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Artificial Neural Network-based Prediction Technique for Waterproofness of Seams Obtained by Using Fusible Threads

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Abstract

The aim of this study was to estimate waterproofness values of seams composed of the combination of fusible threads and antiwick sewing threads through artificial neural networks (ANN). Fusible threads were used to obtain waterproof seams for the first time. Therefore, estimating the value of the waterproofness variable with the help of models created from test values can contribute to accelerating the progress of further studies. Hence, ten different samples were prepared for two fabrics, and the waterproofness values of the seams obtained were tested using a Textest FX 3000 Hydrostatic Head Tester III. For the prediction of waterproofness values of the seams, the Levenberg-Marquardt backpropagation algorithm was used for artificial neural network pattern models with sigmoid and positive linear transfer functions. Finally, the ANN model was successful in estimating the waterproofness of the seams. The highest correlation coefficient was R = 0.95081 which indicated that the prediction made by the neural network model proved to be reliable.

Keywords

waterproof, seams, sewing threads, fusible threads, artificial neural network (ANN).

1. Introduction

In garment making, sewing is widely used for joining; however, the needle causes damage along the seam line while carrying the sewing thread through the fabric. If the fabric has been waterproofed, the needle devastation that occurs during sewing causes the infiltration of water. To hamper this penetration problem, the seams are sealed by waterproof sealing tape [1], where the seam tape affects the physical properties of the sewing area. In addition to this method, thermal bonding and sealing of thermoplastic materials are the other methods of obtaining waterproof seams. Waterproofing is a topic that has a wide coverage in the literature, and with the increasing interest in functional clothing, it has come to the fore even more. The subjects examined in some studies on waterproof joining processes are, for example, the investigation of optimal sealing parameters using the combination of ultrasonic welding-thermo adhesive tape sealing, ultrasonic welding parameters such as the strength, bonding force, seam thickness, seam stiffness of textile bonded seams, water permeability of sealing technological elements' resistance to penetration, and the ultimate tensile strength, as well as the effect of seam sealing on adhesion strength after washing [1-5]. Apart from the known methods of obtaining waterproof seams, fusible threads were used for this purpose for the first time. Rather than covering the seam area widely, fusible threads were used to cover just the needle holes to prevent the penetration of water and in this way increased the waterproof performance of the seam area. Promising results were obtained in the beginning [6, 7]. It is important to select suitable threads because the study is new and there is no previous information. Hence, a prediction can be made about the results to be obtained in advance. Therefore, seeing the possibility of estimation with the limited data available can contribute to the acceleration of study. Furthermore, the results forecasts may also be instructive for manufacturing specific fusible sewing threads to use for this purpose in future researches.

The artificial neural network (ANN) method was applied in this study. ANN is a method used in forecasting in many subjects in textiles. It has been used in the estimation of body dimensions, fabric permeability, body types, thermal resistance of fabrics, needle temperature depending on machine speed, fabric elongation, convective and radiant heat transfer indexes of fabrics and many other issues until today [8-14]. In these studies, it was concluded that the ANN predicted expected outputs were sufficiently successful. In this study, it was more important to make estimations because the number of data available is very limited, and the study of obtaining waterproof seams using fusible threads was attempted for the first time. To that end, in this study, waterproofness results of seams obtained using different sewing thread combinations, such as containing fusible thread in the lower thread and two different fabrics, were used for estimating the waterproofness result of any sewing thread combination.

2. Materials and Method

In this research, two waterproof-coated fabrics and four sewing threads were used as experimental materials. The base

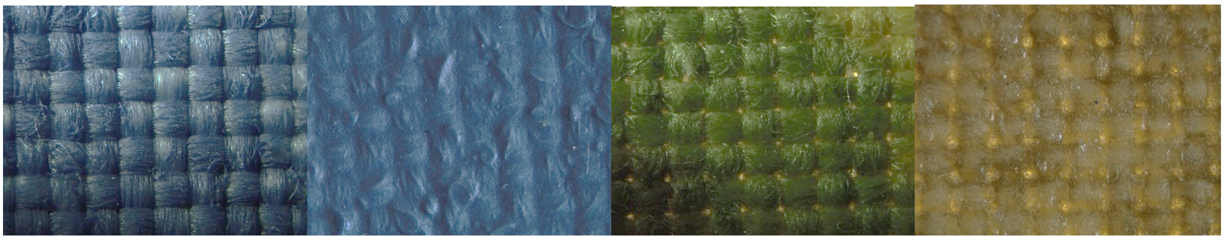


Fig. 1. a) Blue fabric and b) green fabric [7]

Sewing Thread Code	Thread Composition
T80	80 tex, Polyester / Cotton corespun (Antiwick)
T150	150 tex, Polyester / Cotton corespun (Antiwick)
T135	135 tex, low fusible co-polyamide (85%) and polyester (15%) (Co-polyamide fuses between 100-110°C
T40	40 tex, Co-polyamide filament (Co-polyamide fuses between 100-110°C)

Table 1. The sewing threads [7]

Display of thread combinations in seams (Needle thread/ Shuttle thread)	Needle thread (upper thread) (tex)	Shuttle thread (lower thread) (tex)
Threadless sewn (sewn without thread, perforated)	-	-
T80/T80	80	80
T80/T150	80	150
T150/T150	150	150
T80/T80+T40	80	80 and 40
T80/T150+T40	80	150 and40
T80/T135	80	135
T150/T135	150	135
T80/T80+T135	80	80 and 135
T150/T80+T135	150	80 and135

Table 2. Needle and shuttle thread combinations [7]

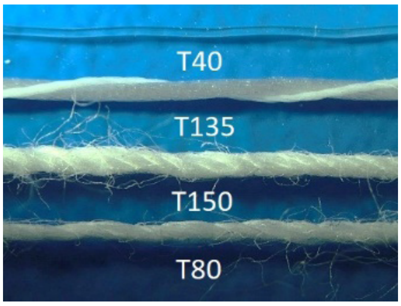


Fig. 2. Sewing threads [7]

fabrics are 100% PA plain-woven fabric with nearly the same fabric density (warp: 12 yarns/cm and weft: 13 yarns/cm). The coated fabrics were manufactured using Fluorocarbon on a Monforts Stork coating line with the knife coating method. The unit fabric weights of base blue and green fabrics were 297.5 g/m^2 and 282.1 g/m^2 and after coating 470.6 g/m^2 (blue fabric) and 365.1 g/m^2 (green fabric) respectively. Therefore, their fabric unit weights in a raw form are close to each other. Their unit weight difference was caused by their coating material quantity over the fabrics. The fabrics are shown in Figure 1.

The specimens were sewn using the combinations of four different sewing threads, two of which were antiwick, and the other two were fusible. The threads are given in Table 1 and shown in Figure 2.

For each type of sample, five test fabrics were cut in 25 cm x 25 cm dimensions. The specimens were sewn in a lockstitch with 3 stitches/cm, a stitch density of Nm 90 (14) , and with a slim set point (SPI) type of sewing needle according to the thread combinations given in Table 2. To obtain a variety of lower thread combinations, two sewing threads, one of which was fusible thread, were wound together on the shuttle by hand.

After the sewing process, the seamed area of the samples having these thread combinations were ironed between 100-110°C for 10 seconds to melt the fusible thread (co-polyamide).

Afterwards, waterproof experiments were carried out with a Textest FX 3000 Hydrostatic Head Tester III in accordance with the ISO 811:2018 standard. Five repetitions of the waterproofness performance tests were made for the ten samples given in Table 2.

Using the waterproofness performance data obtained, waterproofness values of the seams were estimated according to the changes in the thread combinations and fabrics with the help of the artificial neural network method (ANN). The neural network consists of an input layer, one hidden layer and an output layer, shown in Figure 3. The input

Fabric	Thread Composition	Waterproofness (mm)				
		Test 1	Test 2	Test 3	Test 4	Test 5
Blue (0)	Threadlessly sewn (perforated)	177	172	176	173	171
	T80/T80	224	216	215	218	204
	T80/T150	236	229	227	233	235
	T150/T150	227	228	225	242	234
	T80/T80+T40	219	218	236	238	225
	T80/T150+T40	228	254	241	232	230
	T80/T135	236	251	237	245	245
	T150/T135	190	202	198	211	190
	T80/T80+T135	208	201	208	235	214
	T150/T80+T135	239	230	221	237	230
Green (1)	Threadlessly sewn (perforated)	125	132	142	128	134
	T80/T80	225	231	232	218	225
	T80/T150	259	283	291	254	269
	T150/T150	256	295	273	233	233
	T80/T80+T40	272	294	267	262	257
	T80/T150+T40	270	266	263	256	245
	T80/T135	274	271	304	297	317
	T150/T135	261	275	249	254	258
	T80/T80+T135	260	250	307	322	274
	T150/T80+T135	266	283	259	249	260

Table 3. Experimental results of the waterproofness values of samples [7]

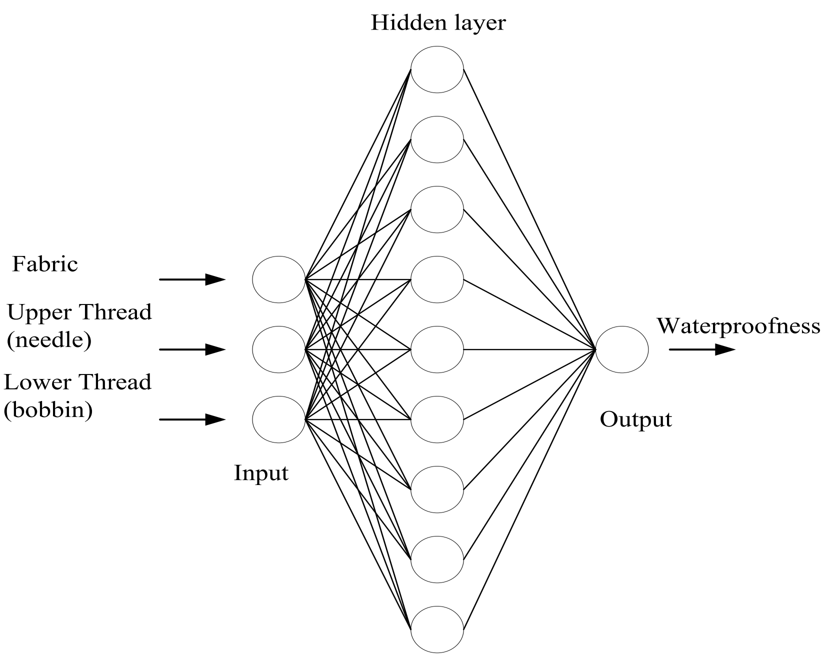


Fig. 3. Neural network architecture

variables are fabrics of different unit fabric weight, with an upper thread (needle) and lower thread (bobbin). The output variable is the waterproofness value of the seams. Hence, three input variables and a single output variable are used in this application. To be used in the neural network operations, the values given in Table 3 were assigned to the fabric samples seamed with different thread combinations and the threadlessly sewn (perforated) fabric samples. In the training of neural networks, input and output values are frequently scaled to a range 0 to 1, which is called the normalisation process. This process is done separately for all network input and output values. First, each value was subtracted from the smallest number in Table 3 and then divided by the difference between the largest and smallest number in the table.

The ANN was trained and implemented using the MATLAB neural network Levenberg-Marquardt backpropagation algorithm [15]. For the training process involved in the estimation, it was found that the following parameters provide fast convergence of the trained artificial neural network with successful performance. The hidden and output layers of the ANN were modelled using logarithmic sigmoid and positive linear transfer functions, respectively. The ideal number of neurons in the hidden layer was obtained as nine. The learning process of the network model was completed in the 87-epoch based on the mean square error method. The program generated the initial weights and biases of the network automatically.

The experimental results, in which a total of 100 data sets were created, given in Table 3, were used for the training and testing of the artificial neural network model. A total of twenty experimental data were selected, one from each thread composition group, to evaluate the performance of the trained network model. However, these twenty data were certainly not used for training the artificial neural network model.

According to the values in Table 3, after the training process, the artificial neural network is expected to estimate the measurement of any test data.

3. Results and discussion

Figures 4 and 5 show the best training performance and network correlation coefficient, respectively. As seen in

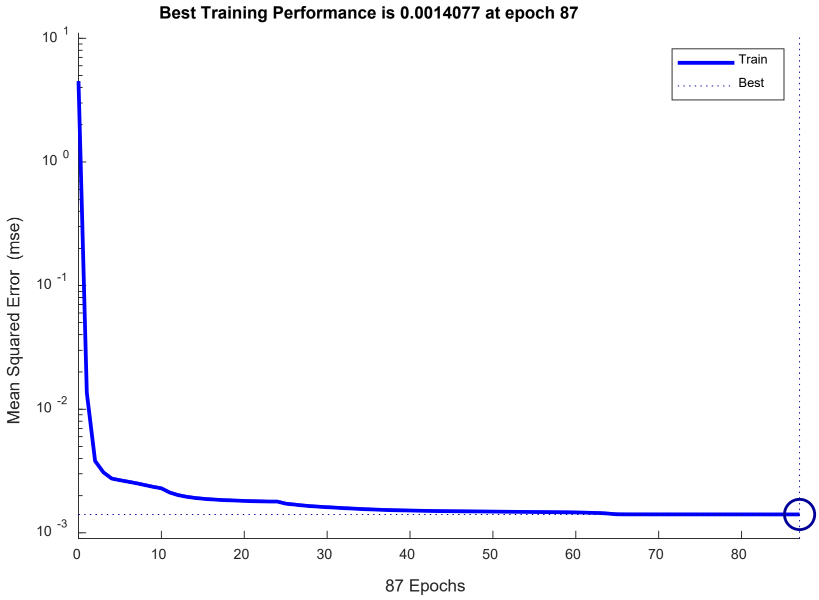


Fig. 4. Network training yielding the best result for the experimental results

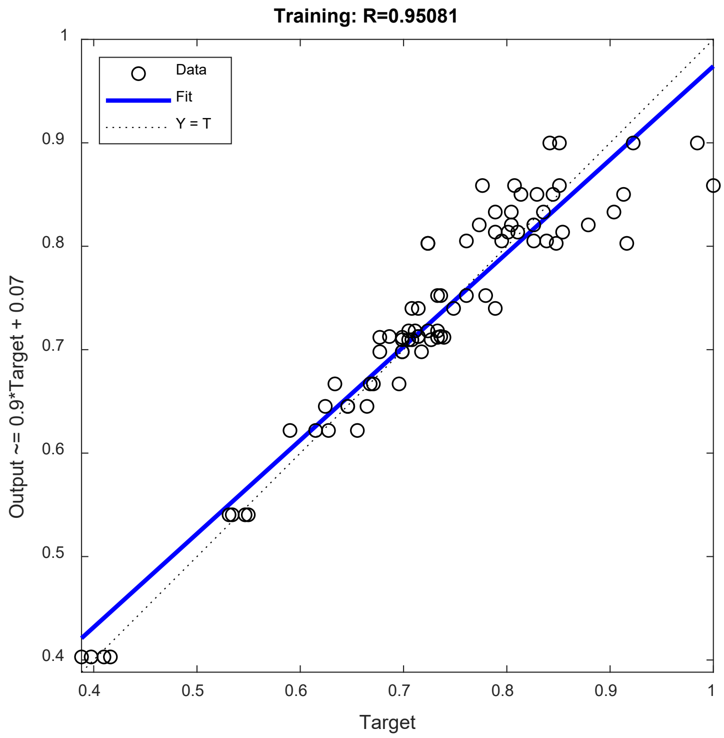


Fig. 5. Network correlation coefficient

Figure 5, since the network model trained at the end of 87 iterations yielded the highest correlation coefficient (R = 0.95081), this network was determined as the best network model. Moreover, the minimum mean squared error was obtained as 0.0014077 during the training process of the network.

As seen in Figure 6, when training data and corresponding ANN output data are compared, the values tested and those values estimated are very close to each other. Therefore, it is observed that the training of the ANN model is good.

Table 4 shows a comparison of the results of waterproofness of seams obtained with different thread combinations between the test data and ANN model. The normalised output values within a range of 0 and 1 were converted to real values in the table. As seen from Table 4, the two highest errors occurred in thread composition T80/T80+135 of blue and green fabrics. When the measurement values of this combination are examined in Table 2, it can be seen that the measurement value range of this combination is wider than for the other combinations. Overall, the close match of the waterproofness values produced by the artificial neural network and the experimental work clearly shows that the network can predict the waterproofness performance within the specified parameter range. Moreover, the mean error is 4.30 percent, which is acceptable. As a result, considering all outcomes concerning the estimation performance of the neural network designed, a match between the predicted and actual values was ascertained, as the high correlation coefficient of R = 0.95081 in Figure 5 shows.

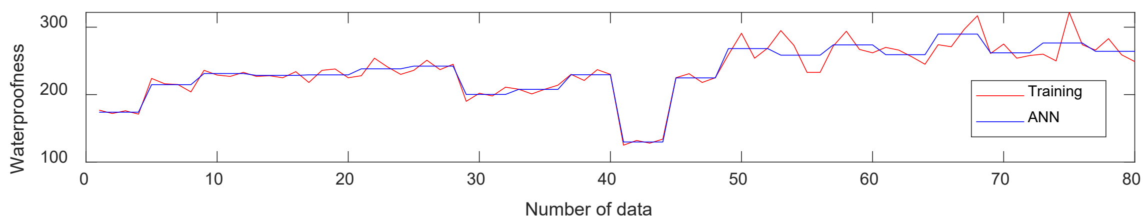
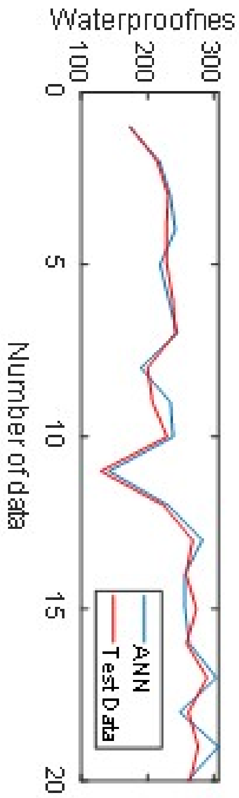


Fig. 6. Comparison of the training data and ANN data

Table 4. Comparison of test data and ANN results

Fabric	Thread Composition	Waterproofness (mm)		Absolute Error %
		Test	ANN	
Blue	Threadlessly sewn (perforated)	173	174.00	0.57
	T80/T80	218	214.75	1.49
	T80/T150	235	231.25	1.59
	T150/T150	242	228.50	5.57
	T80/T80+T40	219	229.25	4.68
	T80/T150+T40	232	238.25	2.69
	T80/T135	245	242.25	1.12
	T150/T135	190	200.25	5.39
	T80/T80+T135	235	207.75	11.59
	T150/T80+T135	239	229.50	3.97
Green	Threadlessly sewn (perforated)	142	129.75	8.62
	T80/T80	232	224.75	3.12
	T80/T150	283	268.25	5.21
	T150/T150	256	258.50	0.97
	T80/T80+T40	257	273.75	6.51
	T80/T150+T40	263	259.25	1.42
	T80/T135	304	289.75	4.68
	T150/T135	249	262.00	5.22
	T80/T80+T135	307	276.50	9.93
	T150/T80+T135	260	264.25	1.63
Mean Error %				**4.30**



4. Conclusion

In this study, the Levenberg-Marquardt backpropagation algorithm with sigmoid and positive linear transfer functions for artificial neural network pattern models was configured to predict the waterproofness of seams. Based on the results obtained, it was possible to deduce that the ANN could successfully predict the waterproofness of seams. The waterproofness value of seams formed with different needle and bobbin thread combinations were determined by an experimental study. Because fusible threads were being tried for the first time in obtaining waterproof seams, the number of inputs and, therefore, data were low. It was attempted to make an estimation with data of not very large size in the study. Despite this, an acceptable level of estimation was successfully achieved. By taking the advantage of the ANN, choosing the right thread combinations, and considering other parameters that may be effective in obtaining waterproof seams with fusible threads, future studies and the development of this method may be accelerated.

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