ESTIMATION OF FOLDING AND LUMINANCE VALUES OF POLYPROPYLENE BCF YARNS USING ARTIFICIAL NEURAL NETWORK TECHNIQUE AND MODELING STUDY

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Abstract: *Polypropylene (PP) yarn commonly used in the production of machine carpets in the world is called BCF (Bulk Continuous Filament) and the production process consists of extrusion - cooling - lubrication - gravitation - texturizing - winding - twisting. It is a fact that PP yarn has a disadvantage in terms of softness and brightness compared to acrylic, polyamide and polyester used in the production of machine-made carpets. Twisting is also an effective parameter on the sense of softness that the yarn gives. Therefore, various R & D studies are carried out to determine the effect of production parameters on softness, crimp and brightness values of PP yarn and / or to determine the production parameters required for PP yarn production with the highest values. In this study, it is aimed to develop an artificial neural network (ANN) algorithm which determines the crimp and brightness values of the heat set and freeze PP yarns by changing the BCF production parameters, the reverse engineering approach and the quantitative or categorical values of the production parameters for the yarn end with the target crimp and brightness values .*

Keywords: *Artificial neural network, BCF, polypropylene, estimation, crimp, brightness.*

1 INTRODUCTION

Synthetic yarns are widely used for the production of machine carpet in the world. Therefore, academic studies about the production and processing of synthetic fibers are increasing day by day. In recent years, polypropylene (PP) has led to its versatile and widely used in the carpet industry due to its low density, good processability, low cost, good elasticity, low melting point such as having superior properties [1].

Production processes of BCF yarn consist of extrusion – cooling – lubrication – drawing – texturized - winding and twisting. Raw material and masterbatch are mixed with certain ratio at dosing unit and filaments are passed through the spinneret holes in molten state. PP filaments are appropriately cooled and drawing process is carried out to product yarn in certain yarn count. Texturized (crimping) process is applied to yarn for bring needed bulkness and elasticity feature. Produced yarns are winded on the bobbins. Twisting and/or fixation processes are applied to BCF PP yarn that will be used as carpet yarn to take its final form.

As the BCF PP yarn passes through all these stages, the yarn number, cross-sectional area, number of filaments, extruder temperatures, godet temperatures and pressures are measured. Within the scope of this study, the effects of these parameter values on the brightness and twist of the yarn will be determined. These determined parameter values will be used in the artificial neural network methodology to develop a model that predicts the effect of the yarn on the brightness and crimp properties.

Artificial neural networks (ANN) are parallel and decentralized data processing structures that are inspired by the human brain. ANN have processing elements, interconnected by weighted connections, and each processing element has its own memory. In a typical ANN structure, the input layer gets the outer information and transmits the information (input) to one or more cells in the hidden layer without any change through the forward feed method. The hidden layer determines the match between input and output (weight function) by trial and error method (learning). In cases where the specified output values and the target output values are incompatible, the weighting functions are updated with error diffusion method. The general principle diagram of an artificial neural network model is given in Figure 1.

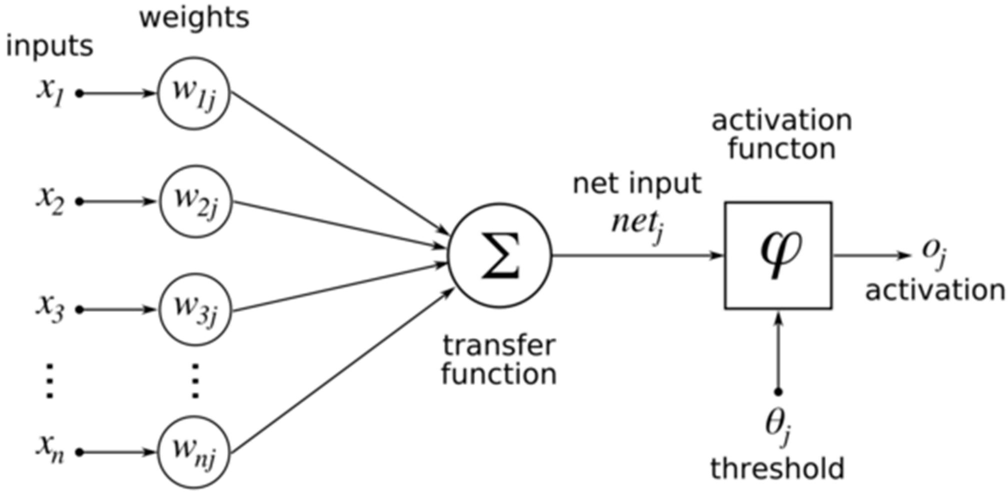

Figure 1 Artificial neural network model

2 EXPERIMENTAL

When consumer demands are evaluated in the carpet market, it seems that there is an increasing demand for softer, brighter and better resilience yarn and carpets to be produced from these yarns. In studies conducted for PP BCF yarns it is observed that changes in production parameters generally concern properties such as strength, elongation and compressibility.

Kebabcı reported that the rate of change in the spinning speed of the BCF PP yarn production and the cross-sectional shape of the yarn have a significant effect on the yarn count, strength, breaking length and the amount of spin finish oil taken by yarn [1].

Sarkeshick et al. examined the changes that the heat set process brings to nature in BCF PP yarns. Heat set operation reduces tenacity, modulus, bending rigidity, crimp and tensile values while increases the linearly density of yarns. As a result of the changes at the end of the process, the resilience values of BCF PP yarns are improved and become more suitable for carpet pile yarn. The results of the heat set effect will be used to compare the results obtained with the ANN algorithm [2]. Dadgar has studied on the estimation of heat-set PP yarn properties by artificial neural network method. It has been shown that yarn twist, yarn count and process temperature are effective on the final yarn count, yarn tension, crimp and packaging factor [3]. Demiryürek reported that the properties of polyester/viscose blended open-end rotor yarn Artificial Neural Networks (ANN) for estimation of production before production and statistical models. In conclusion, both ANN statistical models can be used for the prediction of yarn properties, however, the predictions of ANN gave more reliable results than statistical models [4].

2.1 Brightness and biological properties of BCF PP yarns

When consumer demands are evaluated, demands for softer, brighter and better resilience yarns and carpets to be produced from these yarns seem to be increasing day by day. The upgrading of the bending and compression module (increasing the softness) of the textile materials used in the carpet and the improvement of the resilience feature can be presented as a solution to the expectation in question. This viewpoint has led to various studies in order to improve the brightness, crimp, resilience and softness properties of PP BCF yarns.

BCF PP yarn of heat set, frieze or shaggy type is generally used as pile yarn in machine cases produced with wilton type face-to-face weaving technique. They affect the mechanical properties such as resilience, thickness, abrasion resistance, appearance preservation grade. Every stage of the production process has inputs that affect these properties. Their effects on yarn and carpet properties are made by collecting long-rolling production experiences and traditionally by trial and error. However, the abundance of data, the absence of a specific system for evaluation and the lack of standards in determining production parameter values have led to a lack of industrial practice following BCF yarn production. In particular, BCF PP yarn production parameters such as curl and brightness, such as extremely high commercial value of yarn properties cannot be estimated, the production parameters are changed according to the finished yarn properties are carried out by changing the process. These preliminary studies in production cause time and cost loss. All these imperfections necessitate the passage of ANN study.

2.2 *Artificial neural network method*

In this paper, MATLAB18 will be used for creation ANN algorithm and as the ANN algorithm feed-forward, back propagation, momentum learning rate rule, sigmoid transfer function models will be applied. The constituted ANN models for each yarn property, the model with the smallest error rate will be chosen as the best successful model. With the obtained regression equations it enables to forecast the yarn properties by the constituted models. According to the optimum BCF production conditions heat set and frieze BCF yarns will be produced and will be used for pile yarn of the sample carpets. Then the mechanical properties of the sample carpets and the current production carpets will be compared. Also it can be possible to evaluate the effect of a new spinneret flat section design to brightness of yarn.

3 RESULTS AND DISCUSSION

In this study, the BCF PP production parameters of Kartal Carpet Company were used for the data. Firstly the drawing ratio, yarn number, filament number, fixed heat, cooling heat, frieze heat and etc. were used by Meta-analyze as the scope of this Project (Table 1).

An analysis was made by MINITAB to determine the more effective parameters at the crimp value of heat set and frieze BCF yarns. As a result of this analysis the regression value is found 95.78% the effective five parameters are determined as number of twist, number of filaments, fixed heat, extruder exhausted temperature and drawing rate. Values are shown at Table 2.

Once the ANN input set was determined, the number of data variations was determined and samples were generated. The ANN module was operated until the optimal output result was achieved.

MATLAB18 software from Mathworks and the accompanying Neural Network Toolbox were used in the design and operation of the network. A feedforward back-propagation artificial neural network having two intermediate layers is formed to estimate the model with five input variables and an output variable. In Figure 2, there were 5 processor elements that provide input variables to the network and input layer contains 1 processor element which has network output of the dependent variable. As a result of the experiments performed for the number of processor elements in the intermediate layers, it was decided to have 2 hidden layers and 10 neurons.

Table 1 Parameter values of BCF PP yarn

DTex	PP	Number of twist	Number of filaments	Crimp number	Extruder exhausted temperature [°C]	Cooling temperature [°C]	Shooting rate	Texture temperature [°C]	Texture press [bar]
2600	25.9	145	255	4.74	238	19	3.2	160	7
2400	24.5	145	240	4.42	238	19	3.2	160	7
1750*2	24.5	170	160	5.67	238	18	3.3	155	7
2400*2	25.5	170	240	6.88	238	19	3.2	160	7
5000*2	24.5	140	255	9.52	238	19	3.2	160	7
2220	25.5	145	240	10.59	238	19	3.2	160	7

Table 2 MINITAB Results

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	8	1472.45	184.056	1178.20	0.000
PP	1	0.06	0.060	0.38	0.536
Number of twist	1	79.87	79.867	511.25	0.000
Number of filaments	1	5.63	5.629	36.03	0.000
Fixed heat	1	5.46	5.465	34.98	0.000
Extruder exhausted temperature [°C]	1	39.71	39.710	254.20	0.000
Cooling temperature [°C]	1	0.73	0.733	4.69	0.031
Fixed time [s]	1	0.91	0.911	5.83	0.016
Shooting rate	1	17.96	17.956	114.94	0.000
Error	415	64.83	0.156		
Lack-of-fit	57	15.74	0.276	2.01	0.000
Pure error	358	49.09	0.137		
Total	423	1537.28			

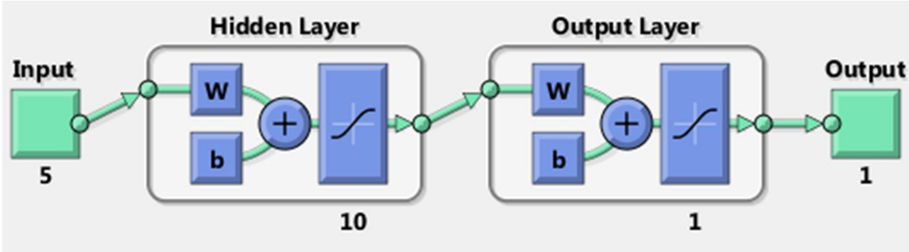

Figure 2 Artificial neural network architecture

The parameter values of the network were estimated based on the results of the experiment which gives the best error value. The selected parameter values of the network are shown in Figure3. In addition, learning and momentum coefficients, according to the results of the test that gives the least error; 0.01 for momentum and 0.09 for momentum.

After the creation of the model's architecture, the training process was started. At the beginning of the training process, the connection weights of the network are assigned randomly. 420 data was used as a training set for the training process. The remaining 150 data were separated as test data.

As a result of the experiments, a minimum error has been obtained. Since the training process is completed with a very small error rate, when the actual values and the estimated values were shown in the same graph, the values were almost overlapping. This relationship is shown in Figure 4.

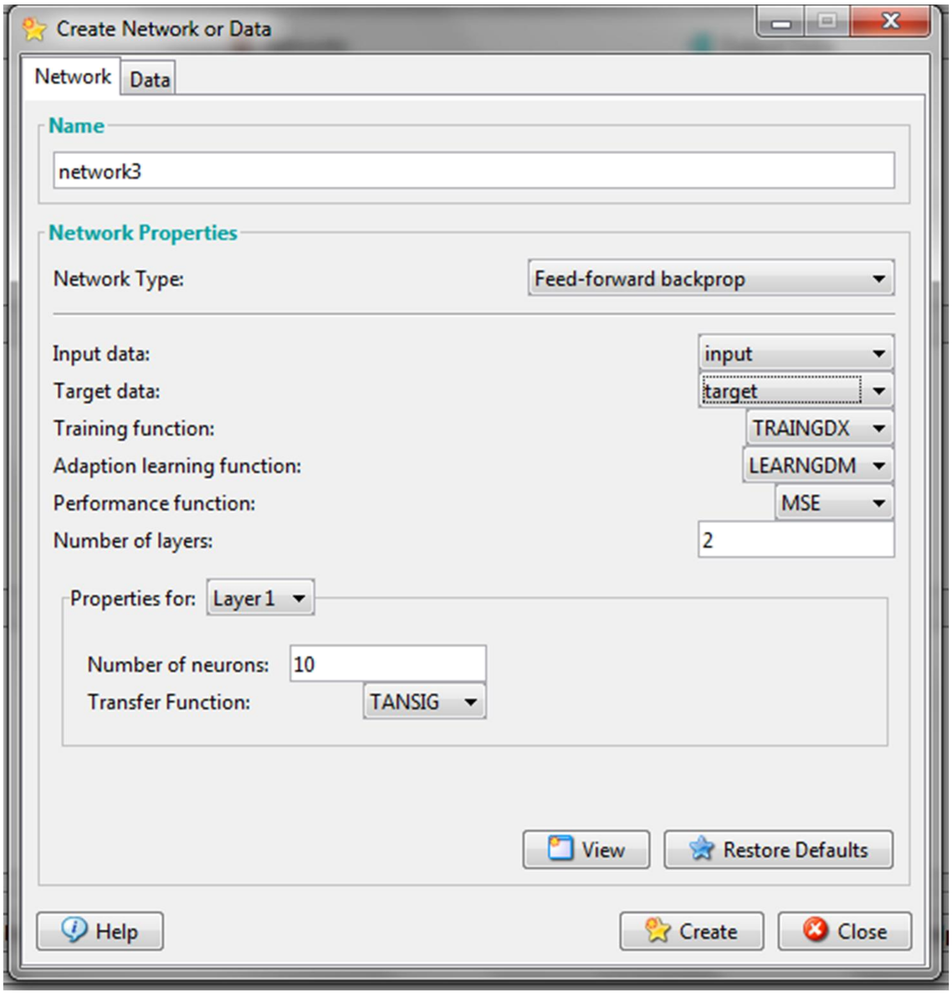

Figure 3 ANN parameters

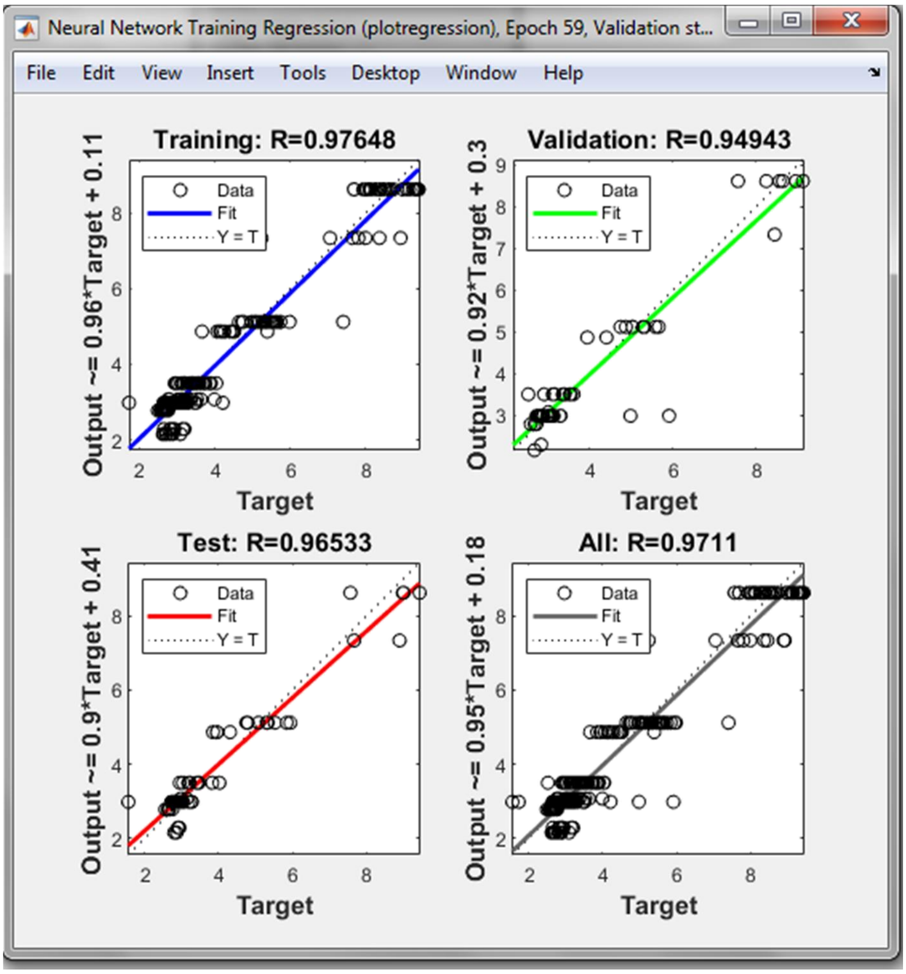

Figure 4 The regression results of ANN

Finally, the artificial neural network was asked to produce the result data for the 5 input variables that were not previously seen. The actual data and the results of the artificial neural network are shown in Table 3.

Table 3 Comparison of actual values with ANN output

Actual values	Estimated values	Difference	MSE values
2.87	2.99	-0.12	0.02
4.31	4.31	0	0.00
5.13	5.31	-0.18	0.03
4.44	4.25	0.19	0.03
5.62	5.31	0.31	0.10
3.73	2.99	0.76	0.54
2.94	2.99	-0.05	0.00
3.74	2.99	0.75	0.56
3.84	3.42	0.42	0.18

As seen in Table 3, the artificial neural network is very close to the actual values and produced results consistent with the actual values.

4 CONCLUSIONS

In this study, as a result of the evaluation of ANN algorithm, categorical and numerical data, it is ensured that outputs are obtained quickly and production parameters are optimized. In the study, 2017 data were used as network learning data, and the data for the first three months of 2018 were used in the estimation of the network.

In the study, the criteria used in the current structure were taken into consideration and the criteria which were of greater importance over the results were selected through the MINITAB program.

Then, the determined parameters the feed nets which are the most widely used in the neural networks and which give successful results were selected and the resulting error was minimized.

Thus, it is ensured that the yarn production of the BCF yarn parameters is determined by estimating the crimp values before the yarn production.

In the continuation of the study, it will be ensured that the yarn brightness data is collected in sufficient level. Then, the data will be estimated in the ANN module.

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