Strength Analysis of Seamless Double Layered Fabric Using FEM

Hamid Reza Elahidoost, Mohammad Sheikhzadeh, Saeed Ajeli and Amir Mostashfi

***Abstract*—The seamless double layer fabrics are of special uses in industry. The strength of these fabrics is an important parameter due to different forces pushed on them. In the areas where there is a seam, the fabric has the lowest strength in comparison to other parts and this is the key point that shows the reasons of the importance of strength of the seam in the industrial double layer fabrics. Present research provides a new method that increases the strength of the seam in double layer fabrics by shuttle less weaving machines. In this method, two layers of fabrics are joined each other during weaving, a hole is created in the joint of the two layers and the hole is filled by fillers with circular cross section. In fact, fillers with different diameters are employed for this purpose. The fillers with smaller diameters than the hole are used as half fillers and those with larger diameter are used as the full or complete fillers. The strength of these samples are then compared with those with holes and without fillers, two layer samples without hole (joined through the two layers), the sewed two layer samples and single layer fabrics. The results of finite element modeling indicate that the tensile strength of the seam increases by adding fillers to the holes and increasing their diameters. Moreover, it is showed that, increasing of diameter of the hole does not affect the tensile strength of the seam for the samples filled with complete fillers.**

Key words: Seamless, strength properties, double layer, woven fabric, finite element method

I. INTRODUCTION

Industrial fabrics have some special non-dressing uses, and this is because of their specific characteristics including physical, mechanical and chemical features. Some of the industrial fabrics are in two layers or tube-shaped forms so that the layers are joined each other in their edges.

If the sewing method is used for the connections and joints, the strength of the seam is reduced due to the stress concentration in the connection point. Other problems that are evident in this structure could be thread tearing, stitch loose or cut and other sewing problems that all have negative effects on tensile specifications of the seam which is important in industrial uses. Many researchers worked on the mechanical properties of the sewing stitch performed over the past 30 years. In some papers, researchers described a consistent approach to these problems. Therefore, the endless methods are used in the production and weaving process of these fabrics [1-5].

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Usually, the weaving machines with shuttles are used for making the two layer fabrics that deal with stress concentration problem. Due to the continuity of the weft yarn in the fabric, one can make the fabric in a tube shape form through crossing the weft package from the bit. On the other hand, fabrics woven by the shuttle-based weaving machines have some problems with their smoothness due to some factors such as lack of modernizing the systems, technical weaving problems, opening the bit beyond its usual amount while the weft yarn is crossing and also the low speed of these machines. Moreover, producing of high density fabrics, especially the heavy types, with these classes of machines provide some problems.

In this research, we tried to introduce a new method of producing these kinds of fabrics using shuttle free weaving machines. In this method, the two folds of the fabric were joined together in their edges. Using this method for connecting the two folds created an angle of 90° when the two folds were open and this led to stress concentration in connection point. If one can decrease the angle between the two fold through creating different tissue or weavings, then the stress concentration in the joints reduces and the tensile strength of the seam increase. In order to achieve this goal, a hole was created in the fabric before two fold were woven together. These holes were filled with circle shape surface fillers to decrease the created angle between the two folds.

In addition to operational tests performed in this research, a mechanical model based on finite element model (FEM) was also used to investigate the proposed plan. This method was used to predict the stress-strain behavior of woven fabric and also employed to study the sewing process [6,7].

II. PREPARING THE FABRIC

The double layer fabrics with plain design were woven on the Smith TP422 loom. The warp and the weft densities were 7 ends/cm and 15 picks/cm, respectively. The warp yarn was plied 300×2 denier polyester filament and the weft yarn was plied by 300 denier and 60 denier polyester filament single yarns.

Ten heald frames were used in this machine to weave the samples in which the background tissue formed by the heald frames 1 to 8 and the edge by the two last heald frames. Two types of double layer fabric were produced in this way as following:

Double Layer Fabric Type A

In this kind of fabric, the heald frame No. 1 and 2 of the upper layer, the heald frame No. 3 and 4 of the lower layer and the 4 remaining heald frames would form the joint point of the two fabrics. Figure 1 shows the manufacturing method of this fabric.

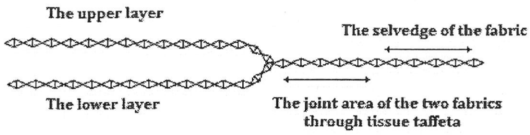
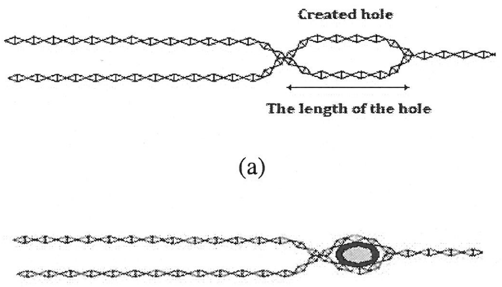


Fig. 1. A view of the double-layer fabric type A.

Double Layer Fabric Type B

This type of fabric was similar to the double-layer fabric type A, except that its lower and upper layers were replaced by each other at the end before being woven together and after a specified distance the two layers joined together again. In the other word, as it is observed in Figure 2, a hole was formed before the two layers join each other. The dimensions of the created holes in type B fabrics are listed in Table I.



(a)

(b)

Fig. 2. (a) View of the double-layer fabric type B, (b) The hole is completely filled with a rod.

III. Preparing Necessary Samples for Test:

Thirteen types of fabrics were prepared for conducting necessary tests. Sample #1 was seamless fabric; Samples #2 and #3 were double-layer sewed fabrics in lock stitch sewing method and with the density of 5 stitches per centimeter, 1 row and 4 stitches respectively. Sample #4 was a double-layer fabric type A and the rest nine samples were double-layer fabrics type B with holes and filled by some aluminum filler which had a circle shape surface and a diameter sizes smaller or greater than the hole and it was half full and full according to the Figure 2b.

As Table II shows, Samples #8 to 10 were produced by fillers that their diameters were less that the fabrics holes. The last three samples were produced by filler with the diameters more than the fabrics holes. As Figure 2b shows, due to the elasticity of the weft yarn in the produced fabrics, the holes were completely filled by fillers.

In the final stage of the experiments, in order to prepare fabrics for checking their strength, the two layers of each samples were separated from each other except in Sample #1 and then, the two layers were placed on a horizontal level. Samples with the width size of 5 cm were placed along with the warp direction and the length was selected in a manner that it could move between the two parts of the strength meter machine at a distance of 15cm. Samples along the weft (in a vertical position to the seam) were tested by a Zwick Strength Meter, model 1446-60. The speed of the fixed jaw apparatus was set at 400mm/min to adjust the tear or breaking time of samples at 20 seconds. At least 4 tests were made on each sample in standard conditions and the maximum breaking force was measured as shown in Figure 3.

TABLE I
SPECIFICATIONS OF THE SAMPLE FABRICS OF TYPE B

Sample #	Hole diameter (cm)	Diameter of aluminum filament (cm)
5	0.27	Without filler
6	0.45	Without filler
7	0.55	Without filler
8	0.27	0.2
9	0.45	0.2
10	0.55	0.2
11	0.27	0.3
12	0.45	0.5
13	0.55	0.6

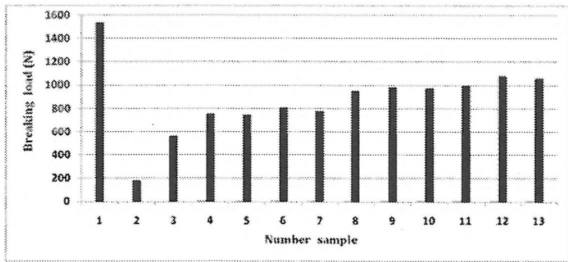


Fig. 3. Maximum breaking force of samples.

IV. Investigating the Results of Strength Test

The variance analysis of mean ANOVA was used to investigate the meaningfulness of the comparison of the means of the groups. The LSD (Least Square Difference) variance analysis and Tukey's test were used to investigate the validity of differences between the means of the two groups. In the cases that comparative analyses of the means of two groups were needed, the t-test analysis was used.

Results of ANOVA analysis for tensile strength amount showed that the existence or lack of a hole without fillers did not affect on the seam tensile strength. In other word, when tensile tension was applied, the pitted fabrics without fillers and with different hole dimensions and the seamy fabrics without holes acted the same. In fact, the lack of filler inside the hole led to sticking of two layers forming the hole to each other and the fabric acted as a seamy pitless fabric. Therefore, the angle created at the junction of two layers was identical for all these fabrics and it was almost 90°.

Meanwhile, the strengths of the three samples of B type of fabric with different dimensions and full and half full fillers did not show any significant differences. However, there was a significant difference between the means differences of the samples without fillers and those with half or full fillers. The reason originates from this fact that when half filler is added, the two layers of the hole open and the angle between them decreases. If completed filler is used, the cutting surface would change into a circle shape and the angle would be increased to more than 90°. Decrease in the created angle in fabric would lead to reduction of tensile density in the yarns at the external surface and consequently the strength would increase.

TABLE II
T-TEST OF TWO-SAMPLE MEAN HALF FILLERS AND FULL FILLERS

Complete fillers (type B)	Half fillers (type B)	
1047.333333	970	Mean
1622.333333	271	Variance
3	3	Observations
	0	Hypothesized Mean Difference
	3	df
	-3.078320376	t Stat
	0.054207255	P(T<=t) two-tail
	3.182446305	t Critical two-tail

TABLE III
T-TEST OF TWO-SAMPLE MEAN WITHOUT FILLERS AND THOSE WITH HALF FILLERS

Half full (type B)	Without fillers (type B)	
970	777	Mean
271	813	Variance
3	3	Observations
	0	Hypothesized Mean Difference
	3	df
	-10.15320828	t Stat
	0.00203563	P(T<=t) two-tail
	3.182446305	t Critical two-tail

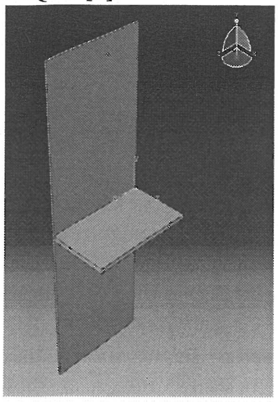
TABLE IV
T-TEST OF TWO-SAMPLE MEAN WITHOUT FILLERS AND FULL FILLERS

Complete fillers (type B)	Without fillers (type B)	
1047.333	777	Mean
1622.333	813	Variance
3	3	Observations
	0	Hypothesized Mean Difference
	4	df
	-9.48814	t Stat
	0.000689	P(T<=t) two-tail
	2.776445	t Critical two-tail

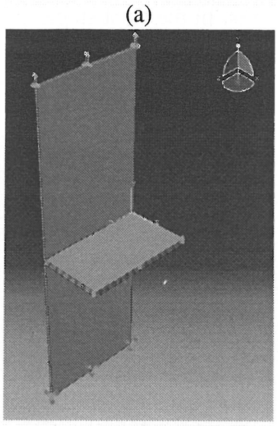
V. SIMULATION

In addition to preparing the samples and measuring the tensile strength, finite component method was also used to suggest a model for anticipating the strength level of the samples. The employed theories for the simulation and modeling are as follows:

Firstly, the fabric was considered as a contiguous environment. The model behavior was supposed to be elastic in the areas where there is exertion of forces or strength. The thickness of the fabric was supposed to be firm and fixed at the time when there is exertion of strength. Finally, samples #1, 4, 12, 11 and 13 were simulated by ABAQUS [8].



(a)



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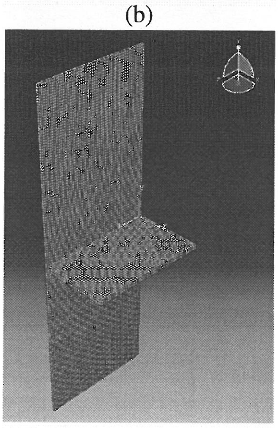

(c)

Fig. 4. Working operations processes by ABAQUS software. (a) geometric model shape (b) boundary conditions and (c) meshing.

Different practices were examined in this software to perform mechanical analysis and inputs and theories were inserted into the software in each stage. First, the geometric shape of the double-layer fabric was modeled, and then the two layers were placed along each other without any seam. This caused that two layers could be separated from each other by the minimum force. Therefore, two layers were linked together by tie point. The link was similar to the state that two fabrics were sewed together. Coding and providing necessary

TABLE V.
ANOVA OF FEM MODEL & EXPERIMENTAL DATAS

	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std	Std. error mean	95% Confidence interval of the difference				
				Lower	Upper			
Pair 1 (FEM model & experimental)	-140.800	159.341	71.260	-338.649	57.049	-1.976	4	0.119

Paired samples correlations

	N	Correlation	Sig.
Pair 1 (FEM model & experimental)	5	0.982	0.003

conditions based on practical tests were the next steps. By following these steps, the solution scope was divided into smaller parts named mesh or element for mechanical analysis of model. The type of element was selected regarding the existing problem and the whole geometric model was ruptured. In this model, the C3D8R element was used for meshing. Figure 4 shows some of the working procedures. In the final stage, the output was seen as the force analysis diagram and length increase. Figure 5 demonstrates the "phone mices counter" in the last coding process.

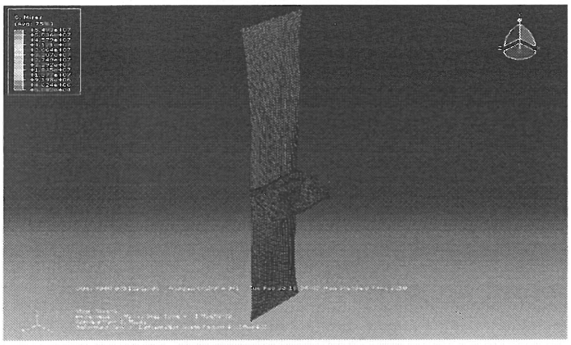

Fig. 5. Phone mices counter in the last coding process.

VI. COMPARISON BETWEEN THE SIMULATION AND EXPERIMENTAL RESULTS

Results of the simulation theory obtained by software and those obtained from the experimental tests could be observed in Figure 6.

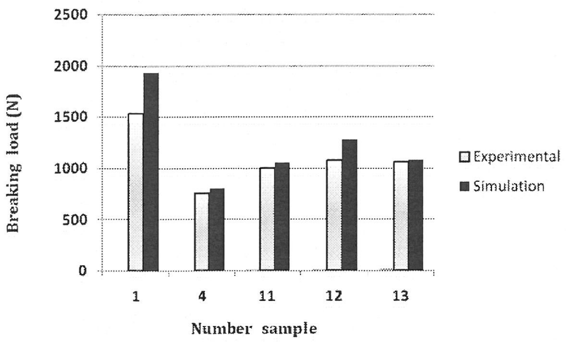

Fig. 6. Comparing the result of simulation and experimental.

Obviously, the theoretical and practical results of samples with holes are not much different from each other. The simulated models of these samples have the strength anticipation ability of similar samples with the maximum error rate of 15% (for Sample #1). It seems that, the error rate probably results from the employed modeling theories.

VII. CONCLUSION

The method applied in this research for producing double-layer fabrics by including a hole in the joint area of the two layers led to increasing the fabric resistance against tearing or other usual methods of joining the two layers by weaving. Locating fillers in the desired hole and increasing the diameter also increased the seam tensile strength. As the filler diameter increased the surface of the hole was closed more to circle shape and the created angle in the joint of the fabric would be decreased. This occurrence leads to reducing tension concentration in this area and causes the seam strength to be increased. When no filler is used or filler with smaller diameter less than the hole is used, then the hole does not affect the tensile strength of the seam. In the other words, there is not a significant difference in the seam tensile strength in the hole-based fabrics without fillers and the seamy fabrics without the holes. This is because the angle created in the junctions of two layers is the same for all fabrics.

The comparison between the measured tensile strength of samples with complete fillers and the strength obtained from simulation by software indicated that the employed model was able to anticipate the strength of the corresponding samples with the maximum error rate of 15%.

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