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Research Article

PREDICTION OF SHRINKAGE AND FABRIC WEIGHT(G/M²) OF COTTON SINGLE JERSEY KNITTED FABRIC USING ARTIFICIAL NEURAL NETWORK AND COMPARISON WITH GENERAL LINEAR MODEL

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ABSTRACT

This paper presents a study which predicts the knitted fabric dimension scientifically in order to eliminate the unpredictable dimensional behavior of cotton knitted fabrics after washing when used by the customer. In this study experimental investigation was conducted to assess the shrinkage and fabric weight of plain knitted fabrics. Following a Full Factorial design of experimental plan, plain knitted fabrics were manufactured with four different yarn counts, each with three levels of twist factors, three machine gauges, and four levels of stitch lengths, making the total number of samples 144. The prepared fabric was then bleached and dyed. The finished fabric samples were divided into two groups; one group was allowed to relaxed in dry condition whereas the other group was subjected to repeated washing and tumble drying to achieve reference state. The shrinkage (in width and length direction) and fabric weight in g/m^2 were measured following the standard procedure as mentioned in ASTM standards. The results were analyzed for shrinkage and fabric weight (g/m^2) of cotton knitted fabric using the General Linear Model (GLM) technique and Artificial Neural Network (ANN) models. The predicted values of shrinkage and fabric weight (g/m^2) from GLM and ANN models were then compared.

INTRODUCTION

Fabric shrinkage is a serious problem for knitwear, which originates from dimensional changes in the fabric. It has become even more prevalent in recent years due to the popularity of casual wear such as tights, pants, blouses, and sportswear.Shrinkage may be simply defined as, the change in dimensions of fabric or garment due to some relaxation process which enables the strains and distortions imposed on the fabric during manufacturing and processing to be released, allowing the fabric to take up a stable relaxed configuration (Stevens, 1985). Shrinkage is a combined effect of number of factors such as relaxation, finishing, dyeing, and effects of machinery. The significance of this problem was investigated by many researchers, who targeted mainly on geometry and dimensions of knitted structures (Onal *et al*., 2003). The problem of dimensional stability is more pronounced with natural fibre yarns like cotton then thermoplastic yarns like polyester since, unlike thermoplastic yarns, the cotton yarns cannot be heat set to attain the minimum energy level and therefore it is extremely difficult to make the resultant cotton knitted fabric dimensionally stable (Banerjee *et al*., 1988).

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The prediction of shrinkage of cotton knitted fabrics is substantially beneficial to garment manufacturers and it has to be based on yarn, machine and finishing parameters as well as nominal finished dimensions. Conversely, we should be able to specify these parameters that must be adhered in order to manufacture finished fabrics with desired dimensional properties and shrinkage levels. Finally, it will be desirable, if not necessary, to be able to predict the final dimensions (shrinkage and fabric weight) even before start to knit. Although a number of models have been developed for predicting shrinkage, but in recent years, artificial neural network has emerged as a substantial prediction tool and can be used in different situations where prior function estimation is not possible. Rajamanickam *et al*, compared the predictive power of various modeling methodologies and found that the performance of ANN model is superior than that of mathematical, empirical and computer simulation models (Rajamanickam *et al.*, 1997). Artificial neural network (ANN) technique is used to model non-linear functions and to predict the output parameters without any assumptions. Artificial neural network is a very powerful analytical tool which is able to predict and represent any kind input-output relationships.
In textile and clothing industries, it involves the interaction of a large number of variables.

Because of the high degree of variability in raw materials, multistage processing and a lack of precise control on process parameters, the relation between such variables and the product properties is relied on the human knowledge but it is not possible for human being to remember all the details of the process-related data over the years. As the computing power has substantially improved over the last decade, the ANN is able to learn such datasets to reveal the unknown relations between various variables effectively. Therefore the application of ANN is more widespread in textiles and clothing industries over the last decade (Hui *et al*., 2011). ANN is set of processing units fabricated in a closely interconnected network, which exhibits some features of a biological neural network. ANN is a massively parallel distributed processor made of single processing units, which has a natural tendency of storing experimental knowledge and making it available for use. The procedure used to perform the learning process is called as learning algorithm, this algorithm is used to modify the synaptic weights of the network in an orderly fashion to attain a desired output.In practice, the ANN cannot provide the solution by working individually; rather it needs to be integrated into a consistent system engineering approach (Rao *et al*.,2005) (Bhambure *et al*., 2013). A typical single output neural network is shown in Fig.1. Here, all the inputs are connected to the output through some processing some elements called as neurons. The goal of this type of network is to create a model that can precisely map the functional relationship between inputs and outputs using historical data.

According to this algorithm, training occurs in two phases, namely a forward pass and a backward pass. In the forward pass, a set of outputs is produced. The calculation of error vector is done from the difference between actual and predicted output according to the following equation:

$$E = ½ \sum(T_r - O_r)^2$$

Where E is the error vector; and T_r and O_r, the target and output respectively at output node r. In the backward pass, this error signal is propagated backwards to the neural network and synaptic weights are adjusted such that the error signal decreases with each iteration process and the neural network model approaches closer and closer to producing the desired output. The corrections necessary in the synaptic weights are carried out by a delta rule which is expressed in the following equation:

$$w_{pq(n)} = -\eta(\partial E/\partial w_{pq(n)})$$

Where $w_{pq(n)}$ is the weight connecting the neurons p and q at the nth iteration; η, a constant known as learning rate.

Experimental

Shrinkage: In this project experimental investigation wasconducted to assess the shrinkage and fabric weight of plainknitted fabrics.

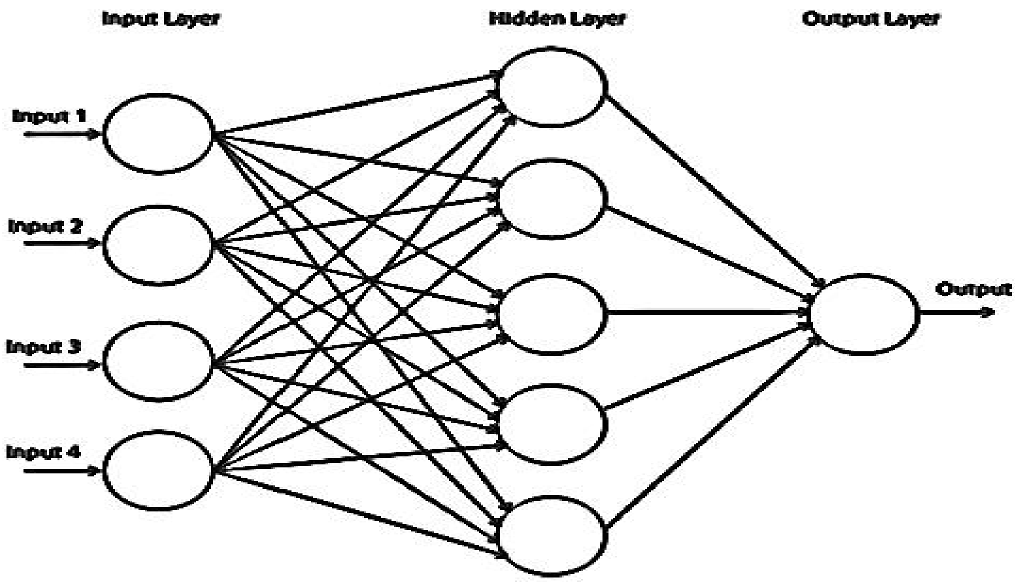

Figure 1. Artificial neural network model

This process is known as "training". The trained model can then be used to predict outputs from the testing data. In this kind of network, each neuron receives a signal from the neurons of the previous layer and each of these signals is multiplied by a separate weight known as synaptic weight. The weighted inputs are then summed up and passed through a transfer function which converts the output to a fixed range of values. The output of the transfer function is then transmitted to the neurons of next layer (Majumdar *et al*., 2004). The back propagation algorithm, which was proposed by Rumelhart*et al.*In 1986, is the most popular training method for ANN models.

Following a Full Factorial design of experimental plan, plain knitted fabrics were manufactured with four different yarn counts, each with three levels of twist factors, three machine gauges, and four levels of stitch lengths, making the total number of samples 144. The prepared fabric was then bleached and dyed. The finished fabric samples were divided into two groups, one group was allowed to relaxed in dry condition whereas the other group was subjected to repeated washing and tumble drying to achieve reference state . The shrinkage (in width and length direction) and fabric weight in g/m^2 were measured following the standard procedure as mentioned in ASTM standards.

Table 1. Performance Parameters for Shrinkage in ANN and GLM

Performance Parameters for Shrinkage in ANN and GLM								
	ANN (REFERENCE STATE)				GLM (REFERENCE STATE)			
	Bleached Widthwise	Bleached Lengthwise	Dyed Widthwise	Dyed Lengthwise	Bleached Widthwise	Bleached Lengthwise	Dyed Widthwise	Dyed Lengthwise
Network Architecture	4-9-1	4-9-1	4-3-3-4	4-3-3-4	N/A	N/A	4-9-1	4-10-1
Performance Goal	0.01	0.01	0.01	0.01	N/A	N/A	N/A	N/A
Epochs	3000	9000	7300	8800	N/A	N/A	N/A	N/A
TRAINING SET					FOR WHOLE DATA SET			
Mean square error(MSE)	0.31	0.31	0.03	0.23	5.65	18.33	26.05	19.30
Root Mean Square Error(RMSE)	0.56	0.56	0.16	0.48	2.38	4.28	5.10	4.39
Maximum Error	71.72	79.91	20.24	12.51	86.00	94.75	88.50	93.45
Minimum Error	0.04	0.36	0.08	0.00	0.54	0.17	0.78	0.27
Correlation Coefficient	0.8929	0.9210	0.9921	0.9509	0.9710	0.9440	0.9940	0.9890
TEST SET								
Mean square error(MSE)	0.69	0.54	0.01	0.17	N/A	N/A	N/A	N/A
Root Mean Square Error(RMSE)	0.83	0.73	0.09	0.42	N/A	N/A	N/A	N/A
Maximum Error	35.49	120.17	7.99	16.34	N/A	N/A	N/A	N/A
Minimum Error	4.67	0.00	0.09	0.48	N/A	N/A	N/A	N/A
Correlation Coefficient	0.8880	0.8525	0.9753	0.9987	N/A	N/A	N/A	N/A

Table 2. Performance Parameters for GSM in ANN and GLM

'Performance parameters of Fabric Weight in ANN and GLM'.								
	ANN				GLM			
	Bleached Ref. State	Bleached Dry State	Dyed Ref. State	Dyed Dry State	Bleached Ref. State	Bleached Dry State	Dyed Ref. State	Dyed Dry State
Network Architecture	4-5-1	4-7-1			N/A	N/A	N/A	4-9-1
Performance Goal	0.01	0.01	0.01	0.01	N/A	N/A	N/A	N/A
Epochs	1	800	1	1	N/A	N/A	N/A	N/A
TRAINING SET					WHOLE DATA SET			
Mean square error(MSE)	64.70	79.41	49.92	54.90	79.50	85.11	64.02	72.26
Root Mean Square Error(RMSE)	8.04	8.91	7.07	7.41	8.92	9.23	8.00	8.50
Maximum Error	47.61	64.05	22.01	41.15	27.85	32.83	35.88	37.65
Minimum Error	1.30	0.36	0.01	0.46	1.10	0.53	0.74	1.21
Correlation Coefficient	0.9604	0.9050	0.9435	0.9335	0.9530	0.9110	0.9510	0.9060
TEST SET								
Mean square error(MSE)	51.63	77.41	31.74	59.45	N/A	N/A	N/A	N/A
Root Mean Square Error(RMSE)	7.19	8.80	5.63	7.71	N/A	N/A	N/A	N/A
Maximum Error	35.98	53.77	13.05	37.32	N/A	N/A	N/A	N/A
Minimum Error	2.54	0.17	0.39	2.06	N/A	N/A	N/A	N/A
Correlation Coefficient	0.9522	0.9086	0.9489	0.9191	N/A	N/A	N/A	N/A

The results were analyzed for shrinkage and fabric weight (g/m^2) of cotton knitted fabric using the SYSTAT 12 software and Artificial Neural Network (ANN) models.

ANN: A total of 144 values of shrinkage of single jersey knitted fabric were taken for the study, of which 129 (about 90%) samples were used for training and 15 (remaining 10%) for testing the network. The fifteen values used for testing data were chosen out of 144 readings by using function randbetwee in ms excel. The prediction of shrinkage using ANN was done separately for bleached and dyed single-jersey fabrics, and also separately for widthwise and lengthwise shrinkage in both reference state and dry state. So the shrinkage was predicted in eight different ways.

RESULTS AND DISCUSSION

Comparing prediction performance of Artificial Neural Network and GLM

After the training or model development of data is complete, the testing data was presented to the trained network for the prediction of shrinkage and fabric weight (g/m^2).

Statistical parameters such as correlation coefficient (R) between the actual and predicted values, mean square error, rrot mean square error, maximum and minimum error were used to compare the predictive power ofGLM and ANN models. Results are shown in Table 1 and Table 2. In Table 1, the prediction performance for shrinkage by GLM and ANN are compared and in Table 2, the comparison of prediction performance of Fabric weight (g/m^2) is shown.

SHRINKAGE: From the table no.1 and 4, it can be observed that the MSE values obtained in ANN is much lower than obtained by the Statistical methods (GLM).

- In the same way, RMSE values and Maximum error and minimum error values obtained in ANN are either lower in ANN compared to GLM values or they are more or less similar.
- Similar trend is obtained for both bleached and dyed fabrics in widthwise as well as lengthwise shrinkage.
- However correlation coefficient values of ANN models and GLM model do not follow any clear trend. These values from ANN models are lower for bleached fabrics. Whereas in dyed fabrics (Reference State), the correlation coefficient

values are higher for GLM whereas the same is lower for dyed dry state.

- It is pertinent to mention that the differences in correlation coefficient values between the ANN and GLM analysis for the respective fabrics is marginal only.
- Therefore, on the basis of MSE and RMSE it is seen that ANN is a superior tool for analysis of the shrinkage of dyed and bleached knitted fabrics.

FABRIC WEIGHT (g/m^2): A careful observation of the data obtained by ANN method and Statistical Analysis by (GLM) gives following inferences:

- The values of MSE are lower in ANN compared to those by GLM.
- Same trend is obtained in RMSE values.
- However, maximum errors are higher in ANN in some cases whereas in others they are lower.
- Same trend is observed with minimum error.
- In correlation coefficient (R) the values do not follow any trend but no significant difference is observed in the respective values.

It can be seen comparing the MSE values between GSM and Shrinkage, the former are showing higher MSE and therefore RMSE values. This can be attributed to higher variation in measured values of GSM which is influenced by yarn count variation, stitch length variation and related fabric parameters.

Conclusion

- In considering shrinkage of dyed and bleached fabrics, the MSE and RMSE values as well as maximum and minimum errors are found to be lower for ANN compared to GLM values. This inference hold good for both widthwise and lengthwise shrinkage.
- In the same way in considering fabric weight (g/m^2), the MSE and RMSE values for ANN is found to be lower compared to GLM. This is valid for both dyed and bleached fabrics.
- However no trend in correlation coefficient values is observed for both shrinkage and fabric weight of the fabric studied although the difference is marginal.
- The case for both the dyed and bleached fabrics the values of correlation coefficient, MSE and RMSE are better for Reference State fabrics compared to the Dry state fabrics which is due to the fact that the fabrics in reference state are more stable compared to dry relaxed state.
- The above results for Shrinkage and Fabric Weight (g/m^2) from ANN are found to be better than from GLM because ANN trains the data and therefore there are scope of autocorrecting the results whereas no such training occurs in GLM.
- Another reason for why ANN is better is that it is much quicker than the GLM technique because neural networks are executing parallel and tolerate more errors and ANN can make rules without any implicit formula which are understandable in an environment of confusion and complexity.

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