Identification of Seam Performance of Natural Wool Textile Fabrics

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Abstract:
Wool is a natural animal fibers spun from the fleece of sheep. To sew a wool fabric garment, play the seam performance the first role in judgment the quality of the garment, since the wool fabrics had special Characteristics. The purpose of this study is to identify the seam quality throughout determining the seam strength, seam elongation, seam efficiency and seam stiffness. For the design of experiments, three wool textile fabrics (light, medium and heavy) are chosen and sewn with different sewing factors. Three seam types (SSa-1, LSq and SSw), they differ in the number of fabric layers in the seam area. Three stitch length (1.5 mm, 3 mm and 4.5 mm) and three level of stitch rows (1 row, 2 rows and 3 rows). Results indicated that for all investigated materials and sewing factors recorded the lapped seam type SSw the highest values of the seam strength, seam elongation, seam performance and seam stiffness, followed by the lapped seam type LSq and the superimposed seam SSa-1). The stitch density, in the form of the stitch length, had a significant positive effect on the four studied seam properties (strength, elongation, efficiency and stiffness). In addition showed the number of stitch rows also a hug effect in changing the seam performance of the wool textiles fabrics.

Keywords:
Natural wool fabrics,
Seam efficiency,
Seam elongation,
Sewing factors,
Seam stiffness,
Seam strength.

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1- Introduction

Fibers are incredibly important to textile production but the first thing we need to know is this: not all fibers are suitable for textiles. Textile fibers are those, which have properties that allow them to be spun into yarn or directly made into fabric. This means they need to be strong enough to hold their shape, flexible enough to be shaped into a fabric or yarn, elastic enough to stretch and durable enough to last. Textile fibers also have to be a minimum of 5 millimeters in length. Shorter fibers can not be spun together.

Textile fibers can have many origins and this is generally the criteria used to classify them. Thus, fibers can be categorized as the following:

Natural, if produced by nature in a way which makes them suitable to be used in a textile process. Natural fibers include those produced by plants, animals, and geological processes. They are biodegradable over time. They can be classified according to their origin.

Man-made, if produced by industrial processes, whether from natural polymers transformed upon the action of chemical reagents (regenerated fibers), or through polymers obtained by chemical synthesis (synthetic fibers). Synthetic or man-made fibers generally come from synthetic materials such as petrochemicals. But some types of synthetic fibers are manufactured from natural cellulose; including rayon, modal, and the more recently developed Lyocell. Figure 1 presented the classification of textile fibers [1].

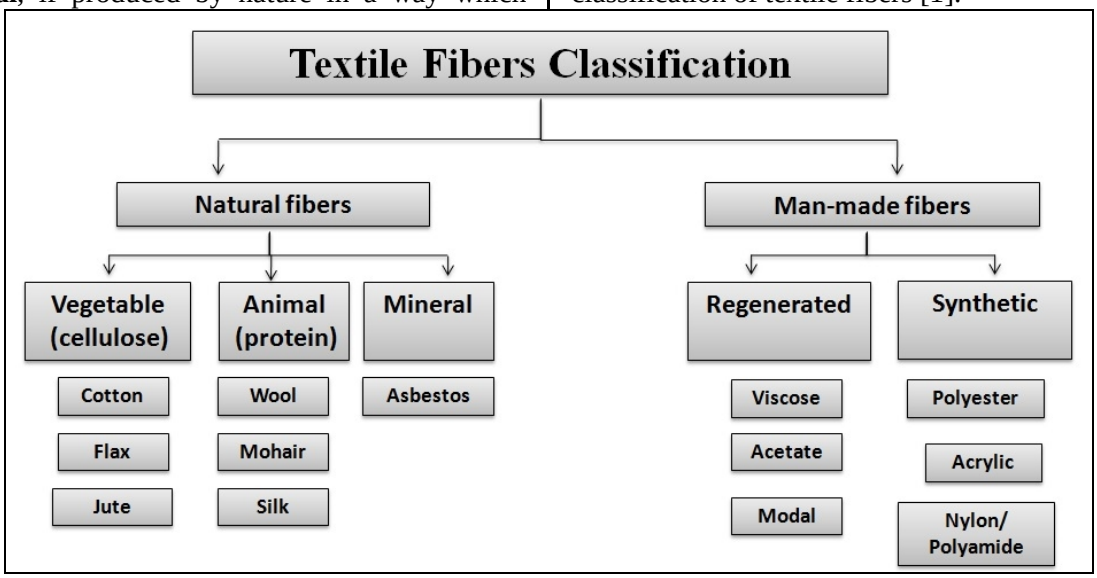

Figure 1: Classification of textile fibers [1]

Natural wool fabrics:

Animals serve as another common source of textile fibers. Most animals that produce textile fibers are mammals. Mammal hair is an abundantly used textile fiber, but not all fibers produce the same quality yarn or fabrics. Most textile fibers are from animals that produce wool, a thick and crimped fur that easily spools, retains heat, and can be quite soft. Wool is a specific kind of mammal hair.

Wool is a natural fiber with naturally great characteristics that make it a top choice for wardrobe classics, year in and year out. Its inherent qualities are unequaled in the world of textiles–qualities that make it one of the most versatile fibers when it comes to fabric production [2].

Wool yarns are used to create a wide variety of wool fabrics, from flannel shirting, soft knits, and fuzzy melton cloth to smooth-surfaced worsted suitings and classic gabardines. The type of wool yarn used– woolen or worsted–often distinguishes the fabric's ultimate appearance, performance and care. The broad assortment of wool fabrics provided by woolen and worsted technologies make it possible to select wool garments that span the seasons and life's many activities in comfort.

Woolen fabrics are made from yarns spun from wool fibers that vary in length from 1" to 3". After carding the raw wool– untangling and combing it to line up the short, fuzzy fibers–it is spun into yarns with low or medium twist. The resulting yarns and the fabrics woven from them have a soft, textured hand. They may also look and feel fuzzy and warm. Easy-to-tailor woolens are available in a range of fabrics from soft knits to flannels, tweeds, and coating fabrics.

Worsted wool fabrics are made from finer wool fibers. Additional combing and a tighter yarn twist ensure a smooth, relatively fuzz-free yarn. The resulting worsted yarns are woven into wool fabrics that are crisp and smooth surfaced and generally lighter in weight than woolens. That makes them perfect for spring and summer wear in particular. Examples include gabardine, lightweight wool suiting, and wool challis. Long-wearing, worsted wool fabrics hold a crease well and retain shape [3].

Wool Characteristics

- Wicks moisture away from the body and evaporates it into the air.
- Water-resistant and repels light rain or snow.
- Insulates and keeps body heat in.
- Durable, resilient and resists abrasion and tearing, making it wear well and retain its shape. Adding a lining also helps retain shape.
- Resists wrinkling. Wrinkles more and is weaker when wet. Wrinkles are been easily removed with steam. High-quality wools are less likely to feel scratchy when worn.
- Dyes easily and resists fading, but may fade in direct sunlight.
- Resists stains and cleans well. Because it shrinks and felts when exposed to heat and agitation, dry-cleaning is best unless the fabric is labeled "washable wool."
- Shapes easily with steam, making it easy to ease seams without puckering and shape curved areas.
- Can be damaged by hot iron, alkali-based stains and moths [3, 4].

Seam quality:

A seam is the application of a series of stitches or stitch types to one or several thickness of material .Seam line is a stitch line of a seam; it is usually parallel to and always appearance of the seams affects overall attractiveness of a garment. Straight, neat, smooth, even seams that are not twisted, ropey or rippled contribute to aesthetics.

The characteristics of a properly constructed seam, depends on the fabric and must take into account the following factors:

- Strength
- Extensibility (including elasticity)
- Security
- Durability
- Appearance [5]

Strength: A seam must be strong, the criteria being maximum strength for minimum thickness and economy of sewing thread. Strength is known as one of the tensile properties of textile materials. The stitches used to make seams help determine the functional and aesthetic performance of the garment. Strong stitches directly affect the durability of seam strength. The strength of the seam can be found within the seam type and seam width. The location and type of seam must be suitable for the overall construction of the garment. The quality of sewn products can be determined by the tensile testing machine [4].

Extensibility: This property is required in all seams, but varies according to the fabric being sewn. If a garment is being made of a material with a rigid characteristic, the seams will require little stretch, therefore a lockstitch 301, would be suitable in most cases.

Durability: A seam must be durable and last the life expectancy of the garment, this must include the laundering technique in order to confirm to the trade description act. The following factors must be considered in order to ensure the seam will perform satisfactorily during wear; Thread type,

Stitch type, Seam type, Fabric type and Fiber content.

Security: Security is closely connected to durability, with the addition of ensuring that the stitching within the seam is fixed securely at the beginning and end of each row of sewing. A lockstitch seam can be easily back-Tacked, whereas the ends of a chain or over lock seam needs to be trapped into another seam or bar-tacked to ensure that the seam will not-unravel.

Appearance: Often the appearance of the seam is overlooked, but sometimes the optimum strength of a seam needs to be re-assessed as the look of the garment may be impaired by the use of a bulky unsightly looking seam. Another factor to consider when assessing the appearance of the seam is that the machinery has been set up correctly, a puckered seam will instantly spoil the hanger appeal of what could have been an attractive garment [5].

Seam Efficiency: Measurement of the seam quality was done by studying the seam efficiency beside the seam strength, seam extensibility, seam puckering and seam stiffness. Seam efficiency is calculated using the following formula [6]:

$$S_E\ (\%) = \frac{S_S}{F_S} \times 100 \qquad \text{(Equation 1)}$$

Where:

E_S = Seam efficiency

S_S = Seam tensile strength

F_S = Fabric tensile strength

Research Problem

Previously, many researches had been done on identifying the parameters that influencing seam performance quality by looking into correlation between fabric properties and sewing parameters. ABDUL GHANI studied the seam performance analysis and modeling [7]. Five different categories of weight per unit area fabrics are used for this investigation. Fabrics were a collection of various fiber types (silk, polyester, cotton, rayon and poly/cotton), Fabrics were sewn with different sewing parameters and then the fabric properties was tested using (KES-F) and FAST system. SEIF studied the sewability of cotton weft knitted fabrics [8]. The relation of physical and mechanical properties of weft knitted fabrics (Weight per unit area, thickness, bending stiffness, drapeability) to the sewability properties (seam strength, seam extensibility, seam pucker and seam appearance) was determined. Some researches interested in the seam quality and the sewing properties [9]. Other researchers concerns with the seam slippage of different fabrics and tried to find solutions for this problem [10], [11]. It can be seen that, the main interest in most of the researches deals with the cotton or polyester fabrics. In opposite side there are a few studies concentrated in different aspects of seam performance properties of wool textile fabrics.

Purpose of the study:

The present paper aimed to identify the seam performance of natural wool textile fabrics through determining the effects of some sewing parameters, such as the seam types, stitch length and numbers of stitch rows, on the seam strength, seam elongation, seam efficiency and seam stiffness.

2- Materials and Methods

For the investigation there are three wool textile fabrics with different weights per unit area (light, medium and heavy), different weave structures, and thickness are used. The classifications of the tested materials are been presented in table 1.

Table 1: Classifications of wool textile fabrics for the experiments

Fabric Code	Fabric contents	Weave structure	Weight per unit area [g/m^{2}]	Thickness [mm]	Fabric density/cm	
					Warps/cm	Picks/cm
F1	100% Wool	Twill 4/1	402	0.37	37.4	18.4
F2	100% Wool	Plain 1/1	135	0.28	21	20
F3	100% Wool	Plain 1/1	90	0.31	15	13

The chosen fabrics have been cut and sewn using traditional sewing machines with different sewing parameters to determine the effect of the sewing parameters on the seam performance of the wool fabrics. Sewing was carrying out using industrial sewing machines under particular sewing conditions that are commercially adopted by apparel manufacturers in clothing factories. Sewing thread produced from spun polyester 40/2 was used for sewing all specimens.

Three seam types, which have three different levels of stitch length and three levels of the number of stitch rows, are chosen for the experimental works. Table 2 lists the variations of the sewing parameters. The information includes the seam type descriptions, stitch length levels and the variations of the stitch row numbers.

Table 2: Chosen sewing parameters for experiments

Sewing parameter	Variation	Description
Seam type	SSa-1 (2 Layers) LSq (3 Layers) SSw (4 Layers)	 (SSa-1) (LSq) (SSw)
Stitch length	3 levels	1.5 mm, 3 mm, 4.5 mm
Number of stitch rows	3 kinds	1 row, 2 rows, 3 rows

After sewing the three wool textile fabrics with chosen seam parameters, fabrics with and without seams are cut and prepared for the laboratory tests. Bending stiffness, seam strength and seam elongation are measured for all tested samples.

Seam strength and seam elongation are carried out using Instron tensile strength machine according to ASTM (D5035-95) [12].

The seam efficiency that takes into account the factors of fabric strength and seam strength according to ASTM 1683-04 standard method, which provides an accurate measure of seam efficiency and thus is widely accepted. It is calculated using equation 1.

Bending stiffness test is carried out with shirley stiffness device according to the Cantilever method and the bending stiffness is calculated according to DIN (53362) [13]. Table 3 presented the design of experiments (DOE) of the sewing factors for all labor tests.

Table 3: Design of Experiments for all labor tests

Sample code	**Seam Factors**								
	Seam type			**Stitch length [mm]**			**Number of stitch rows**		
	Ssa-1	**LSq**	**SSw**	**1.5**	**3**	**4.5**	**1**	**2**	**3**
Fabric without seam									
1	√			√			√		
2	√			√				√	
3	√			√					√
4	√				√		√		
5	√				√			√	
6	√				√				√
7	√					√	√		
8	√					√		√	
9	√					√			√
10		√		√			√		
11		√		√				√	
12		√		√					√
13		√			√		√		
14		√			√			√	
15		√			√				√
16		√				√	√		
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21			√	√					√
22			√		√		√		
23			√		√			√	
24			√		√				√
25			√			√	√		
26			√			√		√	
27			√			√			√

3- Results and Discussion

To determine the seam performance of wool textile fabrics, three 100 % wool fabrics with different weight per unit area and thickness are be chosen for the investigations. Materials were sewn with different sewing parameters, which known from literature that, they could influence the seam performance, such the seam type, stitch length and number of stitch rows. Seam performance would be evaluated through determining the seam strength, seam elongation, seam efficiency and seam stiffness. The results of the seam properties for fabric 1, fabric 2 and fabric 3 are shown in table 4 in the order. The identification of every seam property would be separately described.

Table 4: Results of seam properties of all investigated wool fabrics

Sample code	**Seam strength [Kg]**			**Seam elongation [%]**			**Seam efficiency [%]**			**Bending stiffness [mN.cm]**		
	F 1	**F 2**	**F 3**	**F 1**	**F 2**	**F 3**	**F 1**	**F 2**	**F 3**	**F 1**	**F 2**	**F 3**
Fabric without seam	74	28	17	42	25	20	-	-	-	3.67	0.734	0.606
1	46	19	5	35	25	25	62.16	67.86	29.41	121.6	7.36	2.09
2	41	20	3	30	30	25	55.41	71.43	17.65	114.2	17.56	5.50
3	55	25	7	37	40	40	74.32	89.29	41.18	104.7	25.18	8.82
4	32	21	4	28	35	40	43.24	75.00	23.53	91.53	6.72	1.90
5	30	23	3	28	40	30	40.54	82.14	17.65	93.15	8.17	4.66
6	32	25	2	25	40	30	43.24	89.29	11.76	94.8	10.86	4.76
7	15	19	3	20	30	35	20.27	67.86	17.65	41.4	5.46	2.14
8	15	19	3	20	30	30	20.27	67.86	17.65	45.93	11.18	4.23
9	21	20	6	23	30	40	28.38	71.43	35.29	50.82	19.07	6.20
10	41	18	3	35	30	25	55.41	64.29	17.65	178	17.81	6.20
11	58	22	3	40	35	25	78.38	78.57	17.65	215.8	22.60	9.16
12	40	22	3	40	30	20	54.05	78.57	17.65	306.6	35.28	10.15
13	33	18	3	35	30	20	44.59	64.29	17.65	120.7	27.06	8.71
14	34	25	3	35	35	30	45.95	89.29	17.65	136.8	34.55	10.52
15	29	22	2	30	30	20	39.19	78.57	11.76	165.1	43.04	16.56
16	25	19	2	30	35	20	33.78	67.86	11.76	58.94	29.30	10.33
17	23	26	6	30	45	30	31.08	92.86	35.29	77.91	35.53	10.52
18	46	26	2	40	45	20	62.16	92.86	11.76	68.6	37.96	13.92
19	42	16	13	40	35	60	56.76	57.14	76.47	134.4	45.20	6.77
20	58	22	13	40	35	50	78.38	78.57	76.47	238.5	66.42	17.19
21	56	21	14	50	30	40	75.68	75.00	82.35	316	71.97	24.83
22	36	20	7	35	35	30	48.65	71.43	41.18	169.3	60.00	17.72
23	49	21	14	40	35	40	66.22	75.00	82.35	282.4	72.66	20.41
24	48	23	16	40	40	60	64.86	82.14	94.12	441.6	82.13	25.18
25	16	21	11	25	35	50	21.62	75.00	64.71	186.9	47.40	15.05
26	18	21	14	30	35	50	24.32	75.00	82.35	241.7	63.52	22.15
27	37	25	15	40	40	50	50.00	89.29	88.24	421.5	68.84	23.22

Determining the seam strength

Seam strength refers to the load required to break a seam. Evaluation of the result was been recorded for each of the tests identified for stitched and unstitched specimens. Overall, All specimens with different sewing factors have lesser values of seam strength compared to the fabrics without seam.

In identifying the effect of the seam type on the seam properties, showed the seam SSw maximum seam strength of all seams. The reason for this result could be stated to its formation of four fabric layers and using more sewing thread consumption. Figure 2 presented the seam strength of fabric 1. For investigating the effect of stitch

length on the seam strength, It can be noticed that the stitch length 1.5 mm recorded the highest values of seam strength, then stitch length 3 mm, and at the end the stitch length 4.5 mm, which showed the lesser value of all. This result can be summarized to: the more the stitch density is, the higher the seam strength.

The number of stitch rows played a very clear role in changing the seam strength. Results indicated that, with more stitch rows increased the seam strength because the Load was divided over a larger area.

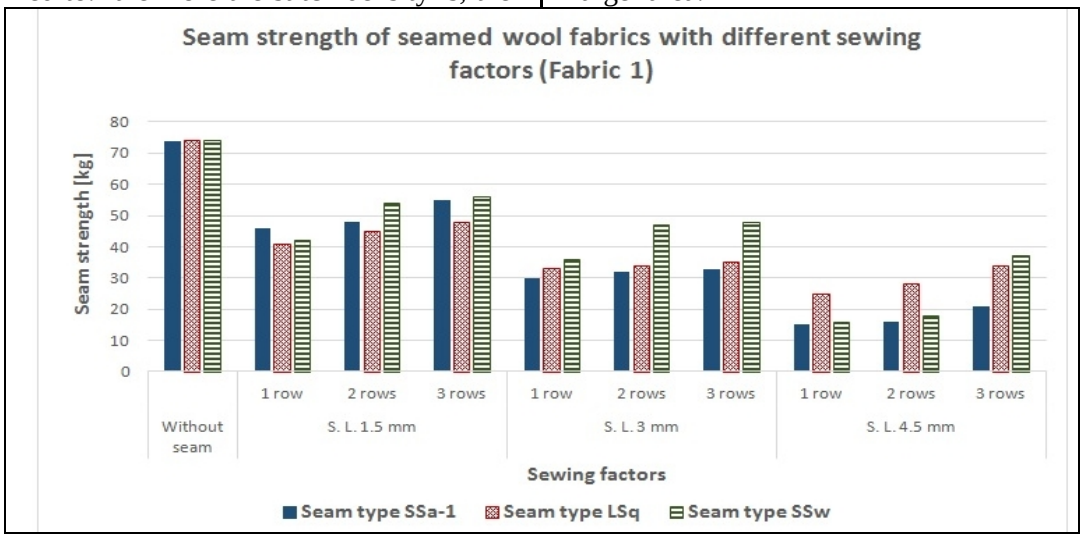

Figure 2: Seam strength of fabric 1 with different sewing factors

Determining the seam elongation

Seam elongation evaluates the elasticity and flexibility of a seam. Seam elongation is defined as the ratio of the extended length after loading to the original length of the seam. It is found from figure 3 that the lapped seam type SSw is found to have the higher seam elongation as compared with the two other types, this is due to increased consumption of sewing thread because the overlapping the layers of fabrics are two phases and two rows of stitches. For investigating the effect of the stitch length on the seam elongation, it is observed from figure 3 that with different stitch length bending stiffness is changing. The seam elongation by stitch length 1.5 mm for all seam types showed high values than by stitch length 3 mm and stitch length 4.5 mm. Logic increased the ability of extension the sewing thread with more stitch density causing increasing in the seam elongation. The number of stitch rows had a significant effect on the seam elongation. The same behaviour, found with of the other two studied sewing factors, showed the seam with the factor of number of stitch rows. The seam extension increased with adding numbers of stitch rows. The seam consists of 3 Stitch rows recorded highest value of seam elongation.

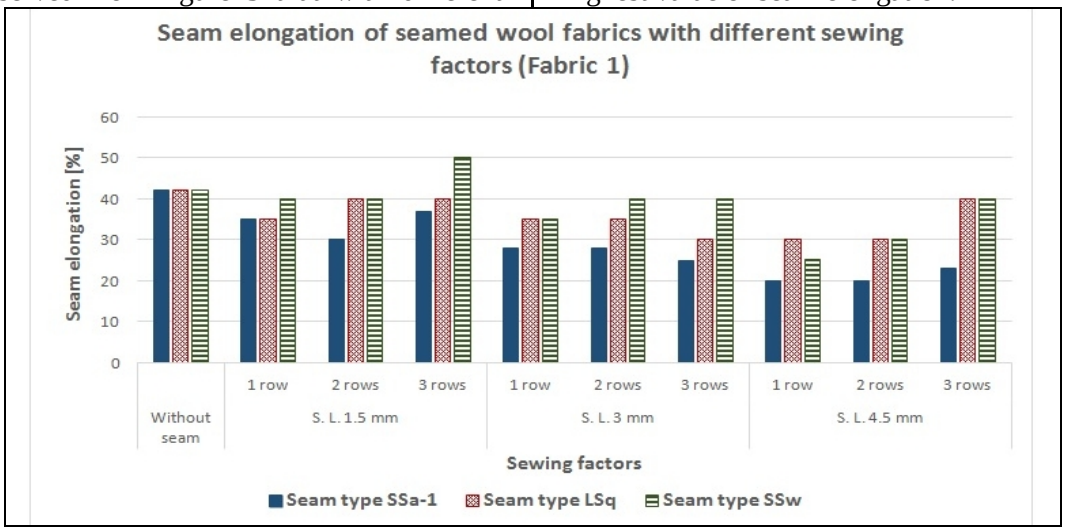

Figure 3: Seam elongation of fabric 1 with different sewing factors

Determining the seam efficiency

Seam efficiency was determined to express the actual seam strength in a percentage of the fabric tensile strength. The results of seam efficiency are more suitable to be used for comparison purposes because the value is in percentage and differences

between fabrics are reasonable. The formula as described in equation (1) is used to calculate the seam efficiency. Usually, seam efficiency is below 85-90% depending on seam type, stitch density, the type of sewing thread, needle type and size [14]. Lower values of seam efficiency indicate that the sewn fabric has been damaged during the sewing operation. This is due to fiber dislocation in the fabric during the penetration of the needle and sewing thread, which cause a reduction in fabric strength [15]. The variations in seam efficiency along with the different sewing parameters for fabric 1 are graphically represented in figure 4. The results introduced in table 4 proved the significant influence of all independent variables on the seam efficiency. From figure 4, it was confirmed that seam efficiency increased with the increase in number of fabric layers. The mean value of seam efficiency by seam type SSw was 53.15 % followed by the seam type LSq (48.50%) and seam type SSa-1 (44.44 %). The highest seam efficiency was 75.68 % and achieved by the seam type SSw (4 layers) with stitch length 1.5 mm and 3 stitch rows. For evaluating the stitch density, which can be defined throughout stitch length, it was found to have a positive influence on the seam efficiency. Higher seam efficiency is associated with higher stitch densities. The third investigated sewing factor was the number of stitch rows. It was observed that, with more stitch row numbers increased the seam efficiency, because the applied load was divided on larger area, causing higher seam strength and in sequence the seam efficiency.

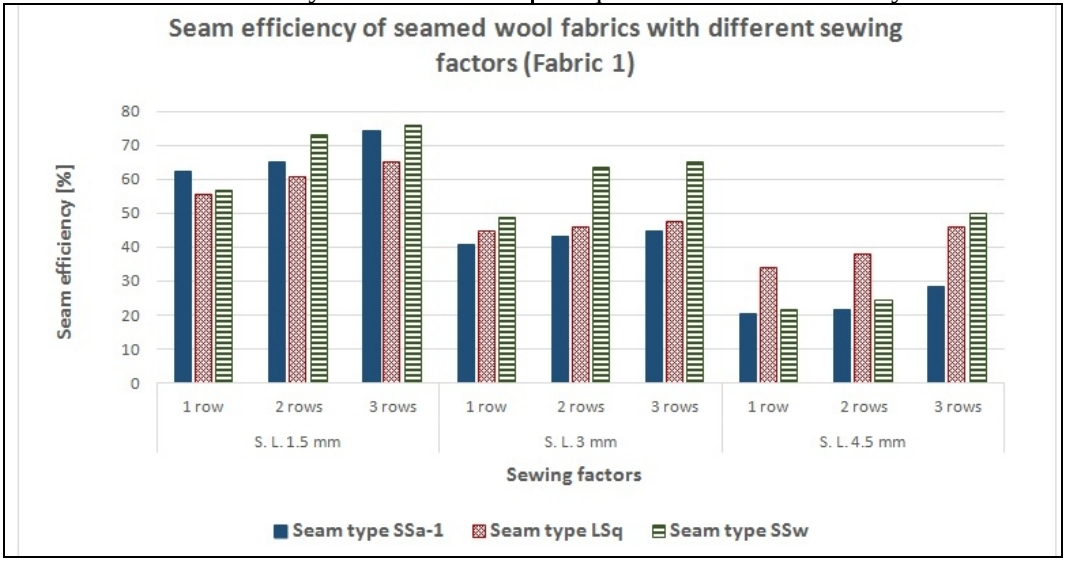

Figure 4: Seam efficiency of fabric 1 with different sewing factors

Determining the seam stiffness

It was observed from table 4 that with the repeat measures seam stiffness is changing for all experimental runs.

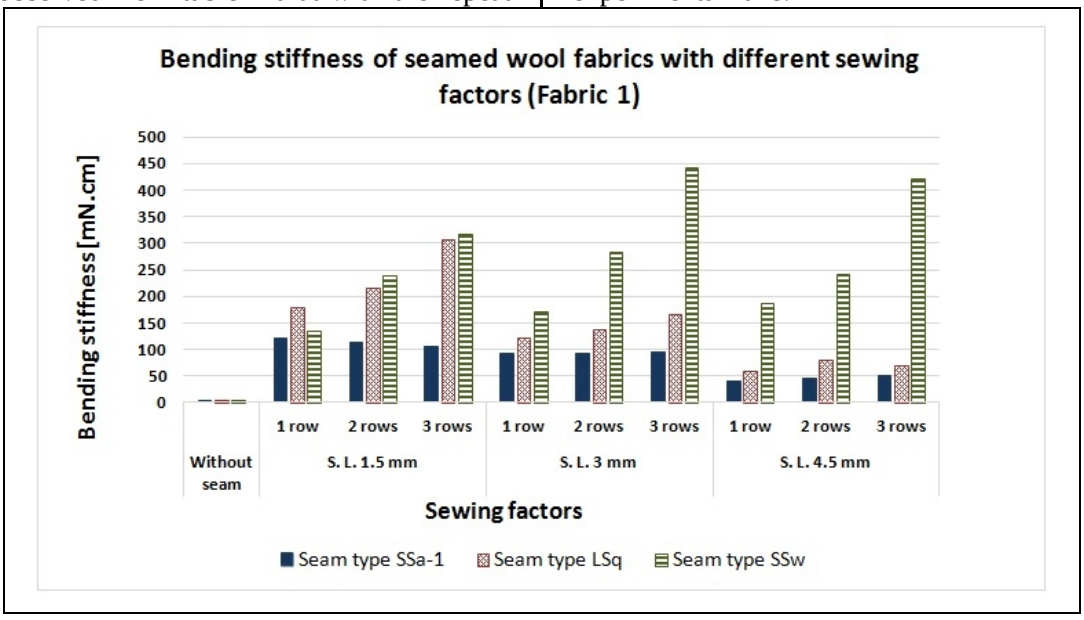

Figure 5: Bending stiffness of fabric 1 with different sewing factors

It was found from figure 5 that all sewing factors affected the stiffness of the wool fabrics

obviously. In general, the stiffness of wool fabrics increased with adding seams. The seam type seam type SSw had achieved the highest bending stiffness, followed by the seam LSq and SSa-1. The results also confirmed that with more stitch density (small stitch length) increased the seam stiffness of wool fabrics in general. The numbers of stitch rows showed the seam behaviour. The more stitch rows number is, the high the seam stiffness. The increasing trend of seam stiffness with the change in seam type, stitch length and number of stitch rows is due to the fact that the more fabric layers, stitched and sewing thread leads to more rigid of the fabric and more mass, in sequence increase of the bending stiffness.

4- Conclusion:

Seam performance of the wool textile fabrics was been investigated in this study. Three different wool fabrics were sewn with different sewing factors, which include three seam types, three stitch lengths and three levels of stitch rows numbers. Seam performance properties were been identified throughout determining the seam strength, seam elongation, seam efficiency and seam stiffness. Based on all experimental work in this study, the following conclusions could be given:

- All specimens with different sewing factors have lesser values of seam strength compared to the fabrics without seam.
- The seam SSw showed maximum seam strength of all seams.
- The more the stitch density is, the higher the seam strength.
- With more stitch rows increased the seam strength because the Load was divided over a larger area.
- Seam elongation evaluates the elasticity and flexibility of a seam. The seam elongation represented the seam behaviour of the seam strength.
- Seam efficiency was determined to express the actual seam strength in a percentage of the fabric tensile strength, seam efficiency increased with the increase in number of fabric layers, The highest seam efficiency was 75.68 % and achieved by the seam type SSw.
- Higher seam efficiency is associated with higher stitch densities.
- with more stitch row numbers increased the seam efficiency.
- In general, the stiffness of wool fabrics increased with adding seams.
- The increasing trend of seam stiffness with the change in seam type, stitch length and number of stitch rows is due to the fact that the more fabric layers, stitched and sewing thread leads to more rigid of the fabric and more mass, in sequence increasing of the bending stiffness.

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