30	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
38	30	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
39	30	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
40	30	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76

41	30	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
42	30	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
43	30	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
44	30	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
45	30	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76
46	35	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
47	35	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
48	35	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
49	35	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
50	35	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22
51	35	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
52	35	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
53	35	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
54	35	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
55	35	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76
56	35	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
57	35	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
58	35	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
59	35	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
60	35	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76
61	45	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
62	45	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
63	45	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
64	45	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
65	45	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22

66	45	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
67	45	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
68	45	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
69	45	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
70	45	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76
71	45	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
72	45	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
73	45	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
74	45	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
75	45	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76
76	60	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
77	60	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
78	60	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
79	60	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
80	60	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22
81	60	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
82	60	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
83	60	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
84	60	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
85	60	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76
86	60	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
87	60	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
88	60	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
89	60	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
90	60	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76

91	90	46.87	241	0.49	669.94	1.66	0.49	6.19	6	7.32	0.23	2.12
92	90	49.99	225	0.52	552.37	6.91	0.41	2.68	6	4.25	0.25	1.23
93	90	33.75	270	0.41	775.65	6.27	0.45	5.78	6	8.97	0.23	2.78
94	90	22.59	76	0.2	152.65	6.42	0.04	1.34	6	3.26	0.005	2.65
95	90	34.72	213	0.38	698.35	8.05	0.19	2.44	6	4.32	0.1	1.22
96	90	50.11	247	0.44	626.3	6.73	0.25	1.43	6	2.76	0.12	1.09
97	90	24.84	147	0.38	217.75	10.49	0.08	0.43	6	1.98	0.01	1.75
98	90	27.91	168	0.34	183.1	5.78	0.12	0.69	6	2.76	0.01	2.97
99	90	54.26	251.5	0.5	486.9	5.32	0.19	1.68	6	3.56	0.11	1.11
100	90	26.73	99	0.21	377.98	2.42	0.11	1.24	6	3.09	0.1	2.76
101	90	26.72	106.1	0.22	485.9	2.95	0.1	1.09	6	2.97	0.005	1.05
102	90	27.49	123	0.32	240.77	3.32	0.08	0.65	6	1.98	0.01	2.99
103	90	25.26	124.5	0.31	302.17	6.2	0.017	0.53	6	1.59	0.011	2.34
104	90	26.73	94	0.2	284.4	6.61	0.07	0.59	6	1.97	0.01	1.07
105	90	29.12	164.3	0.35	345.3	5.54	0.05	0.34	6	1.5	0.01	2.76
106	18	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
107	18	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
108	18	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
109	18	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
110	18	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22
111	18	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
112	18	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
113	18	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
114	18	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
115	18	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76

116	18	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
117	18	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
118	18	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
119	18	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
120	18	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76
121	21	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
122	21	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
123	21	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
124	21	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
125	21	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22
126	21	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
127	21	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
128	21	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
129	21	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
130	21	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76
131	21	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
132	21	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
133	21	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
134	21	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
135	21	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76
136	30	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
137	30	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
138	30	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
139	30	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
140	30	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22

141	30	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
142	30	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
143	30	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
144	30	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
145	30	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76
146	30	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
147	30	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
148	30	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
149	30	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
150	30	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76
151	35	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
152	35	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
153	35	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
154	35	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
155	35	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22
156	35	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
157	35	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
158	35	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
159	35	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
160	35	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76
161	35	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
162	35	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
163	35	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
164	35	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
165	35	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76

166	45	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
167	45	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
168	45	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
169	45	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
170	45	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22
171	45	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
172	45	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
173	45	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
174	45	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
175	45	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76
176	45	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
177	45	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
178	45	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
179	45	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
180	45	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76
181	60	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
182	60	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
183	60	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
184	60	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
185	60	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22
186	60	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
187	60	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
188	60	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
189	60	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
190	60	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76

191	60	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
192	60	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
193	60	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
194	60	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
195	60	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76
196	90	46.87	241	0.49	669.94	1.66	0.49	6.19	10	7.32	0.23	2.12
197	90	49.99	225	0.52	552.37	6.91	0.41	2.68	10	4.25	0.25	1.23
198	90	33.75	270	0.41	775.65	6.27	0.45	5.78	10	8.97	0.23	2.78
199	90	22.59	76	0.2	152.65	6.42	0.04	1.34	10	3.26	0.005	2.65
200	90	34.72	213	0.38	698.35	8.05	0.19	2.44	10	4.32	0.1	1.22
201	90	50.11	247	0.44	626.3	6.73	0.25	1.43	10	2.76	0.12	1.09
202	90	24.84	147	0.38	217.75	10.49	0.08	0.43	10	1.98	0.01	1.75
203	90	27.91	168	0.34	183.1	5.78	0.12	0.69	10	2.76	0.01	2.97
204	90	54.26	251.5	0.5	486.9	5.32	0.19	1.68	10	3.56	0.11	1.11
205	90	26.73	99	0.21	377.98	2.42	0.11	1.24	10	3.09	0.1	2.76
206	90	26.72	106.1	0.22	485.9	2.95	0.1	1.09	10	2.97	0.005	1.05
207	90	27.49	123	0.32	240.77	3.32	0.08	0.65	10	1.98	0.01	2.99
208	90	25.26	124.5	0.31	302.17	6.2	0.017	0.53	10	1.59	0.011	2.34
209	90	26.73	94	0.2	284.4	6.61	0.07	0.59	10	1.97	0.01	1.07
210	90	29.12	164.3	0.35	345.3	5.54	0.05	0.34	10	1.5	0.01	2.76
211	18	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
212	18	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
213	18	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
214	18	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
215	18	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22

216	18	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
217	18	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
218	18	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
219	18	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
220	18	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76
221	18	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
222	18	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
223	18	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
224	18	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
225	18	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76
226	21	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
227	21	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
228	21	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
229	21	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
230	21	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22
231	21	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
232	21	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
233	21	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
234	21	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
235	21	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76
236	21	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
237	21	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
238	21	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
239	21	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
240	21	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76

241	30	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
242	30	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
243	30	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
244	30	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
245	30	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22
246	30	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
247	30	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
248	30	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
249	30	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
250	30	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76
251	30	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
252	30	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
253	30	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
254	30	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
255	30	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76
256	35	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
257	35	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
258	35	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
259	35	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
260	35	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22
261	35	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
262	35	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
263	35	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
264	35	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
265	35	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76

266	35	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
267	35	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
268	35	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
269	35	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
270	35	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76
271	45	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
272	45	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
273	45	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
274	45	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
275	45	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22
276	45	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
277	45	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
278	45	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
279	45	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
280	45	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76
281	45	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
282	45	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
283	45	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
284	45	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
285	45	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76
286	60	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
287	60	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
288	60	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
289	60	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
290	60	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22

291	60	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
292	60	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
293	60	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
294	60	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
295	60	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76
296	60	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
297	60	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
298	60	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
299	60	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
300	60	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76
301	90	46.87	241	0.49	669.94	1.66	0.49	6.19	14	7.32	0.23	2.12
302	90	49.99	225	0.52	552.37	6.91	0.41	2.68	14	4.25	0.25	1.23
303	90	33.75	270	0.41	775.65	6.27	0.45	5.78	14	8.97	0.23	2.78
304	90	22.59	76	0.2	152.65	6.42	0.04	1.34	14	3.26	0.005	2.65
305	90	34.72	213	0.38	698.35	8.05	0.19	2.44	14	4.32	0.1	1.22
306	90	50.11	247	0.44	626.3	6.73	0.25	1.43	14	2.76	0.12	1.09
307	90	24.84	147	0.38	217.75	10.49	0.08	0.43	14	1.98	0.01	1.75
308	90	27.91	168	0.34	183.1	5.78	0.12	0.69	14	2.76	0.01	2.97
309	90	54.26	251.5	0.5	486.9	5.32	0.19	1.68	14	3.56	0.11	1.11
310	90	26.73	99	0.21	377.98	2.42	0.11	1.24	14	3.09	0.1	2.76
311	90	26.72	106.1	0.22	485.9	2.95	0.1	1.09	14	2.97	0.005	1.05
312	90	27.49	123	0.32	240.77	3.32	0.08	0.65	14	1.98	0.01	2.99
313	90	25.26	124.5	0.31	302.17	6.2	0.017	0.53	14	1.59	0.011	2.34
314	90	26.73	94	0.2	284.4	6.61	0.07	0.59	14	1.97	0.01	1.07
315	90	29.12	164.3	0.35	345.3	5.54	0.05	0.34	14	1.5	0.01	2.76

Appendix VI

Values of input variables obtained from experiments for seam quality evaluation of cotton fabric

Sr.No	Sewing thread Size (X1) (Tex)	Cover factor (X2)	Weight (X3) (GSM)	Thickness (X4) (mm)	Strength (X5) (N)	Extensibility (X6) (%)	Bending rigidity (X7) (gf/cm)	Shear rigidity (X8) (gf/cm.deg)	Stitch density (X9) (spi)	Shear hysterisis (X10) (gf/cm)	Bending hysterisis (X11) (gf.cm/cm)	Coefficient of friction (X12)
1	18	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
2	18	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
3	18	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
4	18	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
5	18	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14
6	18	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
7	18	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
8	18	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
9	18	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
10	18	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21
11	18	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
12	18	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
13	18	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
14	18	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
15	18	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98

16	18	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
17	18	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
18	18	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
19	18	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
20	18	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09
21	21	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
22	21	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
23	21	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
24	21	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
25	21	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14
26	21	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
27	21	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
28	21	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
29	21	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
30	21	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21
31	21	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
32	21	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
33	21	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
34	21	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
35	21	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98
36	21	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
37	21	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
38	21	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
39	21	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
40	21	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09

41	30	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
42	30	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
43	30	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
44	30	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
45	30	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14
46	30	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
47	30	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
48	30	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
49	30	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
50	30	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21
51	30	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
52	30	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
53	30	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
54	30	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
55	30	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98
56	30	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
57	30	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
58	30	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
59	30	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
60	30	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09
61	35	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
62	35	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
63	35	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
64	35	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
65	35	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14

66	35	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
67	35	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
68	35	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
69	35	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
70	35	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21
71	35	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
72	35	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
73	35	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
74	35	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
75	35	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98
76	35	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
77	35	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
78	35	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
79	35	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
80	35	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09
81	45	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
82	45	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
83	45	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
84	45	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
85	45	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14
86	45	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
87	45	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
88	45	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
89	45	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
90	45	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21

91	45	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
92	45	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
93	45	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
94	45	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
95	45	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98
96	45	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
97	45	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
98	45	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
99	45	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
100	45	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09
101	60	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
102	60	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
103	60	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
104	60	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
105	60	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14
106	60	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
107	60	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
108	60	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
109	60	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
110	60	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21
111	60	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
112	60	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
113	60	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
114	60	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
115	60	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98

116	60	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
117	60	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
118	60	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
119	60	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
120	60	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09
121	90	36.23	380	0.8	1812	3.12	5.84	13.25	6	40.23	3.76	3.12
122	90	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	6	6.34	0.32	4.22
123	90	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	6	14.98	0.76	2.21
124	90	27.92	376.2	0.83	754.6	4.49	1.05	7.7	6	10.76	0.8	3.06
125	90	33.63	342	0.57	800.8	5.86	0.28	3	6	6.42	0.21	4.14
126	90	34.23	273.6	0.52	540.54	7.37	0.15	2.58	6	5.12	0.1	3.12
127	90	26.75	214.4	0.59	264.97	8.42	0.12	1.36	6	3.23	0.1	1.64
128	90	29.47	153.2	0.42	354	9.22	0.06	0.96	6	2.1	0.04	3.26
129	90	27.18	254	0.43	224.97	7.61	0.05	0.72	6	1.97	0.02	2.43
130	90	24.01	308	0.47	294.46	8.86	0.04	0.74	6	2	0.01	3.21
131	90	34.83	151	0.49	502	3.39	0.13	2.38	6	4.56	0.11	2.43
132	90	25.88	167	0.5	263.84	2.85	0.24	1.36	6	3.21	0.18	4.37
133	90	34.07	150	0.35	469.54	5.47	0.14	0.96	6	1.78	0.1	2.65
134	90	33.86	181	0.52	434.04	7.05	0.11	0.72	6	2.32	0.09	4.56
135	90	46.42	136	0.46	411.73	6	0.1	0.74	6	1.75	0.05	1.98
136	90	34.84	151	0.45	447.11	6.17	0.12	2.38	6	4.21	0.1	2.12
137	90	39.97	184	0.55	493.77	6.66	0.1	4.69	6	6.45	0.5	3.75
138	90	32.04	131	0.38	431.84	8.66	0.08	1.7	6	3.43	0.05	3.87
139	90	24.53	102	0.42	192.41	8.17	1.03	1.79	6	2.22	0.87	2.43
140	90	17.24	167	0.44	328.64	3.15	0.12	1.62	6	2.97	0.1	2.09

141	18	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
142	18	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
143	18	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
144	18	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
145	18	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14
146	18	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
147	18	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
148	18	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
149	18	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
150	18	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21
151	18	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
152	18	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
153	18	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
154	18	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
155	18	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98
156	18	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
157	18	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
158	18	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
159	18	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
160	18	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09
161	21	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
162	21	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
163	21	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
164	21	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
165	21	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14

166	21	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
167	21	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
168	21	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
169	21	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
170	21	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21
171	21	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
172	21	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
173	21	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
174	21	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
175	21	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98
176	21	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
177	21	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
178	21	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
179	21	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
180	21	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09
181	30	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
182	30	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
183	30	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
184	30	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
185	30	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14
186	30	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
187	30	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
188	30	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
189	30	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
190	30	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21

191	30	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
192	30	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
193	30	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
194	30	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
195	30	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98
196	30	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
197	30	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
198	30	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
199	30	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
200	30	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09
201	35	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
202	35	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
203	35	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
204	35	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
205	35	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14
206	35	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
207	35	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
208	35	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
209	35	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
210	35	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21
211	35	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
212	35	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
213	35	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
214	35	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
215	35	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98

216	35	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
217	35	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
218	35	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
219	35	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
220	35	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09
221	45	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
222	45	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
223	45	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
224	45	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
225	45	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14
226	45	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
227	45	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
228	45	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
229	45	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
230	45	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21
231	45	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
232	45	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
233	45	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
234	45	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
235	45	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98
236	45	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
237	45	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
238	45	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
239	45	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
240	45	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09

241	60	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
242	60	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
243	60	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
244	60	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
245	60	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14
246	60	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
247	60	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
248	60	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
249	60	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
250	60	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21
251	60	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
252	60	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
253	60	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
254	60	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
255	60	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98
256	60	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
257	60	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
258	60	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
259	60	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
260	60	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09
261	90	36.23	380	0.8	1812	3.12	5.84	13.25	10	40.23	3.76	3.12
262	90	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	10	6.34	0.32	4.22
263	90	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	10	14.98	0.76	2.21
264	90	27.92	376.2	0.83	754.6	4.49	1.05	7.7	10	10.76	0.8	3.06
265	90	33.63	342	0.57	800.8	5.86	0.28	3	10	6.42	0.21	4.14

266	90	34.23	273.6	0.52	540.54	7.37	0.15	2.58	10	5.12	0.1	3.12
267	90	26.75	214.4	0.59	264.97	8.42	0.12	1.36	10	3.23	0.1	1.64
268	90	29.47	153.2	0.42	354	9.22	0.06	0.96	10	2.1	0.04	3.26
269	90	27.18	254	0.43	224.97	7.61	0.05	0.72	10	1.97	0.02	2.43
270	90	24.01	308	0.47	294.46	8.86	0.04	0.74	10	2	0.01	3.21
271	90	34.83	151	0.49	502	3.39	0.13	2.38	10	4.56	0.11	2.43
272	90	25.88	167	0.5	263.84	2.85	0.24	1.36	10	3.21	0.18	4.37
273	90	34.07	150	0.35	469.54	5.47	0.14	0.96	10	1.78	0.1	2.65
274	90	33.86	181	0.52	434.04	7.05	0.11	0.72	10	2.32	0.09	4.56
275	90	46.42	136	0.46	411.73	6	0.1	0.74	10	1.75	0.05	1.98
276	90	34.84	151	0.45	447.11	6.17	0.12	2.38	10	4.21	0.1	2.12
277	90	39.97	184	0.55	493.77	6.66	0.1	4.69	10	6.45	0.5	3.75
278	90	32.04	131	0.38	431.84	8.66	0.08	1.7	10	3.43	0.05	3.87
279	90	24.53	102	0.42	192.41	8.17	1.03	1.79	10	2.22	0.87	2.43
280	90	17.24	167	0.44	328.64	3.15	0.12	1.62	10	2.97	0.1	2.09
281	18	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
282	18	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
283	18	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
284	18	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
285	18	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14
286	18	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
287	18	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
288	18	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
289	18	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
290	18	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21

291	18	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
292	18	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
293	18	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
294	18	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
295	18	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98
296	18	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
297	18	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
298	18	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
299	18	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
300	18	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09
301	21	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
302	21	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
303	21	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
304	21	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
305	21	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14
306	21	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
307	21	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
308	21	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
309	21	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
310	21	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21
311	21	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
312	21	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
313	21	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
314	21	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
315	21	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98

316	21	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
317	21	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
318	21	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
319	21	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
320	21	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09
321	30	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
322	30	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
323	30	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
324	30	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
325	30	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14
326	30	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
327	30	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
328	30	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
329	30	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
330	30	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21
331	30	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
332	30	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
333	30	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
334	30	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
335	30	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98
336	30	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
337	30	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
338	30	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
339	30	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
340	30	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09

341	35	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
342	35	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
343	35	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
344	35	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
345	35	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14
346	35	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
347	35	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
348	35	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
349	35	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
350	35	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21
351	35	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
352	35	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
353	35	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
354	35	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
355	35	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98
356	35	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
357	35	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
358	35	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
359	35	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
360	35	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09
361	45	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
362	45	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
363	45	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
364	45	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
365	45	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14

366	45	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
367	45	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
368	45	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
369	45	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
370	45	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21
371	45	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
372	45	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
373	45	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
374	45	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
375	45	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98
376	45	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
377	45	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
378	45	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
379	45	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
380	45	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09
381	60	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
382	60	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
383	60	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
384	60	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
385	60	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14
386	60	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
387	60	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
388	60	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
389	60	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
390	60	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21

391	60	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
392	60	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
393	60	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
394	60	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
395	60	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98
396	60	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
397	60	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
398	60	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
399	60	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
400	60	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09
401	90	36.23	380	0.8	1812	3.12	5.84	13.25	14	40.23	3.76	3.12
402	90	28.59	480.2	0.85	1265.75	2.93	1.98	4.63	14	6.34	0.32	4.22
403	90	34.44	344.3	0.81	1015.5	2.64	1.5	9.03	14	14.98	0.76	2.21
404	90	27.92	376.2	0.83	754.6	4.49	1.05	7.7	14	10.76	0.8	3.06
405	90	33.63	342	0.57	800.8	5.86	0.28	3	14	6.42	0.21	4.14
406	90	34.23	273.6	0.52	540.54	7.37	0.15	2.58	14	5.12	0.1	3.12
407	90	26.75	214.4	0.59	264.97	8.42	0.12	1.36	14	3.23	0.1	1.64
408	90	29.47	153.2	0.42	354	9.22	0.06	0.96	14	2.1	0.04	3.26
409	90	27.18	254	0.43	224.97	7.61	0.05	0.72	14	1.97	0.02	2.43
410	90	24.01	308	0.47	294.46	8.86	0.04	0.74	14	2	0.01	3.21
411	90	34.83	151	0.49	502	3.39	0.13	2.38	14	4.56	0.11	2.43
412	90	25.88	167	0.5	263.84	2.85	0.24	1.36	14	3.21	0.18	4.37
413	90	34.07	150	0.35	469.54	5.47	0.14	0.96	14	1.78	0.1	2.65
414	90	33.86	181	0.52	434.04	7.05	0.11	0.72	14	2.32	0.09	4.56
415	90	46.42	136	0.46	411.73	6	0.1	0.74	14	1.75	0.05	1.98

416	90	34.84	151	0.45	447.11	6.17	0.12	2.38	14	4.21	0.1	2.12
417	90	39.97	184	0.55	493.77	6.66	0.1	4.69	14	6.45	0.5	3.75
418	90	32.04	131	0.38	431.84	8.66	0.08	1.7	14	3.43	0.05	3.87
419	90	24.53	102	0.42	192.41	8.17	1.03	1.79	14	2.22	0.87	2.43
420	90	17.24	167	0.44	328.64	3.15	0.12	1.62	14	2.97	0.1	2.09

Appendix VII

Values of output variables obtained from experiments for seam quality evaluation of cotton polyester fabric

Sr. No	Seam efficiency (Y1) (%)	Seam puckering (Y2) (%)	Seam boldness (Y3) (Grade 1-5)
1	3.843	3.1073	1.03
2	18.9465	7.1332	1.50
3	17.6999	2.0885	1.00
4	40.6991	14.1232	1.02
5	17.9958	6.8338	1.30
6	14.7804	2.943	1.00
7	21.3317	8.528	1.00
8	32.7341	1.4199	1.05
9	17.9183	1.2705	1.70
10	15.4253	3.6722	1.80
11	14.9256	9.42	1.00
12	16.0201	0.9836	1.00
13	11.9136	7.7461	1.00
14	0.7795	5.1708	1.25
15	15.2861	7.5043	1.33
16	5.6775	5.1645	1.50
17	20.7809	9.1904	1.44
18	19.5343	4.1456	1.23
19	42.5336	16.1804	1.45
20	19.8302	8.8909	1.25
21	16.6149	5.0001	1.00
22	23.1662	10.5851	1.25
23	34.5685	3.4771	1.00
24	19.7527	3.3277	1.20
25	17.2598	5.7293	1.30
26	16.7601	11.4772	1.25
27	17.8545	3.0408	1.50
28	13.748	9.8032	1.60
29	2.614	7.228	1.50
30	17.1205	9.5615	1.50
31	11.1807	11.336	2.25

32	26.2842	15.3619	2.25
33	25.0376	10.3171	2.55
34	48.0368	22.3518	2.00
35	25.3335	15.0624	2.10
36	22.1181	11.1716	2.40
37	28.6694	16.7566	1.33
38	40.0718	9.6486	2.26
39	25.256	9.4992	2.55
40	22.763	11.9008	2.00
41	22.2633	17.6487	2.00
42	23.3578	9.2122	2.10
43	19.2512	15.9747	2.00
44	8.1172	13.3995	1.50
45	22.6237	15.733	2.60
46	14.2381	14.7646	2.55
47	29.3415	18.7905	2.75
48	28.095	13.7457	2.25
49	51.0942	25.7804	2.55
50	28.3908	18.491	2.66
51	25.1755	14.6002	2.22
52	31.7268	20.1852	2.45
53	43.1291	13.0772	2.25
54	28.3133	12.9278	2.05
55	25.8204	15.3294	2.10
56	25.3207	21.0773	2.00
57	26.4152	12.6408	2.50
58	22.3086	19.4033	2.60
59	11.1746	16.8281	2.45
60	25.6811	19.1616	2.45
61	20.3528	21.6218	2.35
62	35.4563	25.6477	2.75
63	34.2097	20.6029	2.75
64	57.2089	32.6376	2.00
65	34.5056	25.3482	2.00
66	31.2902	21.4574	2.00
67	37.8415	27.0424	2.10
68	49.2439	19.9344	2.30
69	34.4281	19.785	2.20
70	31.9351	22.1866	2.25
71	31.4354	27.9345	2.55

72	32.5299	19.498	2.66
73	28.4233	26.2605	2.43
74	17.2893	23.6853	2.44
75	31.7958	26.0188	2.45
76	28.1266	28.8896	3.55
77	43.23	32.9155	3.65
78	41.9834	27.8708	3.00
79	64.9827	39.9055	3.10
80	42.2793	32.6161	3.00
81	39.064	28.7253	3.00
82	45.6153	34.3103	3.00
83	57.0176	27.2022	3.01
84	42.2018	27.0528	3.15
85	39.7089	29.4545	3.20
86	39.2092	35.2023	3.30
87	40.3036	26.7659	3.33
88	36.1971	33.5284	3.33
89	25.0631	30.9531	3.35
90	39.5696	33.2866	3.75
91	46.4708	49.4612	4.00
92	61.5742	53.4871	4.00
93	60.3276	48.4424	4.10
94	83.3269	60.4771	4.10
95	60.6235	53.1877	4.15
96	57.4082	49.2969	4.55
97	63.9595	54.8819	4.10
98	75.3618	47.7738	4.15
99	60.546	47.6244	4.20
100	58.0531	50.0261	4.22
101	57.5534	55.7739	4.35
102	58.6479	47.3375	4.55
103	54.5413	54.1	4.65
104	43.4073	51.5247	4.25
105	57.9138	53.8582	4.25
106	15.3691	5.991	1.00
107	30.4726	10.0169	1.10
108	29.226	4.9722	1.12
109	52.2252	17.0069	1.15
110	29.5219	9.7175	1.10
111	26.3065	5.8267	1.20

112	32.8578	11.4117	1.30
113	44.2602	4.3036	1.40
114	29.4444	4.1543	1.50
115	26.9514	6.5559	1.60
116	26.4517	12.3038	1.00
117	27.5462	3.8673	1.00
118	23.4396	10.6298	1.00
119	12.3056	8.0545	1.00
120	26.8121	10.388	1.00
121	17.2035	8.0482	1.00
122	32.307	12.0741	1.20
123	31.0604	7.0294	1.30
124	54.0596	19.0641	1.40
125	31.3563	11.7746	1.50
126	28.1409	7.8839	1.60
127	34.6923	13.4689	1.00
128	46.0946	6.3608	1.00
129	31.2788	6.2114	1.00
130	28.7859	8.6131	1.00
131	28.2862	14.3609	1.00
132	29.3806	5.9245	1.10
133	25.2741	12.687	1.20
134	14.14	10.1117	1.30
135	28.6466	12.4452	1.40
136	22.7068	14.2197	2.00
137	37.8102	18.2456	2.10
138	36.5637	13.2008	2.20
139	59.5629	25.2356	2.40
140	36.8595	17.9461	2.00
141	33.6442	14.0553	2.00
142	40.1955	19.6403	1.00
143	51.5979	12.5323	2.00
144	36.782	12.3829	2.00
145	34.2891	14.7845	2.25
146	33.7894	20.5324	2.25
147	34.8839	12.096	2.50
148	30.7773	18.8584	2.55
149	19.6433	16.2832	1.45
150	34.1498	18.6167	2.25
151	25.7642	17.6483	2.45

152	40.8676	21.6742	2.55
153	39.6211	16.6294	2.55
154	62.6203	28.6642	2.00
155	39.9169	21.3747	2.00
156	36.7016	17.4839	2.00
157	43.2529	23.0689	2.00
158	54.6552	15.9609	2.10
159	39.8394	15.8115	2.10
160	37.3465	18.2131	2.10
161	36.8468	23.961	2.20
162	37.9413	15.5246	2.30
163	33.8347	22.287	2.30
164	22.7007	19.7118	2.40
165	37.2072	22.0453	2.50
166	31.8789	24.5055	2.00
167	46.9824	28.5314	2.00
168	45.7358	23.4866	2.00
169	68.735	35.5214	2.10
170	46.0317	28.2319	2.05
171	42.8163	24.3411	2.20
172	49.3676	29.9261	2.20
173	60.77	22.8181	2.30
174	45.9542	22.6687	2.40
175	43.4612	25.0703	2.50
176	42.9615	30.8182	2.60
177	44.056	22.3818	2.70
178	39.9494	29.1442	2.80
179	28.8154	26.569	2.90
180	43.3219	28.9025	3.00
181	39.6527	31.7733	3.00
182	54.7561	35.7992	3.00
183	53.5095	30.7545	3.00
184	76.5088	42.7892	3.10
185	53.8054	35.4998	3 .20
186	50.5901	31.609	3.30
187	57.1414	37.194	3.40
188	68.5437	30.0859	3.20
189	53.7279	29.9366	3.20
190	51.235	32.3382	3.30
191	50.7353	38.0861	3.40

192	51.8297	29.6496	3.50
193	47.7232	36.4121	3.60
194	36.5892	33.8368	3.00
195	51.0957	36.1703	3.45
196	57.9969	52.3449	5.40
197	73.1003	56.3708	5.00
198	71.8537	51.3261	5.00
199	94.853	63.3608	5.00
200	72.1496	56.0714	5.00
201	68.9343	52.1806	5.00
202	75.4856	57.7656	5.00
203	86.8879	50.6575	5.00
204	72.0721	50.5082	5.10
205	69.5792	52.9098	5.20
206	69.0795	58.6577	5.30
207	70.174	50.2212	5.45
208	66.0674	56.9837	5.00
209	54.9334	54.4084	5.10
210	69.4399	56.7419	5.20
211	26.8952	8.8748	2.55
212	41.9987	12.9007	2.65
213	40.7521	7.8559	2.75
214	63.7513	19.8906	1.00
215	41.048	12.6012	2.00
216	37.8326	8.7104	2.00
217	44.3839	14.2954	1.00
218	55.7863	7.1874	2.10
219	40.9705	7.038	2.20
220	38.4775	9.4396	1.30
221	37.9778	15.1875	1.40
222	39.0723	6.751	2.20
223	34.9657	13.5135	1.10
224	23.8317	10.9383	1.20
225	38.3382	13.2718	2.20
226	28.7296	10.9319	2.25
227	43.8331	14.9578	2.50
228	42.5865	9.9131	2.55
229	65.5857	21.9478	2.65
230	42.8824	14.6584	2.55
231	39.667	10.7676	2.45

232	46.2184	16.3526	1.25
233	57.6207	9.2445	2.35
234	42.8049	9.0951	2.42
235	40.312	11.4968	2.00
236	39.8123	17.2446	2.10
237	40.9067	8.8082	2.20
238	36.8002	15.5707	2.20
239	25.6661	12.9954	1.10
240	40.1727	15.3289	2.20
241	34.2329	17.1034	2.20
242	49.3363	21.1293	2.25
243	48.0898	16.0846	2.25
244	71.089	28.1193	2.25
245	48.3856	20.8298	2.35
246	45.1703	16.9391	2.45
247	51.7216	22.524	2.55
248	63.124	15.416	2.65
249	48.3081	15.2666	2.75
250	45.8152	17.6682	2.75
251	45.3155	23.4161	2.45
252	46.41	14.9797	2.35
253	42.3034	21.7421	2.45
254	31.1694	19.1669	2.25
255	45.6759	21.5004	2.75
256	37.2903	20.532	2.75
257	52.3937	24.5579	2.00
258	51.1471	19.5132	2.02
259	74.1464	31.5479	2.20
260	51.443	24.2584	2.50
261	48.2277	20.3677	2.50
262	54.779	25.9526	2.50
263	66.1813	18.8446	2.50
264	51.3655	18.6952	2.45
265	48.8726	21.0968	2.40
266	48.3729	26.8447	2.20
267	49.4674	18.4083	2.20
268	45.3608	25.1707	2.20
269	34.2268	22.5955	2.20
270	48.7333	24.929	2.00
271	43.405	27.3892	3.00

272	58.5084	31.4151	3.00
273	57.2619	26.3704	3.12
274	80.2611	38.4051	3.20
275	57.5577	31.1156	3.30
276	54.3424	27.2249	3.20
277	60.8937	32.8098	3.30
278	72.2961	25.7018	3.00
279	57.4802	25.5524	3.00
280	54.9873	27.954	3.00
281	54.4876	33.7019	3.00
282	55.5821	25.2655	3.10
283	51.4755	32.0279	3.10
284	40.3415	29.4527	3.10
285	54.848	31.7862	3.10
286	51.1787	34.6571	3.00
287	66.2822	38.683	3.00
288	65.0356	33.6382	3.00
289	88.0348	45.6729	3.10
290	65.3315	38.3835	3.12
291	62.1161	34.4927	3.15
292	68.6675	40.0777	3.20
293	80.0698	32.9697	3.20
294	65.254	32.8203	3.00
295	62.7611	35.2219	3.00
296	62.2614	40.9698	3.00
297	63.3558	32.5333	3.00
298	59.2493	39.2958	3.00
299	48.1152	36.7206	3.00
300	62.6218	39.054	3.00
301	69.523	55.2287	5.20
302	84.6264	59.2546	5.20
303	83.3798	54.2098	5.20
304	106.3791	66.2445	5.20
305	83.6757	58.9551	5.20
306	80.4604	55.0643	5.20
307	87.0117	60.6493	5.00
308	98.414	53.5413	5.00
309	83.5982	53.3919	5.00
310	81.1053	55.7935	5.00
311	80.6056	61.5414	5.25

312	81.7001	53.1049	5.55
313	77.5935	59.8674	5.45
314	66.4595	57.2922	5.45
315	80.966	59.6256	5.45

Appendix VIII

Values of output variables obtained from experiments for seam quality evaluation of cotton spandex fabric

Sr. No	Seam efficiency (Y1) (%)	Seam puckering (Y2) (%)	Seam boldness (Y3) (Grade 1-5)
1	2.415	7.1019	2.00
2	11.6388	-1.6343	2.00
3	7.2842	2.929	2.15
4	54.8823	20.0329	2.15
5	1.7439	0.5029	1.15
6	5.4786	0.1707	1.50
7	41.5944	1.0073	2.20
8	48.232	5.1943	2.00
9	18.4951	-5.1532	2.20
10	21.8612	18.9078	2.00
11	20.518	19.4151	1.00
12	38.8782	3.7291	2.25
13	25.542	5.3654	2.25
14	31.0115	28.3059	2.55
15	24.6273	-1.4427	1.05
16	4.2121	9.3757	2.45
17	13.4359	0.6394	2.55
18	9.0813	5.2028	2.45
19	56.6794	22.3066	2.55
20	3.5411	2.7767	1.05
21	7.2757	2.4445	2.35
22	43.3915	3.2811	2.35
23	50.0291	7.468	2.35
24	20.2922	-2.8795	2.55
25	23.6583	21.1816	2.45
26	22.3151	21.6889	2.55
27	40.6753	6.0028	2.65
28	27.3391	7.6392	2.75
29	32.8086	30.5797	2.55
30	26.4244	0.8311	2.45
31	9.6034	16.197	2.35

32	18.8272	7.4607	2.33
33	14.4727	12.0241	2.45
34	62.0707	29.1279	2.43
35	8.9324	9.598	2.50
36	12.667	9.2658	2.70
37	48.7828	10.1024	2.80
38	55.4204	14.2893	2.50
39	25.6835	3.9418	2.00
40	29.0496	28.0029	2.00
41	27.7064	28.5102	2.50
42	46.0667	12.8241	2.50
43	32.7305	14.4605	2.05
44	38.1999	37.401	2.50
45	31.8157	7.6524	2.55
46	12.5986	19.9866	2.45
47	21.8224	11.2503	3.00
48	17.4678	15.8137	2.35
49	65.0658	32.9175	3.05
50	11.9275	13.3876	2.00
51	15.6622	13.0554	2.00
52	51.778	13.892	2.10
53	58.4156	18.0789	3.10
54	28.6787	7.7314	2.15
55	32.0448	31.7925	3.55
56	30.7016	32.2998	2.55
57	49.0618	16.6137	2.00
58	35.7256	18.2501	2.05
59	41.1951	41.1906	2.05
60	34.8109	11.442	2.15
61	18.5889	27.5658	3.75
62	27.8127	18.8296	3.75
63	23.4582	23.3929	3.85
64	71.0562	40.4968	3.55
65	17.9179	20.9668	3.65
66	21.6525	20.6346	3.75
67	57.7683	21.4712	3.26
68	64.406	25.6582	3.55
69	34.6691	15.3107	3.75
70	38.0352	39.3717	3.75
71	36.692	39.879	3.25

72	55.0522	24.193	3.45
73	41.716	25.8293	3.45
74	47.1854	48.7698	3.55
75	40.8012	19.0212	3.65
76	25.9465	36.5976	3.75
77	35.1703	27.8614	4.45
78	30.8157	32.4247	3.75
79	78.4138	49.5286	4.00
80	25.2755	29.9986	3.00
81	29.0101	29.6664	3.10
82	65.1259	30.503	4.20
83	71.7635	34.69	4.35
84	42.0266	24.3425	4.45
85	45.3927	48.4035	4.55
86	44.0495	48.9108	3.00
87	62.4097	33.2248	3.35
88	49.0735	34.8611	3.55
89	54.543	57.8016	4.00
90	48.1588	28.053	3.00
91	43.9176	59.3353	5.55
92	53.1413	50.599	5.65
93	48.7868	55.1624	5.45
94	96.3848	72.2662	5.45
95	43.2465	52.7363	5.55
96	46.9812	52.4041	5.65
97	83.097	53.2407	5.45
98	89.7346	57.4277	5.65
99	59.9977	47.0801	5.00
100	63.3638	71.1412	5.00
101	62.0206	71.6485	5.15
102	80.3808	55.9624	5.15
103	67.0446	57.5988	5.00
104	72.514	80.5393	5.05
105	66.1298	50.7907	5.25
106	13.3486	12.679	2.25
107	22.5723	3.9427	2.25
108	18.2178	8.5061	2.25
109	65.8158	25.6099	2.52
110	12.6775	6.08	1.00
111	16.4122	5.7478	1.00

112	52.528	6.5844	2.15
113	59.1656	10.7714	2.15
114	29.4287	0.4239	2.15
115	32.7948	24.4849	2.15
116	31.4516	24.9922	1.55
117	49.8118	9.3061	1.55
118	36.4756	10.9425	1.55
119	41.9451	33.883	2.10
120	35.5608	4.1344	1.25
121	15.1457	14.9528	2.35
122	24.3694	6.2165	2.45
123	20.0149	10.7799	2.55
124	67.6129	27.8837	2.65
125	14.4746	8.3538	1.20
126	18.2093	8.0216	1.00
127	54.3251	8.8582	2.00
128	60.9627	13.0451	2.00
129	31.2258	2.6976	2.01
130	34.5919	26.7587	2.10
131	33.2487	27.266	1.20
132	51.6089	11.5799	2.30
133	38.2727	13.2162	2.45
134	43.7422	36.1568	2.55
135	37.3579	6.4082	1.65
136	20.537	21.7741	2.30
137	29.7607	13.0378	2.40
138	25.4062	17.6012	2.45
139	73.0042	34.705	2.55
140	19.8659	15.1751	2.65
141	23.6006	14.8429	2.75
142	59.7164	15.6795	2.60
143	66.354	19.8664	2.00
144	36.6171	9.5189	2.01
145	39.9832	33.58	2.10
146	38.64	34.0873	2.10
147	57.0002	18.4012	2.22
148	43.664	20.0375	2.32
149	49.1335	42.9781	2.45
150	42.7493	13.2295	2.55
151	23.5322	25.5637	2.65

152	32.7559	16.8274	3.80
153	28.4014	21.3908	2.75
154	75.9994	38.4946	2.55
155	22.8611	18.9647	2.45
156	26.5958	18.6325	2.55
157	62.7116	19.4691	2.05
158	69.3492	23.656	2.10
159	39.6123	13.3085	2.20
160	42.9784	37.3696	2.30
161	41.6352	37.8769	2.55
162	59.9954	22.1908	2.75
163	46.6592	23.8272	2.33
164	52.1286	46.7677	2.00
165	45.7444	17.0191	2.00
166	29.5225	33.1429	3.00
167	38.7463	24.4066	3.00
168	34.3918	28.97	3.00
169	81.9898	46.0738	3.00
170	28.8515	26.5439	2.00
171	32.5861	26.2117	3.15
172	68.7019	27.0483	3.20
173	75.3395	31.2353	3.25
174	45.6026	20.8878	3.75
175	48.9687	44.9488	3.35
176	47.6255	45.4561	3.75
177	65.9858	29.77	3.45
178	52.6496	31.4064	3.55
179	58.119	54.3469	3.65
180	51.7348	24.5983	3.75
181	36.8801	42.1747	3.35
182	46.1038	33.4385	4.55
183	41.7493	38.0018	3.55
184	89.3473	55.1057	3.75
185	36.209	35.5757	3.40
186	39.9437	35.2435	3.45
187	76.0595	36.0801	3.55
188	82.6971	40.2671	3.65
189	52.9602	29.9196	3.75
190	56.3263	53.9806	4.20
191	54.9831	54.4879	3.20

192	73.3433	38.8019	3.00
193	60.0071	40.4382	3.00
194	65.4766	63.3787	3.00
195	59.0924	33.6301	3.25
196	54.8511	64.9124	5.35
197	64.0749	56.1761	5.45
198	59.7204	60.7395	5.65
199	107.3184	77.8433	5.55
200	54.1801	58.3134	4.05
201	57.9147	57.9812	5.00
202	94.0305	58.8178	5.45
203	100.6681	63.0047	5.35
204	70.9312	52.6572	5.05
205	74.2973	76.7183	5.55
206	72.9541	77.2256	5.45
207	91.3144	61.5395	5.22
208	77.9782	63.1759	5.05
209	83.4476	86.1164	5.35
210	77.0634	56.3678	5.00
211	24.2821	18.2561	1.00
212	33.5059	9.5198	2.00
213	29.1514	14.0832	1.00
214	76.7494	31.187	2.00
215	23.6111	11.6571	1.50
216	27.3457	11.3249	1.00
217	63.4615	12.1615	1.25
218	70.0992	16.3485	2.50
219	40.3622	6.001	1.20
220	43.7284	30.062	2.30
221	42.3852	30.5693	1.50
222	60.7454	14.8832	1.60
223	47.4092	16.5196	1.70
224	52.8786	39.4601	1.75
225	46.4944	9.7115	1.55
226	26.0792	20.5298	2.00
227	35.303	11.7936	2.00
228	30.9485	16.357	2.10
229	78.5465	33.4608	2.45
230	25.4082	13.9309	1.55
231	29.1428	13.5987	1.65

232	65.2586	14.4353	2.00
233	71.8963	18.6222	2.10
234	42.1594	8.2747	2.10
235	45.5255	32.3358	2.10
236	44.1823	32.8431	1.00
237	62.5425	17.157	1.01
238	49.2063	18.7933	1.10
239	54.6757	41.7339	2.00
240	48.2915	11.9853	1.00
241	31.4706	27.3511	2.00
242	40.6943	18.6149	2.00
243	36.3398	23.1783	2.25
244	83.9378	40.2821	2.55
245	30.7995	20.7522	2.65
246	34.5342	20.42	2.75
247	70.65	21.2566	2.85
248	77.2876	25.4435	2.55
249	47.5507	15.096	2.65
250	50.9168	39.1571	2.75
251	49.5736	39.6644	2.85
252	67.9338	23.9783	2.00
253	54.5976	25.6146	2.00
254	60.067	48.5552	2.00
255	53.6828	18.8066	2.00
256	34.4657	31.1408	2.00
257	43.6895	22.4045	2.10
258	39.335	26.9679	2.20
259	86.933	44.0717	2.30
260	33.7947	24.5418	2.40
261	37.5293	24.2096	2.50
262	73.6451	25.0462	2.60
263	80.2827	29.2331	2.70
264	50.5458	18.8856	2.55
265	53.912	42.9467	2.65
266	52.5687	43.454	2.45
267	70.929	27.7679	2.25
268	57.5928	29.4043	2.55
269	63.0622	52.3448	2.65
270	56.678	22.5962	2.56
271	40.4561	38.72	3.45

272	49.6798	29.9837	3.55
273	45.3253	34.5471	3.65
274	92.9233	51.6509	3.75
275	39.785	32.121	2.75
276	43.5197	31.7888	2.05
277	79.6355	32.6254	3.55
278	86.2731	36.8124	3.54
279	56.5362	26.4649	3.00
280	59.9023	50.5259	3.10
281	58.5591	51.0332	2.20
282	76.9193	35.3471	3.25
283	63.5831	36.9835	3.55
284	69.0526	59.924	3.45
285	62.6684	30.1754	2.50
286	47.8136	47.7518	3.60
287	57.0374	39.0156	4.55
288	52.6829	43.5789	3.45
289	100.2809	60.6828	3.20
290	47.1426	41.1528	3.35
291	50.8773	40.8206	3.45
292	86.9931	41.6572	3.25
293	93.6307	45.8442	3.00
294	63.8938	35.4967	3.00
295	67.2599	59.5577	3.10
296	65.9167	60.065	3.20
297	84.2769	44.379	3.00
298	70.9407	46.0153	3.35
299	76.4101	68.9558	3.45
300	70.0259	39.2072	3.45
301	65.7847	70.4895	5.55
302	75.0085	61.7532	5.50
303	70.6539	66.3166	5.50
304	118.252	83.4204	5.55
305	65.1137	63.8905	4.45
306	68.8483	63.5583	4.45
307	104.9641	64.3949	5.00
308	111.6017	68.5818	5.00
309	81.8648	58.2343	5.00
310	85.2309	82.2954	5.00
311	83.8877	82.8027	4.25

312	102.2479	67.1166	5.00
313	88.9117	68.753	5.15
314	94.3812	91.6935	5.50
315	87.997	61.9449	4.00

Appendix IX

Values of output variables obtained from experiments for seam quality evaluation of cotton fabric

Sr. No	Seam efficiency (Y1) (%)	Seam puckering (Y2) (%)	Seam boldness (Y3) (Grade 1-5)
1	6.2	0	1.00
2	7.36	0.73	1.00
3	7.13	0	1.00
4	12.06	0.78	1.15
5	8.01	0.93	1.15
6	13.36	2	1.15
7	41.09	71	1.20
8	29.6	1.02	1.25
9	30.48	3	1.55
10	29.71	13.9	1.55
11	10.82	6.95	1.50
12	28.17	3.55	1.20
13	17.89	5	1.40
14	20.62	5.25	1.45
15	12.19	8.84	1.55
16	18.61	4	1.25
17	12.21	1.48	1.55
18	18.02	4.81	1.50
19	23.69	4	1.25
20	17.87	3.98	1.45
21	7.65	0.31	1.45
22	11.89	1.06	1.55
23	10.58	0.45	1.25
24	13.61	1.24	1.00
25	10.39	1.87	1.00
26	18.63	5.07	1.00
27	43.88	0	1.20
28	31.57	3.04	1.25
29	36.92	6.01	1.45
30	23.68	14.81	1.65
31	13.23	10.81	1.75

32	27.31	7.81	1.75
33	20.16	9.08	1.75
34	19.01	11.46	1.25
35	16.26	10.79	1.25
36	21.32	9.74	1.25
37	13.91	3.89	1.00
38	21.53	11.8	1.00
39	31.32	6.88	1.00
40	19.72	5.07	1.25
41	9.45	0.29	1.35
42	12.64	2.01	2.45
43	12.46	1	1.55
44	17.23	2.08	2.45
45	16.72	3.01	2.55
46	19.01	6.67	1.55
47	46.03	0.69	1.00
48	39.29	7.06	1.25
49	37.58	8.5	2.45
50	33.73	19.53	1.55
51	17.19	16.08	2.65
52	37.29	8.36	2.55
53	24.32	11.01	1.75
54	25.79	11.17	1.85
55	23.02	15.54	2.35
56	25.52	15.07	1.45
57	16.22	8.21	1.55
58	22.91	12.19	1.65
59	33.21	10.81	1.45
60	25.23	8.89	1.25
61	10.2	0.66	3.45
62	13.26	2.92	2.75
63	19.23	1.88	3.33
64	21.32	3.88	3.30
65	18.5	6.42	3.05
66	23.07	7.77	2.00
67	49.57	1.08	1.15
68	42.91	25.6	3.25
69	43.37	12.84	2.35
70	49.03	23.17	3.35
71	26.88	20.78	3.45

72	39.09	10.39	3.55
73	25.59	17.79	2.50
74	33.49	12.81	1.15
75	28.19	20.27	3.25
76	26.09	19.82	2.35
77	21.87	10.96	1.45
78	31.07	13.21	3.00
79	42.51	17	2.00
80	39.41	11.77	3.45
81	12.33	0.99	4.25
82	14.31	4.24	4.25
83	20.12	3.03	3.55
84	28.66	5.19	3.35
85	22.09	9.84	3.55
86	29.01	20.61	3.44
87	59.78	2.88	3.25
88	56.86	32.08	4.00
89	57.06	17.28	4.00
90	55.35	27.61	3.00
91	24.68	26.54	3.00
92	49.23	14.92	3.00
93	31.66	20.91	3.25
94	35.62	14.86	3.55
95	30.29	33.58	3.65
96	29.25	22.67	3.50
97	23.94	15.61	3.50
98	33.61	23.12	4.65
99	44.41	20.73	4.45
100	40.43	16.21	3.35
101	13.59	1.01	5.00
102	22.25	5.01	4.00
103	24.11	3.23	4.00
104	31	6.48	4.00
105	28.66	10.67	3.00
106	33.61	21.22	4.00
107	68.88	4.1	3.00
108	71.69	28.78	5.25
109	59.57	21.77	4.55
110	66.39	35.91	4.25
111	33.42	27.43	4.45

112	50.71	19.06	3.35
113	42.78	26.56	4.25
114	40.38	22.74	3.55
115	39.75	39.91	3.50
116	36.68	25.88	4.55
117	29.23	17.75	3.55
118	31.69	40.52	5.65
119	51.01	32.69	4.55
120	49.56	22.09	4.55
121	19.39	1.91	5.20
122	27.42	3.91	5.25
123	31.39	4.76	5.65
124	39.56	10.25	5.45
125	35.71	20.51	4.25
126	41.23	30.93	4.55
127	79.71	13.16	4.25
128	80.01	50.98	5.25
129	57.09	51	5.25
130	69.75	64.59	5.10
131	41.79	48.89	5.10
132	58.12	39.75	4.12
133	45.53	57.32	4.15
134	52.09	50.22	4.00
135	46.2	66.58	4.00
136	46.18	59.67	4.00
137	37.52	38.34	4.00
138	50.73	51.89	5.50
139	53.92	46.98	5.25
140	51.32	50.95	5.25
141	9.94	0	1.25
142	10.18	0.87	1.25
143	14.23	0	1.25
144	21.65	0.78	1.20
145	16.01	1.06	1.00
146	21.36	2.26	1.15
147	58.07	0.85	1.50
148	38.06	2.58	1.25
149	38.84	3.02	1.55
150	47.17	14.8	1.45
151	13.82	7.97	1.35

152	35.51	4.01	1.55
153	23.48	4.32	1.45
154	23.96	5.25	1.45
155	26.09	9.78	1.65
156	20.06	4.67	1.75
157	21.04	2.37	1.85
158	19.7	6.68	1.80
159	58.36	4.87	1.80
160	19.77	4.19	1.20
161	10.56	0.35	1.20
162	13.48	1.76	2.20
163	15.25	0.55	1.30
164	18.59	1.24	1.35
165	17.62	2.08	1.35
166	23.83	5.67	1.45
167	47.78	0	1.45
168	39.75	5.03	1.55
169	64.82	6.19	2.00
170	46.66	16.78	1.00
171	22.65	12.78	1.00
172	49.31	8.12	1.00
173	29.71	10.08	1.25
174	32.09	10.46	1.25
175	29.12	12.97	2.25
176	25.02	10.88	1.55
177	23.59	4.68	1.65
178	27.35	14.88	1.75
179	60.13	7.99	1.55
180	32.77	6.97	1.65
181	11.41	0.39	2.00
182	15.64	2.9	1.10
183	19.39	1.27	1.20
184	28.12	2.08	1.15
185	21.72	3.97	1.25
186	24.57	6.68	1.55
187	68.2	0.86	1.25
188	41.42	10.11	2.55
189	51.58	9.06	1.05
190	59.37	20.35	1.20
191	27.71	19.08	1.25

192	61.82	9.23	1.45
193	35.72	12.9	1.24
194	37.67	10.17	1.35
195	37.99	17.75	1.45
196	37.15	16.9	1.55
197	25.32	9.29	1.65
198	36.49	18.09	1.45
199	79.82	11.18	1.75
200	45.12	9.68	1.55
201	14.4	0.76	3.65
202	16.22	3.82	3.55
203	28.24	2.39	2.00
204	31.28	3.88	2.15
205	26.7	7.88	1.15
206	39.8	8.889	2.15
207	69.97	1.78	2.20
208	56.51	27.6	3.40
209	75.67	13.64	3.45
210	78.01	24.61	2.55
211	30.88	23.87	2.25
212	78.49	12.37	1.00
213	25.75	18.67	2.00
214	46.95	12.9	2.00
215	37.91	24.28	3.15
216	30.89	20.18	2.25
217	36.87	12.69	2.55
218	49.6	22.91	1.65
219	80.51	19.03	2.75
220	60.4	13.79	1.55
221	19.57	1.54	5.05
222	18.59	4.67	2.20
223	21.85	3.63	3.25
224	39.66	5.19	3.55
225	35.03	10.84	2.45
226	48.81	22.26	2.35
227	84.78	3.49	2.40
228	74.86	32.28	5.40
229	81.6	18.29	2.45
230	83.51	29.86	3.55
231	35.96	28.65	3.65

232	83.23	14.78	2.65
233	43.36	22.99	2.65
234	53.96	16.98	2.00
235	45.26	35.57	2.20
236	35.85	24.67	3.20
237	42.59	18.46	3.30
238	45.76	27.9	2.30
239	87.47	23.87	2.25
240	54.74	19.82	2.50
241	18.54	1.18	5.00
242	28.24	5.48	4.00
243	37.66	3.69	3.25
244	46.01	6.48	4.50
245	37.96	13.76	3.25
246	50.71	22.27	2.56
247	87.28	4.29	2.55
248	81.86	29.87	5.20
249	87.57	22.78	4.25
250	89.33	37.9	3.00
251	51.24	33.34	4.25
252	84.71	20.06	3.25
253	62.97	30.05	2.25
254	79.53	23.47	2.50
255	78.57	41.9	4.45
256	65.76	27.78	3.45
257	68.72	19.57	4.00
258	48.56	44.37	3.00
259	90.2	36.56	2.00
260	88.45	26.69	3.15
261	26.81	2.21	5.15
262	32.85	4.66	5.00
263	49.69	5.37	4.25
264	58.47	10.25	5.25
265	44.92	24.58	4.55
266	60.23	33.39	3.35
267	91.67	16.17	3.35
268	91.8	50.56	5.00
269	93.6	53.56	5.25
270	92.26	68.57	4.55
271	65.47	58.78	5.65

272	88.01	42.75	4.25
273	61.65	58.69	3.00
274	78.03	53.25	325
275	82.6	68.57	5.00
276	72.08	63.17	4.00
277	82.65	40.23	5.25
278	51.57	61.78	4.55
279	91.89	52.49	3.45
280	82.49	57.49	4.55
281	14.49	0.12	1.65
282	16.82	1.56	1.65
283	19.31	0.33	1.55
284	26.51	1.28	1.45
285	21.12	1.78	1.55
286	28.69	3.2	1.65
287	66.74	1.03	1.75
288	44.16	3.89	1.85
289	42.44	4.02	1.00
290	52.77	15.08	1.25
291	18.21	8.99	1.20
292	41.51	5.03	1.00
293	31.81	5.32	1.25
294	32.68	5.25	1.25
295	36.19	9.98	1.25
296	29.61	5.67	1.20
297	28.14	1.39	1.20
298	24.04	7.8	1.00
299	59.01	6.79	1.00
300	24.73	5.24	1.00
301	16.61	0.96	1.00
302	19.18	2.69	1.25
303	22.51	0.96	1.25
304	28.91	1.96	1.00
305	24.21	3.09	1.35
306	31.32	6.79	1.55
307	68.81	0.66	1.05
308	48.57	7.61	1.10
309	68.29	7.19	1.00
310	50.61	17.81	1.00
311	25.52	13.28	1.20

312	52.13	9.22	1.00
313	37.18	12.81	1.00
314	39.9	11.46	1.00
315	42.23	13.78	1.00
316	35.21	11.12	1.25
317	35.6	5.89	1.25
318	33.31	16.89	1.00
319	64.32	8.99	1.00
320	37.22	7.77	1.00
321	20.61	1.02	1.00
322	21.49	3.98	2.00
323	25.39	2.2	1.25
324	31.23	2.98	1.50
325	29.21	4.99	1.00
326	36.71	7.89	1.25
327	76.11	1.09	1.55
328	55.42	11.21	1.25
329	69.22	11.06	2.20
330	65.74	22.36	1.10
331	33.11	20.81	1.35
332	66.29	10.36	1.55
333	45.28	13.07	1.65
334	43.79	12.17	1.65
335	51.99	19.58	1.75
336	43.22	18.2	1.55
337	41.24	10.29	1.45
338	41.9	20.14	1.45
339	77.21	14.18	1.55
340	51.23	10.81	1.75
341	32.43	1.89	2.25
342	32.21	5	1.50
343	40.22	3.9	2.50
344	43.81	4.78	2.25
345	40.01	5.98	1.00
346	50.01	9.93	1.20
347	83.72	2.8	1.20
348	68.15	29.63	2.25
349	82.77	15.44	1.25
350	88.01	25	2.20
351	43.12	26.37	2.20

352	88.41	14.39	1.20
353	55.58	21.71	1.25
354	60.51	15.1	1.55
355	59.9	27.29	2.65
356	51.91	23.8	1.75
357	53.79	14.98	1.55
358	62.04	21.32	1.25
359	88.22	21.31	2.20
360	72.04	15.89	2.25
361	49.71	2.49	3.55
362	35.59	6.67	2.65
363	47.54	4.68	2.00
364	51.16	6.92	2.00
365	51.31	12.84	2.00
366	61.14	24.28	2.10
367	95.81	4.6	1.00
368	86.68	35.82	3.15
369	94.6	21.49	2.00
370	91.34	28.86	2.10
371	49.61	31.54	2.00
372	91.33	17.89	2.15
373	58.69	25.89	2.45
374	69.62	17.8	1.55
375	60.13	38.55	2.65
376	62.53	25.6	2.75
377	68.91	22.69	2.75
378	69.76	31.08	1.85
379	89.74	29.74	3.50
380	78.48	20.21	3.00
381	62.46	3.86	3.25
382	48.24	7.89	3.60
383	51.86	5.99	4.44
384	55.11	8.93	3.35
385	56.64	16.68	2.76
386	65.19	25.78	2.00
387	97.29	5.6	2.00
388	91.69	37.78	3.00
389	96.56	25.83	3.00
390	95.83	39.9	4.10
391	67.41	37.34	3.20

392	94.18	23.62	2.22
393	77.71	31.05	2.35
394	86.35	26.49	2.50
395	83.77	46.01	3.35
396	78.61	30.89	2.55
397	79.21	25.78	2.45
398	81.6	49.73	2.45
399	96.6	39.64	3.50
400	91.56	28.01	3.20
401	77.29	4.13	4.00
402	60.85	6.69	4.00
403	58.32	6.07	4.00
404	69.73	13.23	3.00
405	61.23	29.83	3.15
406	75.31	36.93	2.20
407	97.67	20.17	2.20
408	95.02	56.56	4.25
409	98	59.91	4.25
410	99.25	67.41	4.20
411	77.73	65.89	3.35
412	98.18	48.58	3.45
413	84.56	65.59	2.44
414	94.31	59.52	2.02
415	96.61	71.67	3.50
416	88.01	65.72	3.50
417	91.52	47.39	2.20
418	95.7	66.87	2.20
419	94.89	55.97	4.00
420	97.09	59.68	4.00

Appendix X

Values of input variables obtained from experiments for validation of the best fit models of cotton-polyester fabric

Sr. No	Sewing Thread Size (X1) (Tex)	Cover Factor (X2)	Weight (X3) (GSM)	Thickness (X4) (mm)	Strength (X5) (N)	Extensibility (X6) (%)	Bending Rigidity (X7) gf/cm	Shear Rigidity (X8) gf/cm.deg	stitch density (X9) spi)
1	18	26.4992	147	0.441	200.3022	8.036	0.1274	2.2834	6
2	21	33.8296	179.34	0.5292	418.0288	7.1148	0.049	1.078	6
3	21	32.1342	181.3	0.3332	431.3176	5.7134	0.2646	2.7244	6
4	21	35.5544	304.78	0.588	482.9538	9.3492	0.294	3.9004	6
5	30	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	6
6	30	35.7112	194.04	0.3136	466.1174	6.6738	0.196	2.5382	6
7	35	31.4384	245	53.9	787.038	3.7436	0.1078	2.058	6
8	45	26.4992	147	0.441	200.3022	8.036	0.1274	2.2834	6
9	45	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	6
10	45	35.7112	194.04	0.3136	466.1174	6.6738	0.196	2.5382	6
11	60	41.307	211.68	0.4704	488.2556	5.7526	0.2842	2.5284	6
12	60	41.307	211.68	0.4704	488.2556	5.7526	0.2842	2.5284	6
13	90	41.307	211.68	0.4704	488.2556	5.7526	0.2842	2.5284	6
14	90	39.69	254.8	0.49	356.4848	4.3806	0.0784	3.0576	6
15	90	49.1666	189.14	0.3822	522.2126	6.958	0.1862	1.5386	6
16	18	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	10
17	18	47.1576	272.44	0.5488	509.9038	5.5958	0.3724	3.2536	10
18	18	46.9322	282.24	0.5488	650.5534	5.6154	0.3724	2.8322	10
19	21	31.4384	245	53.9	787.038	3.7436	0.1078	2.058	10
20	21	26.2542	195.02	0.392	167.041	5.6448	0.196	1.4504	10
21	21	41.307	211.68	0.4704	488.2556	5.7526	0.2842	2.5284	10
22	21	35.7112	194.04	0.3136	466.1174	6.6738	0.196	2.5382	10
23	30	41.307	211.68	0.4704	488.2556	5.7526	0.2842	2.5284	10
24	30	35.7112	194.04	0.3136	466.1174	6.6738	0.196	2.5382	10
25	35	38.759	127.4	38.22	402.388	8.918	0.0686	1.519	10

26	35	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	10
27	35	39.69	254.8	0.49	356.4848	4.3806	0.0784	3.0576	10
28	45	31.4384	245	53.9	787.038	3.7436	0.1078	2.058	10
29	45	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	10
30	45	41.307	211.68	0.4704	488.2556	5.7526	0.2842	2.5284	10
31	90	31.4384	245	53.9	787.038	3.7436	0.1078	2.058	10
32	90	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	10
33	90	46.9322	282.24	0.5488	650.5534	5.6154	0.3724	2.8322	10
34	21	33.8296	179.34	0.5292	418.0288	7.1148	0.049	1.078	14
35	21	26.2542	195.02	0.392	167.041	5.6448	0.196	1.4504	14
36	21	35.5544	304.78	0.588	482.9538	9.3492	0.294	3.9004	14
37	35	31.4384	245	53.9	787.038	3.7436	0.1078	2.058	14
38	35	39.69	254.8	0.49	356.4848	4.3806	0.0784	3.0576	14
39	45	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	14
40	45	47.1576	272.44	0.5488	509.9038	5.5958	0.3724	3.2536	14
41	45	35.5544	304.78	0.588	482.9538	9.3492	0.294	3.9004	14
42	60	45.8934	249.9	0.5488	500.0254	6.076	0.245	3.087	14
43	90	33.8296	179.34	0.5292	418.0288	7.1148	0.049	1.078	14
44	90	39.69	254.8	0.49	356.4848	4.3806	0.0784	3.0576	14

Appendix XI

Values of output variables obtained from experiments (Y1, Y2 and Y3) and best fit models (Yp1, Yp2 and Yp3) for validation of the best fit models of cotton-polyester fabric

Sr. No	Experimental seam efficiency (Y1) (%)	Predicted seam efficiency (Yp1) (%)	Experimental Seam puckering (Y2) (%)	Predicted seam puckering (Yp2) (%)	Seam boldness (Y3) (grade)	Predicted seam boldness (Yp3) (grade)
1	32.158	33.075	7.802	9.800	1.051	1.138
2	23.254	16.542	5.045	9.222	2.100	1.553
3	25.013	19.257	7.946	8.644	1.200	1.322
4	16.130	15.886	7.816	8.908	1.810	1.560
5	22.092	23.804	15.911	13.191	2.010	2.183
6	32.627	26.940	17.752	15.308	2.001	2.107
7	19.583	12.044	15.100	11.525	2.850	2.550
8	57.012	59.986	33.131	36.309	3.010	2.977
9	33.090	33.193	27.119	26.382	3.205	2.996
10	43.625	37.701	28.960	27.558	3.00	2.920
11	43.415	49.314	34.762	39.190	3.90	3.611
12	43.415	48.304	34.762	29.723	4.00	3.490
13	54.413	54.517	45.970	56.154	4.13	4.304
14	61.122	46.334	46.697	31.429	4.00	4.501
15	50.978	51.048	44.886	53.145	4.20	4.334
16	22.195	21.874	5.224	9.418	1.25	1.135
17	18.200	21.903	3.872	6.468	1.00	1.117
18	15.723	14.651	2.349	9.016	1.05	1.105
19	19.685	13.789	4.413	4.861	2.20	1.503
20	38.789	53.038	8.181	8.477	1.00	1.493
21	28.897	33.879	9.175	9.908	1.20	1.361
22	36.911	35.760	11.326	12.289	1.50	1.368
23	38.572	41.042	19.035	14.308	2.50	2.077
24	46.585	40.739	21.185	18.532	2.50	2.084
25	44.206	48.304	27.292	20.707	3.05	2.507
26	40.232	46.040	23.606	21.913	2.10	2.469

27	49.462	44.776	24.023	15.288	3.50	2.584
28	40.359	33.741	25.480	24.608	3.25	3.032
29	47.049	48.265	30.553	30.145	3.50	2.973
30	49.571	48.079	30.243	19.816	3.20	2.890
31	59.160	55.135	44.641	59.594	4.70	4.423
32	65.851	58.624	49.713	52.763	4.05	4.364
33	59.379	56.272	46.838	49.127	4.30	4.335
34	46.407	39.357	10.740	10.349	2.00	1.516
35	47.983	56.732	10.442	8.781	1.40	1.478
36	39.284	37.838	13.511	15.896	1.70	1.522
37	42.736	39.484	20.795	17.140	2.90	2.513
38	58.657	51.019	26.284	17.934	2.40	2.569
39	56.244	54.851	32.815	32.105	2.50	2.959
40	52.249	54.723	31.463	20.786	3.00	2.940
41	59.957	57.536	34.579	33.869	3.10	3.051
42	64.047	60.633	40.767	39.210	3.80	3.536
43	85.882	72.912	50.968	54.782	4.80	4.436
44	84.275	63.671	52.392	44.218	4.50	4.464

Appendix XII

Values of input variables obtained from experiments for validation of the best fit models of cotton-spandex fabric

Sr. No	Sewing Thread Size (X1) (Tex)	Cover Factor (X2)	Weight (X3) (GSM)	Thickness (X4) (mm)	Strength (X5) (N)	Extensibility (X6) (%)	Bending Rigidity (X7) gf/cm	Shear Rigidity (X8) gf/cm.deg	stitch density (X9) spi)
1	18	24.7548	122.01	0.3038	296.1266	6.076	0.01666	0.5194	6
2	21	22.1382	74.48	0.196	149.597	6.2916	0.0392	1.3132	6
3	21	28.5376	161.014	0.343	338.394	5.4292	0.049	0.3332	6
4	30	26.1856	103.978	0.2156	476.182	2.891	0.098	1.0682	6
5	35	45.9326	236.18	0.4802	656.5412	1.6268	0.4802	6.0662	6
6	35	33.075	264.6	0.4018	760.137	6.1446	0.441	5.6644	6
7	35	49.1078	242.06	0.4312	613.774	6.5954	0.245	1.4014	6
8	35	27.3518	164.64	0.3332	179.438	5.6644	0.1176	0.6762	6
9	35	53.1748	246.47	0.49	477.162	5.2136	0.1862	1.6464	6
10	35	26.1856	103.978	0.2156	476.182	2.891	0.098	1.0682	6
11	45	34.0256	208.74	0.3724	684.383	7.889	0.1862	2.3912	6
12	45	26.1856	103.978	0.2156	476.182	2.891	0.098	1.0682	6
13	60	48.9902	220.5	0.5096	541.3226	6.7718	0.4018	2.6264	6
14	60	27.3518	164.64	0.3332	179.438	5.6644	0.1176	0.6762	6
15	60	26.1954	97.02	0.2058	370.4204	2.3716	0.1078	1.2152	6
16	60	26.1856	103.978	0.2156	476.182	2.891	0.098	1.0682	6
17	90	33.075	264.6	0.4018	760.137	6.1446	0.441	5.6644	6
18	90	28.5376	161.014	0.343	338.394	5.4292	0.049	0.3332	6
19	21	45.9326	236.18	0.4802	656.5412	1.6268	0.4802	6.0662	10
20	21	33.075	264.6	0.4018	760.137	6.1446	0.441	5.6644	10
21	21	24.7548	122.01	0.3038	296.1266	6.076	0.01666	0.5194	10
22	30	26.1954	97.02	0.2058	370.4204	2.3716	0.1078	1.2152	10
23	30	24.7548	122.01	0.3038	296.1266	6.076	0.01666	0.5194	10
24	30	28.5376	161.014	0.343	338.394	5.4292	0.049	0.3332	10
25	35	24.7548	122.01	0.3038	296.1266	6.076	0.01666	0.5194	10
26	35	26.1954	92.12	0.196	278.712	6.4778	0.0686	0.5782	10

27	45	26.1856	103.978	0.2156	476.182	2.891	0.098	1.0682	10
28	60	24.7548	122.01	0.3038	296.1266	6.076	0.01666	0.5194	10
29	90	45.9326	236.18	0.4802	656.5412	1.6268	0.4802	6.0662	10
30	90	49.1078	242.06	0.4312	613.774	6.5954	0.245	1.4014	10
31	18	34.0256	208.74	0.3724	684.383	7.889	0.1862	2.3912	14
32	18	26.9402	120.54	0.3136	235.9546	3.2536	0.0784	0.637	14
33	21	24.7548	122.01	0.3038	296.1266	6.076	0.01666	0.5194	14
34	21	26.1954	92.12	0.196	278.712	6.4778	0.0686	0.5782	14
35	35	53.1748	246.47	0.49	477.162	5.2136	0.1862	1.6464	14
36	45	22.1382	74.48	0.196	149.597	6.2916	0.0392	1.3132	14
37	45	26.1856	103.978	0.2156	476.182	2.891	0.098	1.0682	14
38	45	26.1954	92.12	0.196	278.712	6.4778	0.0686	0.5782	14
39	60	33.075	264.6	0.4018	760.137	6.1446	0.441	5.6644	14
40	60	49.1078	242.06	0.4312	613.774	6.5954	0.245	1.4014	14
41	60	26.1954	92.12	0.196	278.712	6.4778	0.0686	0.5782	14
42	90	49.1078	242.06	0.4312	613.774	6.5954	0.245	1.4014	14
43	90	26.9402	120.54	0.3136	235.9546	3.2536	0.0784	0.637	14

Appendix XIII

Values of output variables obtained from experiments (Y1, Y2 and Y3) and best fit models (Yp1, Yp2 and Yp3) for validation of the best fit models of cotton-spandex fabric

Sr. No	Experimental seam efficiency (Y1) (%)	Predicted seam efficiency (Yp1) (%)	Experimental Seam puckering (Y2) (%)	Predicted seam puckering (Yp2) (%)	Seam boldness (Y3) (grade)	Predicted seam boldness (Yp3) (grade)
1	18.3925	18.4044	2.5609	3.864	1.0241	1.026432
2	52.6189	53.9294	22.289	18	2.1000	1.751607
3	23.1124	22.2754	0.0241	8.568	1.1020	1.376001
4	24.6549	24.2354	31.1229	30	2.3200	2.188296
5	19.4278	19.3158	18.2403	25.704	2.5200	2.661219
6	17.671	16.4836	19.5955	17.556	3.4200	2.499156
7	19.6717	18.4632	17.1163	15	2.5000	2.510937
8	64.16	51.1658	21.3089	24.696	2.2142	2.696661
9	25.9096	30.2722	13.7431	16.5	3.0000	2.572416
10	28.6384	30.4094	36.1315	38.172	2.9001	2.495394
11	23.1007	21.854	27.9135	30	3.0000	2.946141
12	35.1328	36.4168	44.2972	66.432	3.5200	2.996136
13	39.02	37.289	32.4395	31.296	4.2010	3.804174
14	78.0886	69.8446	38.8218	44.112	4.4210	3.770613
15	52.0535	49.7448	56.3207	74.28	4.6230	3.665376
16	42.5671	45.7366	53.6445	78.216	3.2150	3.569247
17	42.0775	42.3948	50.2828	66.456	4.6000	4.380849
18	60.7196	67.6298	47.309	42.852	4.9200	4.275414
19	19.5072	18.0712	8.2378	19.608	1.5000	1.52262
20	17.7505	16.8854	9.593	11.712	1.4200	1.360557
21	35.6562	39.2686	9.0428	11.604	1.2000	1.21275
22	47.4214	45.3152	40.3942	37.14	2.5100	2.163546
23	44.8733	44.8154	20.6318	19.344	1.5000	1.923372
24	45.6096	47.0498	18.2082	22.284	2.2520	1.965744

25	48.8568	48.314	25.6404	29.028	2.4200	2.23047
26	59.9353	56.6146	44.6694	59.844	2.9000	2.471931
27	48.4129	46.4226	50.8923	69.96	3.2512	2.875257
28	62.7854	55.4778	43.1534	51.72	4.2010	3.304323
29	57.1144	54.0176	55.5226	80.772	5.2555	4.422132
30	57.3583	55.7032	54.3986	55.548	5.2547	4.271751
31	21.4496	23.1182	9.0808	9.468	1.2000	0.920106
32	55.978	54.7036	12.7912	11.244	1.2555	1.138698
33	44.4035	43.5218	13.3869	19.344	1.5000	1.133154
34	55.482	57.7024	32.4158	37.86	1.9255	1.374615
35	47.9371	46.5108	24.6823	24.132	2.4020	2.37204
36	94.3414	89.8954	57.9915	69	3.1620	3.069594
37	57.1603	56.4872	55.2364	65.448	2.8025	2.795661
38	75.1771	69.5016	57.1791	98.988	3.1020	2.892978
39	53.6271	54.6056	48.0477	57.456	4.4082	3.372534
40	55.6278	54.8604	45.5684	43.632	3.000	3.384315
41	82.6113	75.0778	66.5264	114.336	3.010	3.466188
42	66.1057	60.2504	58.7427	60.12	4.025	4.192155
43	97.5687	95.5696	65.0847	71.244	4.555	4.345209

Appendix XIV

Values of input variables obtained from experiments for validation of the best fit models of cotton fabric

Sr. No	Sewing Thread Size (X1) (Tex)	Cover Factor (X2)	Weight (X3) (GSM)	Thickness (X4) (mm)	Strength (X5) (N)	Extensibility (X6) (%)	Bending Rigidity (X7) gf/cm	Shear Rigidity (X8) gf/cm.deg	stitch density (X9) spi)
1	18	26.215	210.112	0.578	259.671	8.252	0.118	1.333	6
2	18	25.362	163.66	0.49	258.563	2.793	0.235	1.333	6
3	18	16.895	163.66	0.431	322.067	3.087	0.118	1.588	6
4	21	26.215	210.112	0.578	259.671	8.252	0.118	1.333	6
5	30	27.362	368.676	0.813	739.508	4.4	1.029	7.546	6
6	30	28.881	150.136	0.412	346.92	9.036	0.059	0.941	6
7	30	26.636	248.92	0.421	220.471	7.458	0.049	0.706	6
8	30	34.133	147.98	0.48	491.96	3.322	0.127	2.332	6
9	30	33.389	147	0.343	460.149	5.361	0.137	0.941	6
10	30	34.143	147.98	0.441	438.168	6.047	0.118	2.332	6
11	35	34.133	147.98	0.48	491.96	3.322	0.127	2.332	6
12	35	25.362	163.66	0.49	258.563	2.793	0.235	1.333	6
13	35	31.399	128.38	0.372	423.203	8.487	0.078	1.666	6
14	35	16.895	163.66	0.431	322.067	3.087	0.118	1.588	6
15	45	16.895	163.66	0.431	322.067	3.087	0.118	1.588	6
16	60	33.389	147	0.343	460.149	5.361	0.137	0.941	6
17	60	33.183	177.38	0.51	425.359	6.909	0.108	0.706	6
18	90	27.362	368.676	0.813	739.508	4.4	1.029	7.546	6
19	90	34.133	147.98	0.48	491.96	3.322	0.127	2.332	6
20	90	39.171	180.32	0.539	483.895	6.527	0.098	4.596	6
21	18	27.362	368.676	0.813	739.508	4.4	1.029	7.546	10
22	18	28.881	150.136	0.412	346.92	9.036	0.059	0.941	10
23	18	26.636	248.92	0.421	220.471	7.458	0.049	0.706	10
24	18	33.389	147	0.343	460.149	5.361	0.137	0.941	10
25	18	39.171	180.32	0.539	483.895	6.527	0.098	4.596	10
26	30	28.881	150.136	0.412	346.92	9.036	0.059	0.941	10

27	35	33.751	337.414	0.794	995.19	2.587	1.47	8.849	10
28	35	33.545	268.128	0.51	529.729	7.223	0.147	2.528	10
29	35	45.492	133.28	0.451	403.495	5.88	0.098	0.725	10
30	45	27.362	368.676	0.813	739.508	4.4	1.029	7.546	10
31	45	33.389	147	0.343	460.149	5.361	0.137	0.941	10
32	45	39.171	180.32	0.539	483.895	6.527	0.098	4.596	10
33	18	33.751	337.414	0.794	995.19	2.587	1.47	8.849	14
34	18	26.636	248.92	0.421	220.471	7.458	0.049	0.706	14
35	30	35.505	372.4	0.784	1775.76	3.058	5.723	12.985	14
36	30	33.183	177.38	0.51	425.359	6.909	0.108	0.706	14
37	35	35.505	372.4	0.784	1775.76	3.058	5.723	12.985	14
38	35	28.018	470.596	0.833	1240.435	2.871	1.94	4.537	14
39	35	33.751	337.414	0.794	995.19	2.587	1.47	8.849	14
40	35	27.362	368.676	0.813	739.508	4.4	1.029	7.546	14
41	35	32.957	335.16	0.559	784.784	5.743	0.274	2.94	14
42	35	34.133	147.98	0.48	491.96	3.322	0.127	2.332	14
43	45	28.018	470.596	0.833	1240.435	2.871	1.94	4.537	14
44	45	33.751	337.414	0.794	995.19	2.587	1.47	8.849	14

Appendix XV

Values of output variables obtained from experiments (Y1, Y2 and Y3) and best fit models (Yp1, Yp2 and Yp3) for validation of the best fit models of cotton fabric

Sr. No	Experimental seam efficiency (Y1) (%)	Predicted seam efficiency (Yp1) (%)	Experimental Seam puckering (Y2) (%)	Predicted seam puckering (Yp2) (%)	Seam boldness (Y3) (grade)	Predicted seam boldness (Yp3) (grade)
1	31.652	40.268	3.371	3.146	1	0.946
2	24.086	27.607	3.728	3.479	1	1.043
3	18.752	17.513	4.179	3.900	1.255	1.152
4	35.857	43.002	0.000	0.000	1.55	1.247
5	18.461	16.885	2.184	2.038	2.22	2.170
6	33.221	38.504	7.413	6.919	1.5	1.974
7	45.555	36.828	8.925	8.330	2.225	1.974
8	17.589	16.846	16.884	15.758	2.24	2.018
9	20.847	23.834	11.561	10.790	2	2.084
10	22.433	25.010	15.824	14.769	1.855	1.992
11	21.793	26.342	21.819	20.364	2.5	2.318
12	42.224	38.308	10.910	10.182	2.555	2.340
13	28.092	30.449	13.871	12.946	2.605	2.301
14	36.890	38.622	12.359	11.535	3.1	2.449
15	43.744	39.621	17.021	15.886	3.255	2.939
16	39.753	41.924	27.888	26.029	3.9	3.436
17	50.063	39.572	23.877	22.285	3.35	3.338
18	48.425	38.769	10.763	10.045	5.525	4.313
19	47.553	40.954	51.335	47.912	5.855	4.160
20	49.629	36.770	40.257	37.573	4.25	4.072
21	20.964	21.217	0.819	0.764	1	0.754
22	35.724	37.299	2.709	2.528	1.355	0.558
23	48.058	38.063	3.171	2.960	1.55	0.557
24	23.350	23.010	4.536	4.234	2.55	0.668

25	22.168	20.619	2.489	2.323	1.955	0.513
26	49.657	40.592	10.616	9.908	2.425	1.554
27	26.714	27.675	2.510	2.342	2.55	2.082
28	42.530	39.004	9.333	8.711	2.54	1.933
29	47.334	37.152	25.494	23.794	2.2	1.791
30	45.956	38.867	5.450	5.086	2.5	2.541
31	48.342	42.493	24.140	22.530	2.45	2.455
32	47.159	41.738	19.383	18.091	3.5	2.300
33	19.403	18.924	0.347	0.323	1.75	0.508
34	58.884	41.591	4.221	3.940	1.2	0.281
35	20.367	20.198	1.071	1.000	1.5	1.643
36	58.419	42.914	12.779	11.927	1.85	1.290
37	24.571	31.781	1.985	1.852	2.12	1.944
38	38.435	31.566	5.250	4.900	2.2	1.918
39	37.540	39.416	4.095	3.822	2.2	1.805
40	49.927	42.934	5.019	4.684	2.5	1.775
41	44.649	39.210	6.279	5.860	1.9	1.756
42	49.055	42.258	27.689	25.843	2.555	1.622
43	45.289	34.878	7.004	6.537	2	2.409
44	44.395	46.589	4.914	4.586	2	2.295

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