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Evaluation of the Seam Quality in Garments

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Abstract
In the production of garments, seams are considered as fundamental requirement. The quality of garment is normally considered to be strongly affected by seam performance. Durability and smoothness of the seams are considered important in garment. Based on the kind of fabric and garment, the choice of stitch and seam types and stitch and seam parameters should be done. The types of stitch and seam, their parameters, seam defects and damages determine the appearance and performance of seams. Seam performance of a garment also depends on structural and mechanical properties of the fabric and strength, extensibility, security, durability, appearance and efficiency of the seams. In this study, the importance of the seam performance of garments is investigated. In this context, stitch and seam types used in garments are explained. However, the stitch and seam parameters, sewing needle penetration force, needle damage index, seam defects and damages that are effective at seam performance have been explained and their
relations with each other are compared.

Key words: *Garment, Quality, Seam, Stitch, Performance, Mechanical properties.*

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I. INTRODUCTION

During the past few years the clothing sector has laid major emphasis on quality, comfort and fit of the garment. The properties such as durability, serviceability, performance, conformance and aesthetic are highly desired of a garment. With regard to customer requirements, the crucial aspects to be considered are design and aesthetic appearance. Pattern, colour and fabric structure affect the design and aesthetic appearance of a garment. Comfort is one of the most important parameters of clothing. Thermophysiological aspects, sensorial or tactile aspect, physiological aspect and fitting comfort are four basic elements for clothing comfort [1]. Fitting is a crucial factor of wearing comfort [2, 3]. The fitting comfort of the garment in use mainly depends on the elasticity of the seam. Stitch type, seam type, sewing thread type and stitch density affect the fitting comfort of the garment. Some of the manufacturers select stitch classes, stitch densities and sewing threads without consideration to their influence on the fitting comfort of the garment. It is therefore very important to select appropriate seam and stitch types in terms of fitting comfort [4]. Consumers want that the apparel must be fit to their bodies. Size of the garment does not be large or small to their bodies. Fitness is directly related to the pattern design, sizing, fabric structure and seams used to contour curves of the body. There are different fit-types for garment items that range from the slim and form-fitting to oversized [5].

Seam and stitch types are one of the most important elements in joining the patterns and giving a form to the garment. Seam and stitch types directly affect the quality, comfort and fitness of the garment. Choosing a stitch or seam type that is not suitable for garment reduces the quality, comfort and fitness of the garment. Appearance and performance of the seams are dependent upon the stitch and seam types, stitch densities, sewing machine settings and quality of sewing threads. Seam performance of a garment depends on fabric structural and mechanical properties and strength, extensibility, security, durability, appearance and efficiency of the seams. In this study, it is planned to explain the importance of the seam performance of garments. In this context, stitch and seam types used in garments are explained. But, the important factors such as seam strength, extensibility, seam slippage, sewing needle penetration force, seam appearance and seam efficiency have been analyzed.

II. KINDS OF SEAMS AND STITCHES

Regarding garment sewing the choice of appropriate kinds of stitch and seam needs consideration. Stitch and seam types which are not selected properly affect the sewing performance negatively. The tensile characteristics of seamed fabric changes with the change of fabric bias angle of stitching and stitch densities. Some of the seams on a garment are not subjected to high levels of stress or extension in use, like the shoulder seams on a jacket. In contrast, some seams, such as arm joint seams and seams at the crotch area of the trousers are subjected to high levels of stretching in wear [6]. Therefore, high strength seams are preferred in these areas.

2.1 Categories of stitches

Stitch is defined as a loop of thread or yarn resulting from the single pass or movement of the needle in sewing. Stitch types are shown as a numerical designation relating to the essential characteristics of the interlacing of sewing thread in a stitch. Standards are very important in determining stitch types. Six stitch types are specified in the ASTM D 6193-16 'Standard Practices for Stitches and Seams' standard [7]. Stitch types are shown in **Table 1**.

Figures of six stitch types are shown in **Figure 1**. Stitch type 101 is formed with one needle thread which passes through the material and interlooped with itself on the undersurface of the material. Stitch type 100 has five different subgroups.

Stitch type 201 is formed with two needle threads which passed through the material in the same perforations from opposite directions without interlacing or interlooping. Stitch type 200 has five different subgroups.

Stitch class	Stitch type	Subgroup numbers of seam types	Subgroups of stitch types
100	Chain stitch with one needle thread	5	101–105
200	Hand stitch	5	201–205
300	Lockstitch	16	301–316
400	Multi Thread chain stitch	11	401–411
500	Overlock stitch	22	501–522
600	Covering chain stitch	10	601–610

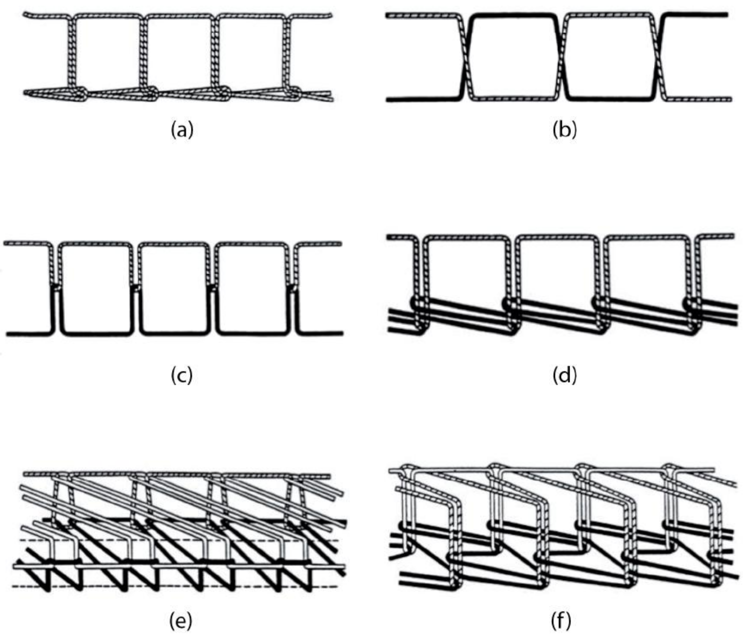

Figure 1.
Stitch types [7]: (a) stitch type 101; (b) stitch type 201; (c) stitch type 301; (d) stitch type 401; (e) stitch type 504; and (f) stitch type 601.

Stitch type 301 is formed with two threads, one needle thread and one bobbin thread. Loops of needle thread are passed through the material and interlaced with the bobbin thread. Needle thread is pulled back so that the interlacing was midway between surfaces of the materials being sewn. Stitch type 300 has 16 different subgroups. Stitch type 401 is formed with two threads; one needle thread and one looper thread. Loops of needle thread are passed through the material and interlaced and interlooped with loops of bobbin thread. Interlooping was drawn against the underside of the bottom ply of the material. Stitch type 400 has 11 different subgroups.

Stitch type 504 is formed with three threads; one needle thread, one looper thread and one cover thread. Stitch type 500 has 22 different subgroups.

Stitch type 601 is formed three threads; two needle threads and one looper thread. Loops of the needle threads are passed through the material where they are looped with looper thread on the underside. Stitch type 600 has 10 different subgroups [7].

2.2 Categories of seams

The seam is defined as a juncture at which two or more planar structures, such as textile fabrics, are joined by sewing, usually near the edge. Seam types are shown as an alphanumeric designation relating to the essential characteristics of fabric positioning and rows of stitching in a seam. Standards are very important in determining seam types. Six seam types are specified in the ASTM D 6193-16 'Standard Practices for Stitches and Seams' standard [7]. Seam types are shown in **Table 2**.

Figures of six seam types are shown in **Figure 2**. Seam type SSa-2 is formed by superimposing two or more plies of material and seaming them with one or more rows of 301 or 401 stitches a specified distance from their edges. Seam type SS (superimposed seam) has 55 different subgroups.

Seam class	Seam type	Subgroup numbers of seam types
SS	Superimposed seam	55
LS	Lapped seam	101
BS	Bound seam	18
FS	Flat seam	6
OS	Ornamental seam	8
EF	Edge finishing seam	32

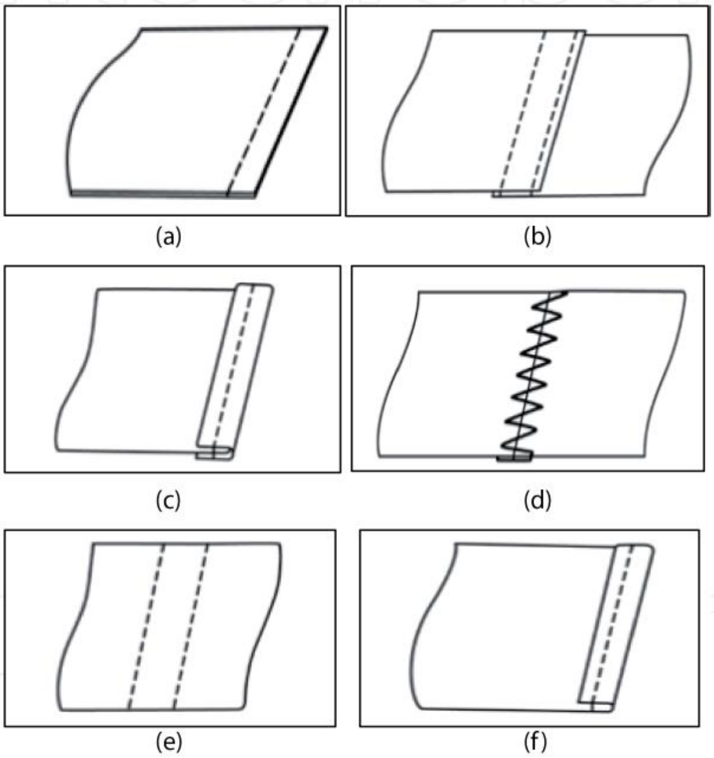

Figure 2.

Seam types [7]: (a) SSa-1; (b) LSa-1; (c) BSa-1; (d) FSc-1; (e) OSa-2; and (f)-EFa-1.

Seam type LSa-1 is formed by overlapping two or more plies of material a specified distance and seaming with one or more rows of stitches. Seam type LS (lapped seam) has 101 different subgroups.

Seam type BSa-1 is formed by folding a binding strip over the edge of the ply or plies of body material and seaming the binding strip and body material with one or more rows of stitches. Seam type BS (bound seam) has 18 different subgroups. Seam type FSc-1 is formed by turning and abutting the turned edges of two plies of material and seaming with a row of stitches extending across and covering the turned edges of the material. Seam type FS (flat seam) has six different subgroups.

Seam type OSa-2 is produced with one or more straight rows of stitches. Seam type OS (ornamental seam) has eight different subgroups. Seam type EFa-1 is produced by turning the edge of the material and stitching the turned portion to the body of the material with one or more rows of stitches. EF (edge finishing seam) seam type has 32 different subgroups [7].

Eight seam types are specified in ISO 4916:1991 'Textiles-Seam Types- Classification and Terminology' standard, which are as follows: Class 1— Superimposed seam, Class 2—Lapped seam, Class 3—Bound seams, Class 4—Flat seams, Class 5—Decorative/Ornamental stitching, Class 6—Edge finishing/neatening, Class 7—Attaching of separate items, Class 8—Single ply construction, Class 7—Attaching of separate items and Class 8—Single ply construction [8].

III. STITCH AND SEAM PARAMETERS

3.1 Stitch density (SPI)

Stitch density is the number of stitches per unit length (stitch per inch-SPI) in one row of stitching in the seam. A higher SPI indicates greater stitch density and often higher quality stitching. In general, the more thread consumed in a stitch, the stronger the seam. Stitches in the 6–8 per inch range convey a more primitive quilting style, suitable for heavy thread or utility quilts. Stitch 10–12 per inch is considered normal for most quilting styles and yields the best stitch quality as well. Longer stitch lengths create needle flex and increase tension changes. The average stitch length is 2.5 mm. This is the typical setting on the sewing machines. The equivalent of 2.5 mm is about 10–12 stitches per inch.

3.2 Stitch width

Stitch width is the distance between the lines of the outer most parts of the stitches. The stitch width determines how far the stitch will go from side to side. A straight stitch like lockstitch has length but not width. The standard range for a lockstitch is stitch length 2.5 mm and stitch width 0. A zig-zag stitch or overlock stitch has length and width. The middle range of the stitch length for a zig-zag stitch is 2.5 mm and stitch width is 3 or 4 mm. Decorative stitches also have both length and width.

3.3 Seam allowance

Seam allowance is the area between the edge and the stitching line on two or more pieces of material being stitched together. Seam allowances can range from 1/4 inch (6.4 mm) wide to as much as several inches. Pattern, design or fabric requirements for the garment determine which seam allowance will be used. A 5/8 inch (1.5 cm) seam allowance is generally considered a standard. For curved areas, such as necklines or armholes, the seam allowance may be only inch. But in areas that need extra fabric for the final fitting for the wearer seam allowances can be 1 inch or more.

3.4 Stitch length

The range of the stitch length is between 0 and 5 mm on most sewing machines. The average stitch length is 2.5 mm. The equivalent of 2.5 mm is about 10–12 stitches per inch. When stitch length increased, stitch density decreased. Sewing machines indicate stitch length in millimetres. 2.5 mm stitch length means each stitch will be 2.5 mm long.

The short stitch length will be packed into each inch of stitching, creating a tighter seam. The long stitch length, the fewer each inch, therefore the looser the seam. Stitches with long stitch lengths are holding the fabric together with less tension. These stitches are also better on thicker fabrics or when sewing through multiple layers.

3.5 Seam thickness

Seam thickness is used as a measure of seam pucker [9]. Seam thickness decreased as thread tensions and linear stitch density increased.

Eq. (1) was used to calculate the seam thickness [9, 10].

$\Sigma\, t = 100\,(ts–2tf)\,/\,2tf$ (1)

where ts is the seam thickness and 2tf is the fabric thickness.

3.6 Seam extensibility

In recent years, the elasticity of the seam has become more important with the use of stretched fabrics in the garment. Extensibility of the seamed fabric was defined as the difference in stitch length between the original stitch length S and the extended stitch length Slim.

Eq. (2) was used to calculate the seam extensibility [11].

Seam extensibility = (S lim –S) / S (2)

where S is the original stitch length and Slim is the extended stitch length.

The elasticity of a sewn seam should be slightly greater than that of the material which it joins. This will enable the material to support its share of the forces encountered for the intended end use of the sewn item. The elasticity of a sewn seam depends on fabric type and strength, stitch and seam type, stitch density (SPI) and sewing thread elasticity [7].

Increasing the stitch density helps to increase stitch extensibility. An improvement in the stretch performance of a seam can be achieved by a balanced stitch.

3.7 Seam strength

Different types of garments have different seam strength requirements. Many factors affect the level of seam strength. These are fabric structure and properties, stress location of a garment, sewing thread type and construction, sewing machine tension, sewing needle type, stitch and seam types and stitch density [12]. It was observed that in woven and knitted fabrics, the seam strength increased when the number of stitches/cm and sewing thread size increased [13]. Seam strength can be measured according to ASTM D 1683-81 'Standard Test Method for Failure in Sewn Seams of Woven Apparel Fabrics'. This test method measures the sewn seams strength in woven fabrics by applying a force perpendicular to the sewn seams [14]. Seam strength depends on the thread strength and stitch density. Seam performance of the garment depends on the fabric cover factor, fabric weight, thickness, tensile strength, fabric shrinkage along the fabric length and width, resiliency, bending rigidity, flexural rigidity and shear rigidity [15]. Seam strength affects the functional and aesthetic performance of a garment and is important to its durability. Different seam angles affect seam strength too.

3.8 Seam efficiency

Seam efficiency is defined as the capacity of the material itself to carry a seam. Seam efficiency is the ratio of seam strength to fabric strength. Eq. (3) was used to calculate the seam efficiency [10, 16].

Seam efficiency = 100 . (Seamed fabric strength / Unseamed fabric strength) (3)

The durability of the seam can be measured in terms of seam efficiency. Stitch efficiency can be optimized through various factors, such as fabric structure, seam type, type and density of stitches and the selection of sewing threads and needles.

Seam efficiencies of 60–80% are common but efficiencies between 80 and 90% are more difficult obtaining from garment seams. Low seam efficiency values indicate that the sewn fabric is damaged during sewing.

IV. FACTORS AFFECTING SEAM PERFORMANCE

Seams are basic requirements in the garments. The characteristics of a properly constructed seam are its strength, elasticity, durability, stability and appearance, which depend on the seam type, stitches per unit length, the thread tension and the seam efficiency of the fabric [17]. Experience has shown that if the seam efficiency ratio falls below 80%, the fabric has been excessively damaged by the sewing operation [18]. Needle penetration force is one of the most important factors affecting the seam performance of a sewn garment. Sewing needle-related damage due to sewing in fabrics is another important factor affecting seam performance.

4.1 Sewing needle penetration force

The quantitative value of the needle penetration force is important in the manner of determining sewing damages that can appear in the sewing process on the fabric and is an important influence on the quality of the garment [19]. A high sewing needle penetration force means that the fabric has a high resistance and so there is a high risk of damage. Sewing needle penetration force and fabric deformation during sewing are effective factors for seam performance. L&M Sewability tester is used for measurement sewing needle penetration force. The L&M Sewability tester enabled consecutive readings of force for penetration of fabric by a selected needle without sewing thread at a rate of 100 rpm. The fabric specimens were 30–40 mm wide and 350 mm length and a minimum of 100 perforations must be carried out [17]. If the penetration force did not exceed set level 75 cN, then the sewability value was zero, and sewability was considered to be very good. When sewability values ranged between 0 and 10%, the fabric sewability was considered good; between 10 and 20%, even though no great difficulties arose during sewing, the sewability was considered fair [20]. Lots of studies were done about needle penetration force. A study observed that needle penetration force values in both the warp and weft direction of the plain woven fabrics were higher than twill woven fabrics because of the plain dense structure. Sewing needle penetration force was affected by the weave type, yarn type and fabric density. While the fabric density increased, the needle penetration forces increased [17].

4.2 Sewing needle-related damage due to sewing in fabric

The sewing machine needles caused damages when a sewn seam assembly is used for a woven fabric. Sewing needle-related damage affected the seam performance by decreasing the seam strength. Needle-related damage due to sewing in woven fabrics can be measured according to ASTM D 1908-89 'The Needle-Related Damage due to Sewing in Woven Fabric' standard. Eq. (4) was used to calculate the needle damage index [19].

$ND\ \% = 100\ (N_y / P_n)$ (4)

where ND is the needle damage index due to fusing, severance or deflection (%), Ny is the number of yarns damaged in the direction evaluated and Pn is the number of needle penetrations.

This test method provides for determining a ratio of either the damaged yarns to the total number of yarns present in a seam assembly or the damaged yarns to the total number of needle penetrations. There are lots of parameters that have an influence on the needle-related damage due to sewing in a fabric. These are fabric construction (yarn construction, structure, tightness, etc.), chemical treatments of the fabric (softness, dyes, finishing, washing), sewing needle number, design and sewing machine settings [12].

4.3 Seam defects and damages

4.3.1 Seam defects

Seam defects affect seam performance. Broken, skipped or missing stitches and seam pucker occur during the sewing process. Seam slippage and seam grinning are the other defects that occur during wearing the clothes. These defects are usually attributed to either a fault with the sewing machine, improper material or a worker error.

4.3.1.1 Seam slippage

Seam slippage is defined as that which occurs when the yarns in the fabric pull out of the seam at the edge or, alternatively, where the threads of a fabric begin to pull away from the stitching in a seam [12]. Resistance to slippage of yarns in woven fabrics can be measured according to ASTM D 434-75 'Resistance to Slippage of Yarns in Woven Fabrics Using a Standard Seam' standard [6]. This method covers the determination of the resistance to slippage of weft yarns over warp yarns, or warp yarns over weft yarns, using a standard seam. Fibre, yarn and fabric composition, structure and properties and their processing parameters, finishing, laundering and seam allowance are affected seam slippage. Seam slippage can also occur because of the stress location of a garment, thread type and properties, sewing needle, stitch type, stitch density, seam type and sewing machine condition. Flexibility of the fabric is affected seam slippage too [12, 21].

4.3.1.2 Seam grinning

The seam grinning is defined as that when two pieces of fabric are pulled at right angles to the seam, a gap is revealed between the two pieces of the fabric revealing the thread in the gap. When a seam is loaded perpendicular to the direction of stitch line it tends to grin. It was observed that seam grinning on the sewn fabric increased with decreased stitch density and increased thread extensibility. The seam grinning also increased as the fabric becomes rigid against deformation [22].

4.3.1.3 Seam pucker

Seam pucker is a wrinkled appearance along the seam, which influences the appearance of the garment. Seam pucker is usually caused by improper selection of seam parameters and fabric properties in the garment production. In subjective evaluation method, experts or experienced judges grade the fabric seam appearance according to certain standards. According to AATCC 88B 'Smoothness of Seams in Fabrics after Repeated Home Laundering' standard, seam appearance is classified into five grades: grade 1 refers to the worst fabric which is heavily puckered and grade 5 refers to smooth fabric with little pucker or no pucker at all. **Figure 3** illustrates the photographs of reference seam specimens from AATCC 88B [23]. The sample fabrics are sewn as per standard procedures, and the appearance of the seam is compared with standard reference specimens. The grade of fabric is the grade of the reference specimen which matches most nearly to sample fabric specimen [24].

Puckering is usually caused by one or more of the following conditions:

- yarn displacement (structural compression of fabric yarns),
- tension puckering (excessive sewing thread extension and recovery),
- feeding pucker (irregular feeding of fabric ply), and

• fabric and sewing thread shrinkage.

In recent years, many techniques have been developed by researchers to measure seam pucker. Subjective and objective techniques are the most common techniques to measure seam pucker. Eq. (5) was used to calculate the seam pucker percentage [24].

$$SP\,\% = (L2 - L1) / L1 \,.\, 100 \quad (5)$$

where SP% is the seam pucker percentage, L1 is the length of sewn fabric and L2 is the length of unravelled fabric.

According to Eq. (5), the difference between original length and puckered length gives a percentage for seam pucker.

Researchers used photometric instruments, computer vision, shadows by parallel light, laser triangulation, fractal geometry, artificial neural network and neuro fuzzy logic methods to measure seam pucker [24].

4.3.2 Seam damages

Seam damages affect seam performance by reducing seam strength. The sewing damages can be occurred by high needle temperature, high pressure on pressure foot, unbalanced tension in sewing threads, irregular feeding system under the feed dog and sewing speed variation. Selection proper needle size and needle shape, thread lubrication ratio and sewing machine setting parameters can reduce seam damages during the process of sewing. Seam damages occur with thermal and mechanical damages. Seam damages are caused when fabric restricts the penetration of the sewing needle. This not only depends upon the spaces in the fabric, but also on needle profile, needle size, sewing machine setting and sewing thread [21, 25]. Fabric structure has an important effect on seam damages too [26].

4.3.2.1 Thermal damages

During the stitching, heat is dissipated from the needle. High needle heat causes thermal damages on the fabric. The heat held by the needle is concentrated in a small mass of metal, and the temperature can reach 300–350°C. Heat is transferred through the needle-bar to other sewing machine parts, to fabric around the needle, and to the sewing thread in the needle. Thermoplastic sewing threads, such as nylon and polyester, may be heated by the needle, melt and break. Nylon and polyester threads melt at 240–260°C. Cotton and silk are not thermoplastic, but degrade at around 400°C. Sewing thread breaks during sewing process disrupts the continuity of sewing process [27].

Sewing speed has the greatest influence on the needle temperature. Fabric needle surface characteristics, fabric frictional characteristics, fabric density and thickness are also significant on the needle temperature. These parameters determine whether the needle temperature will be increased or lowered [10]. Increasing the number of the fabric plies leads to an increase in the needle temperature. An approximately linear relationship between the temperature and thickness has also been observed. When sewing one ply of cotton fabric, the needle temperature was measured as 100°C, while the same fabric was measured at 245°C when sewing four plies [28].

4.3.2.2 Mechanical damages

Mechanical damages affect the aesthetics and performance of the garment. During the stitching, fabric may be damaged by a sewing needle mechanically. In the case of mechanical damage, the yarns of the fabric are broken or fragmented. Such damages may be apparent immediately after stitching but frequently will not appear until after the product has been used, that is, when seams have been subjected to some form of tension, stress, strain, deformation or after successive cleaning.

Machine variables such as needle size, needle point design; material variables such as fabric structural properties, fabric finishing process causes mechanical damage [10]. It is critical to choose the correct sewing needle size for the correct sewing machine, sewing thread and fabric weight. Selection of correct sewing needle size is critical to the success of a quality sewn seam. The sewing thread selected for the garment should move freely through the eye of the selected sewing needle to ensure smooth passage during sewing. Appropriate sewing needle size according to the sewing thread ticket number and fabric weight should be selected to prevent mechanical seam damages. Finer needle size, bulged-eye needles and lower sewing speed can reduce mechanical sewing damage [29-31].

V. CONCLUSION

Seams are basic requirements in the manufacturing of garments. In general, seam performance has a great influence on garment products. Seam and stitch types affect the quality and appearance of garments. Appearance and performance of the seams are dependent upon the stitch and seam types, stitch and seam parameters like stitch density, stitch width, seam allowance, stitch length, seam thickness, seam extensibility, seam strength, seam efficiency, sewing needle penetration force, sewing needle-related damage due to sewing and seam defects and damages. Seam performance of a garment also depends on structural and mechanical properties of the fabric and strength, extensibility, security, durability, appearance and efficiency of the seams. Seam strength and seam efficiency should be tested to determine the effect of sewing parameters on sewing performance. Seam defects and damages affect seam performance by making negative effects on sewing. Needle penetration force is one of the most important factors affecting the seam efficiency of a sewn garment. A high sewing needle penetration force means that the fabric has a high resistance and so there is a high risk of damage. Sewing needle-related damage due to sewing in fabrics is another important factor affecting seam efficiency. Seams of the garment must be durable and smooth. Stitch and seam types and stitch and seam parameters should be selected according to the garment and fabric type. Stitches and seam types are very important for garment quality. Stitches are used to join the patterns of the garment, and seams give the shape and detail of the garment.

Standards are very important in determining stitch types. Six stitch types are specified in the ASTM D 6193-97 'Standard Practices for Stitches' standard. Six seam types are specified in the ASTM D 6193-97 'Standard Practices for Stitches' standard and eight seam types are specified in ISO 4916:1991 'Textiles-Seam Types- Classification and Terminology' standard.

Seam efficiency is defined as the capacity of the material itself to carry a seam. Seam efficiencies of 60–80% are common, but efficiencies between 80 and 90% are more difficult obtaining from garment seams. Low seam efficiency values indicate that the sewn fabric is damaged during sewing.

Seam slippage, seam grinning and seam pucker is important seam defects, which influences the appearance of the garment. Seam defects are usually caused by improper selection of seam parameters and fabric properties in the garment production. Seam damages affect seam performance by reducing seam strength. Thermal and mechanical damages affect the aesthetics and performance of the garment. Appropriate sewing needle size according to the sewing thread ticket number and fabric weight should be selected to prevent mechanical seam damages. Stitch and seam types and seam parameters must be selected correctly in order to obtain a quality seam.

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