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Application of Artificial Neural Networks to Predict the Air Permeability of Woven Fabrics

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Abstract
Air permeability is one of the most important utility properties of textile materials as it influences air flow through textile material. Air permeability plays a significant role in textiles for clothing due to their influence on physiological comfort. Air permeability is also very important in technical textiles, especially for filtration, automotive airbags, parachutes, etc. The air permeability of textile materials depends on their porosity. There are a lot of structural properties of textile materials influencing air permeability and there are also statistically significant interactions between the main factors influencing the air permeability of fabrics. It justifies the application of artificial neural networks (ANNs) to predict the air permeability of textile materials on the basis of their structural parameters. Within the framework of the work presented ANNs were applied to predict the air permeability of cotton woven fabrics.

Key words: *woven fabrics, air permeability, artificial neural networks, modelling.*

Introduction

Air permeability is one of the most important utility properties of fabrics. It determines the resistance of fabrics (woven, knitted and nonwoven) to the passage of air [1, 2]. The higher the resistance, the tighter the fabric is. Air permeability influences the technical and utility functions of textile materials both in direct and indirect ways [3]. The air permeability of clothing directly influences gas exchange between a human being and the surroundings and, in the same way, the physiological comfort of the clothing user. Due to this fact air permeability is considered as one of the crucial comfort–related properties of clothing [4, 5]. It is strongly connected with the carbon dioxide release by the human body, the necessity of carrying sweat from the human skin, and body ventilation. In an indirect way the air permeability of fabrics influences their thermal insulation because the air movement through textile material causes the forced convection of heat. Air permeability is very important from the point of view of filtration functions of technical fabrics. It also plays a crucial role in fabrics for automotive airbags, parachutes, sails and similar applications.

The air permeability of textile materials depends of their structure, especially their porosity, which is characterised by the number and size of pores as well as by the pore size distribution [2, 4]. The porosity of woven fabrics results mainly from the structural parameters: the warp and weft diameter, warp and weft density, weave, fibre and yarn arrangement and fabric thickness [5]. Investigations confirmed that there is strong relationship between the porosity and air permeability. It was stated that the total porosity, size and number of pores affect the air permeability [6 – 8]. There are also other investigations showing that porosity not always allows to predict the air permeability of woven fabrics. Havlova demonstrated that relationships between the permeability and fabric structure cannot be investigated only on the basis of fabric porosity characterisation [9]. Porosity rather expresses air contained in the fabric structure, and says nothing about individual pores – size, size distribution and relative positions. Researchers [9,10] identify two kinds of porosity of woven fabrics:

- surface porosity,
- volume porosity.

The surface porosity, also called 'vertical porosity', is derived from the fabric geometry. It is defined as a complement to the woven fabric cover factor according to the following equation:

$$P_S = 1 - (d_1 g_1 + d_2 g_2 - d_1 d_2 g_1 g_2) \quad (1)$$

where:
P_S – surface porosity,
d_1 – diameter of the warp yarn,
d_2 – diameter of the weft yarn,
g_1 – warp density,
g_2 – weft density.

This kind of porosity does not take into consideration the pores in the yarns between fibres. It also completely neglects the type of weave, which is very important from the point of view of the size and placement of pores. ***Figure 1*** presents microscopic pictures of woven fabrics made of the same yarn at the same density of warp and weft. We can see that the application of different weaves results in an arrangement of warp and weft yarns and, in the same way, in differences in fabric porosity – the size and placement of pores [11, 12]. Especially in the case of canvas fabric (***Figure 1.c***) the yarns are arranged unevenly, which results in very small and very large pores occurring. This geometry of pores (***Figure 1.b*** and ***1.c***) does not fit to the theoretical models of woven fabric porosity [7, 13].

The volume porosity, P_V, reflects the volume of air spaces in the total volume of fabric, expressed by the following equation:

$$P_V = 1 - \frac{m}{h \cdot q_f} \quad (2)$$

where:
m – mass per square meter,
h – fabric thickness,
q_f – fibre density.

The volume porosity indicates the amount of air contained inside the fabric, but it does not give information about pore placement, their shape, size and size distribution.

The microporosity of yarn is also very important from the point of view of fabric permeability. The microporosity of yarn results from many factors connected

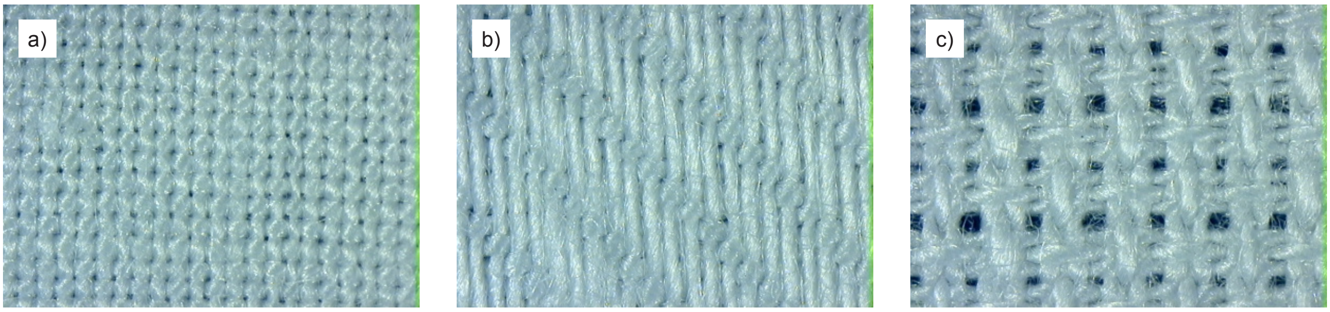


Figure 1. *Microscopic pictures of woven fabrics made of the same yarn and yarn density, but with different weaves: a – plain, b – twill, c – canvas [11].*

with fibres, yarn parameters and spinning technology. It depends on the kind and properties of fibres used for yarn manufacturing. The most important fibre-related factors are the stiffness and resilience of fibres as well as the shape of the fibres' cross-section. Technologies for the spinning, twisting and linkage of yarns also significantly influence the structure of yarn and, in the same way, its packing density and porosity [14 - 18].

Due to the fact that theoretical determination of the air permeability of woven fabrics is highly complex and difficult in relating the parameters to air permeability, establishing air permeability is usually undertaken experimentally. There have also been some theoretical attempts. Xiao et al. [19] identified four independent geometric variables relevant to woven fabric permeability: the radius of the flow channel, that of yarn, the shape factor of the yarn cross-section and the thickness of fabric. They developed an analytical model to predict the static permeability of woven fabric based on the measured geometry of the flow channel formed between yarns. This model can be used for permeability prediction when clear gaps exist between yarns, i.e. for loose fabrics [19].

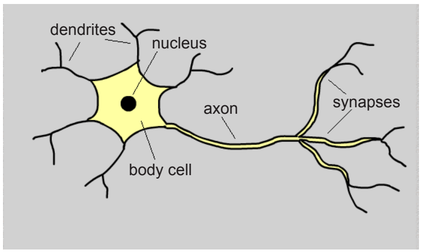


Figure 2. *Structure of biological neuron.*

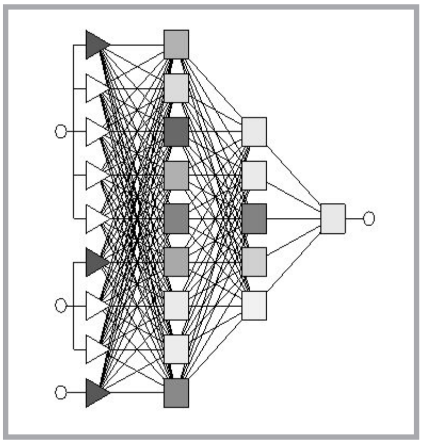


Figure 3. *Example of the scheme of an artificial neural network: MLP with 2 hidden layers.*

The complexity of relationships between the air permeability of woven fabrics and their structural parameters justifies the application of artificial neural networks for modelling this phenomenon. We can mention here a lot of arguments supporting the application of ANNs to predict the air permeability of woven fabrics.

First of all both porosity parameters: surface porosity and volume porosity are derivative parameters determined by the basic structural parameters of woven fabrics: linear density of warp and weft yarns as well as the density of warp and weft. When predicting the air permeability of fabrics based on the porosity, first it is necessary to calculate the fabric porosity and next to calculate the predicted air permeability. However, the fabric porosity calculated is also a predictive, theoretical value and does not reflect the real porosity of woven fabrics. Hence we have to establish two prediction errors: the first one while predicting porosity and the second while predicting air permeability.

What is more, in order to calculate the surface porosity we have to calculate the yarn diameter or measure it by means of available instruments. The calculation of yarn diameter also gives a predictive value with some prediction error. Theoretical models of yarn diameter commonly applied do not consider the spinning technology, which significantly influences the structure of the yarn manufactured. Measurement of the yarn diameter can be performed using instruments such as the Uster® Tester or OASYS, both of which provide values of the diameter of yarn from a bobbin, having a round shape of the cross-section, whereas the yarns in fabrics are usually flattened.

The porosity of woven fabrics made of yarns from staple fibres is also significantly affected by chemical agents present in the fabric structure. In the case of grey fabrics there is a sizing agent on the surface and between fibres of the warp yarn. In the finished fabrics there are different dyestuffs and other chemical agents applied to the fabric finishing. This aspect is very difficult to describe in a mathematic way.

ANNs are very helpful in the prediction of different, sometimes very complex phenomena, although they do not explain them. An artificial neural network (ANN) is a mathematical model that is inspired by the structure and functions of the human brain [20]. The human brain is a biological network of neurons, which are specialised biological cells able to transfer and process electrochemical signals. The biological neuron consists of a cell body with a nucleus, axon, dendrites and synapses (***Figure 2***).

The ANN consists of an interconnected group of artificial neurons. There are various types of ANNs of different topology, neural neutron models as well as algorithms of activation and learning function. ***Figure 3*** presents an example of an artificial neural network - Multilayer perceptron (MLP) with 2 hidden layers.

In most cases the ANN is an adaptive system that changes its structure based on external or internal information flowing through the network during the learning phase. ANNs are powerful tools for modelling, especially when the underlying data relationships are unknown [21]. ANNs are used in classification, categorisation, regression and optimisation problems. They are applied in different areas: medicine, economy, chemistry, physics, geology, etc. In textile engineering the application of ANNs has become more and more popular since 1990 [22]. Today ANNs are used in all fields of textiles: fibres, yarns, fabrics and clothing.

In fibres, ANNs are used for the classification of natural fibres of both plant [23] and animal [24] origin. In the area of synthetic fibres, ANNs have been applied for the identification of production control parameters and prediction of the properties of melt spun fibres [25, 26]. In spinning technology ANNs have been successfully used for modelling the technological processes and properties of yarns [27, 28]. In the area of fabrics ANNs have found application in the inspection of manufactured materials, in the detection and classification of fabric faults, in weave identification as well as in the predicting structural, mechanical and utility properties, such as tensile strength, stiffness, hand, permeability, drape, comfort related properties [29 - 35], etc. The prediction of air permeability by means of ANNs was also investigated by [36, 37], however investigations have been performed on the basis of a small number of data, which should influence the results significantly.

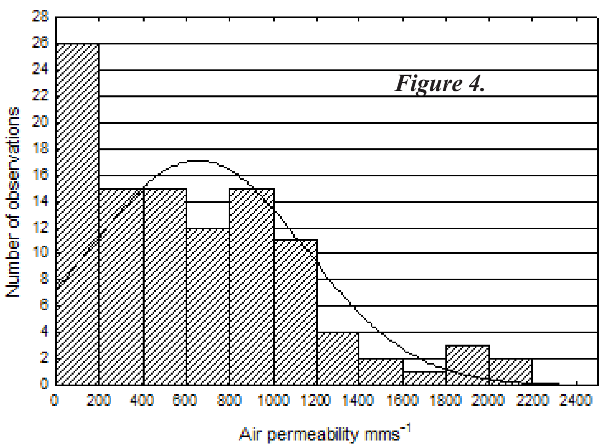
In the work presented ANNs were used for predicting the air permeability of woven fabrics.

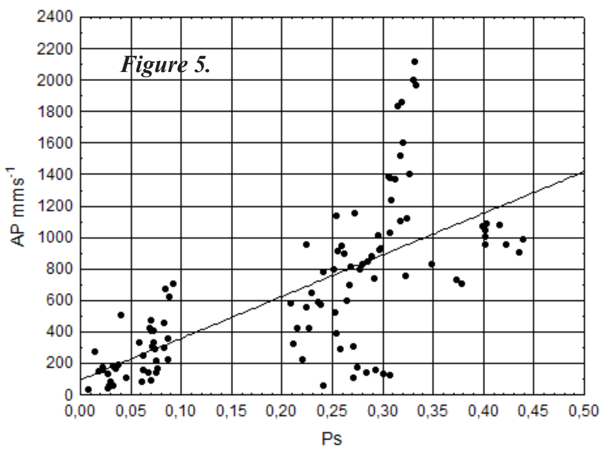
Materials and methods used

In order to analyse the possibility of the application of ANNs for modelling the air permeability of woven fabrics, first of all an appropriate set of woven fabrics of different structure was collected. They were 106 variants of cotton woven fabrics of different weave and compactness resulting from different linear densities of warp and weft yarns as well as from the different number of picks and ends. To manufacture the fabric samples, cotton yarns of linear density typical for European spinning mills were applied: 15, 20, 25, 30, 40, 50, 60 and 100 tex. Fabrics were woven in different weaves: plain, twill 3/1, twill 2/2, rep 2/2 (2), rep 1/1 (0,1,0) and hopsack 2/2 (0,2,0). Basic characteristics of the fabric set investigated are given in ***Table 1***.

Table 1. *Basic characteristics of the set of woven fabrics investigated; *) Linear density of warp and weft yarns were not measured. Nominal values were taken according to the declaration of the fabric manufacturers.*

Parameter	Unit	Measurement error	Average	Min.	Max.
Linear density of warp	Tt	*)	30.7	15	60
Linear density of weft	Tt	*)	51.1	20	100
Warp density	dm^{-1}	± 2	288.9	231	336
Weft density	dm^{-1}	± 2	164.2	73	301
Mass per square meter	gm^{-2}	± 1	178.0	68.3	379.0
Thickness	mm	± 0.1	0.57	0.22	1.31





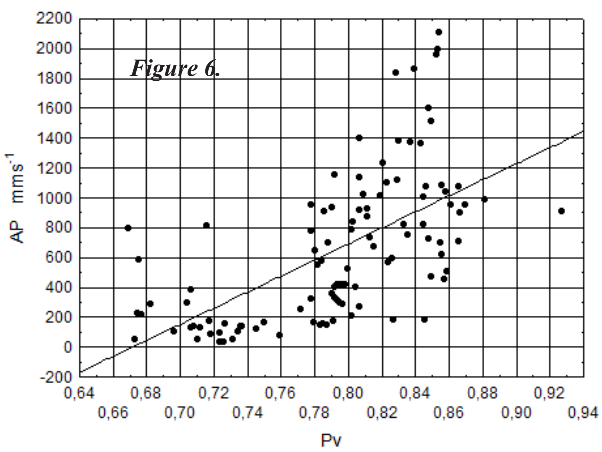


Figure 4. *Distribution of air permeability in the set of woven fabrics investigated.*

Figure 5. *Relationship between the surface porosity and air permeability of the woven fabrics.*

Figure 6. *Relationship between the volume porosity and air permeability of the woven fabrics.*

Table 2. Set of variables applied for modelling.

Variable	Scale	Role
Sample symbol	Nominal	Identifier
Weave		Input
Warp linear density	Numerical	
Weft linear density		
Warp density		
Weft density		
Mass per square meter		
Thickness		
Air permeability		Output

All fabrics were measured in the range of their basic structural parameters according to the standardised procedures. The measurement of air permeability was performed using the procedure described in Standard PN–EN ISO 9237 [38]. In this method the permeability of fabrics to air is expressed by the velocity of air passing through the sample in the direction perpendicular to the sample at the predetermined conditions: surface area, pressure drop and time.

The distribution of air permeability in the set of fabrics investigated is presented in ***Figure 4***.

For each fabric variant the values of surface porosity P_S and volume porosity P_V were calculated on the basis of those of the basic structural parameters. Relationships between the calculated values of both porosity parameters and air permeability (*AP*) are presented in ***Figures 5*** and ***6***.

Theresults obtained confirmed that there is a positive correlation between the porosity and air permeability; but the relationships are not strong. For the surface porosity the value of the correlation coefficient is 0.68 and for the volume porosity $R_{x,y}$ it is 0.61. Additionally in the case of the surface porosity, it is clearly seen (***Figure 5***) that there are two groups of fabrics: those of very low surface porosity, below 0.10, and those of porosity bigger than 0.20. For each group of fabrics a separate regression line could be derived expressing the relationships between the surface porosity and air permeability. Moreover there are fabrics of similar air permeability, although they belong to different groups from the point of view of surface porosity.

The results obtained confirmed that not always can the porosity be a good predictor of the air permeability of woven fabrics. Due to this fact it was decided to check the possibility of the prediction of air permeability by means of ANNs.

An analysis of the application of ANNs for modelling the air permeability of the woven fabrics was performed using STATISTICA software. Elaboration of the ANNs was done by the following steps:
- selection of variables for modelling,
- division of data into training, selection and test sets,
- selection of the type of ANN,
- selection of the initial configuration of the ANN,
- selection of a training algorithm.

The topic investigated represents a typical regression problem. The set of data used for the elaboration of the ANN consisted of:
- numerical variables: linear density of weft yarn, linear density of warp yarn, the number of weft threads per decimetre, the number of warp threads per decimetre, the mass per square meter, and thickness,
- nominal variable: weave.

The set of variables applied for modelling is presented in ***Table 2***.

Due to the small number of cases the nominal variable - weave was classified into two categories:
- plain,
- other.

In the work presented the nominal variable was introduced into the model as the numerical variable after its appropriate encoding. A two-state nominal variable was transformed into numeric values using an ordinal encoding: 0 and 1.

The data were divided into training, selection and test sets randomly: 70% of cases were selected for the training set and 15% - for selection and test sets. The multilayer perceptrons (MLP) was used in the investigation, which is the most popular type of ANN used in regression problems. Due to the small number of cases (75 in the training set) the structures: 1 hidden layer with 2 – 4 neurons were taken into the further consideration. For activation of neurons in the hidden layer the S-shaped functions were applied: logistic, exponential and hyperbolic tangents. In additional to the abovementioned functions for activation of the neuron in the output layer, the linear function was used. The quality of prediction of the ANNs designed was assessed on the basis of:
- comparison of values of air permeability observed and predicted,
- analysis of prediction errors,
- external validation.

Results and discussion

After several trials from 200 generated ANNs, 50 of them were saved. All ANNs generated have 7 neurons in the input layer and 1 neuron in the output layer. Next the best ones from the group of ANNs with 2, 3 and 4 neurons in the hidden layer were chosen from the point of view of prediction quality. ***Table 3*** presents the characteristics of ANNs chosen for predicting the air permeability of cotton woven fabrics. For comparison, in ***Table 3*** a network is also presented characterized by the lowest quality of prediction among all ANNs generated, marked as ANN 4 i.e., the lowest values of correlation coefficients between values observed and predicted as well as the highest prediction errors. It is marked as ANN 4.

They have different numbers of neurons in the hidden layer (***Table 3***). The ANNs generated differ between each other in

Table 3. Characteristic of ANNs chosen.

Parameter	ANN 1 MLP 7-4-1	ANN 2 MLP 7-3-1	ANN 3 MLP 7-2-1	ANN 4 MLP 7-2-1
Number of neurons in hidden layer	4	3	2	2
Correlation coefficient between values observed and predicted (training set)	0.966	0.956	0.958	0.880
Correlation coefficient between values observed and predicted (selection set)	0.931	0.918	0.897	0.901
Correlation coefficient between values observed and predicted (test set)	0.970	0.962	0.940	0.891
Prediction error (training set)	9135	11800	11420	36080
Prediction error (selection set)	10970	13186	15630	16350
Prediction error (test set)	3879	3720	5746	10040
Activation function (hidden neurons)	hyperbolic tangent		logistic	exponential
Activation function (output neuron)	linear	hyperbolic tangent		

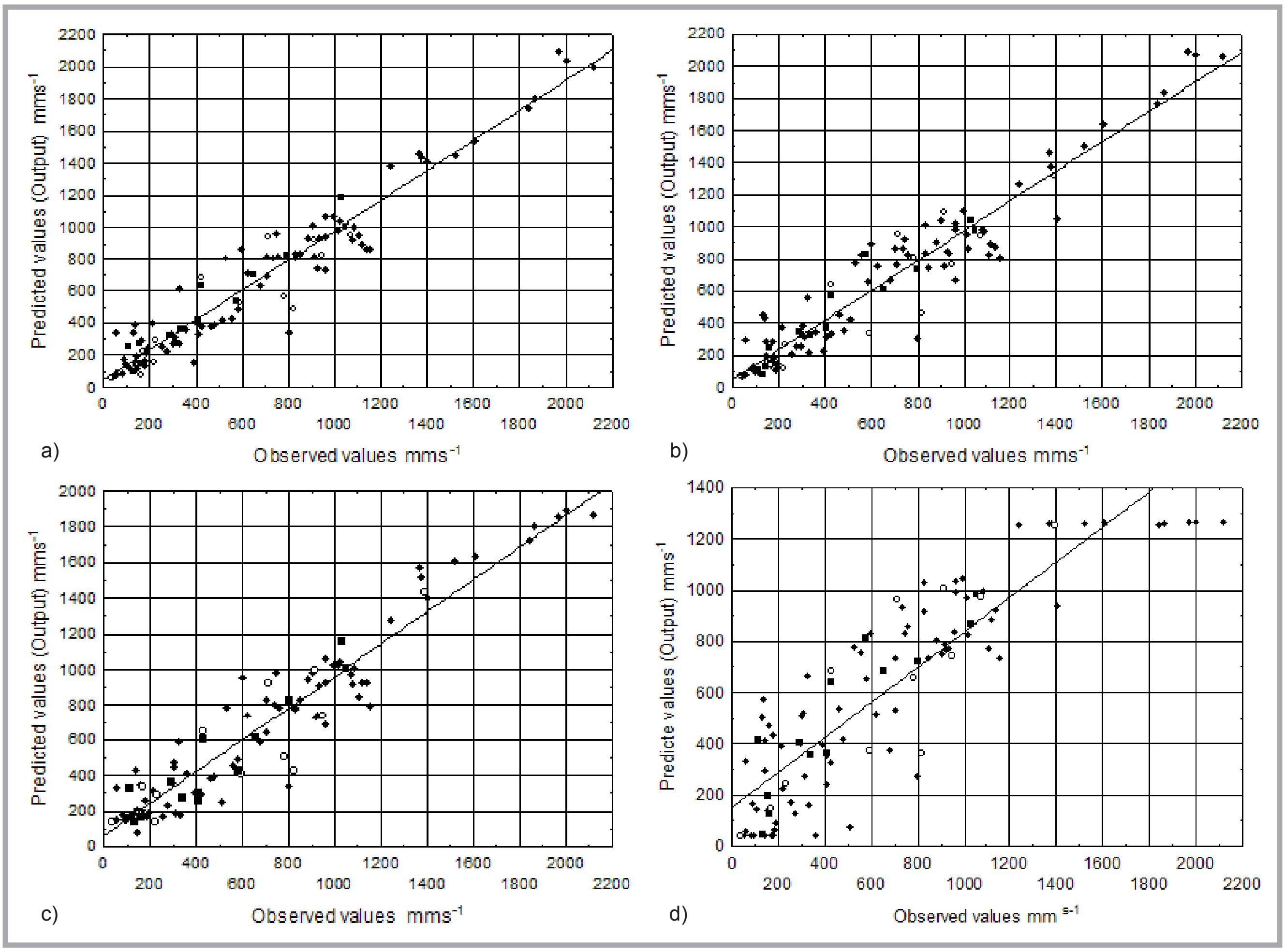


Figure 7. a) - ANN 1, b) ANN 2, c) ANN 3, d) ANN 4 – comparison of observed and predicted values of the air permeability of woven fabrics: ♦ – training set, ■ – selection set, ○– test set.

the range of the function of activation of hidden and output neurons. ANN 1 with 4 neurons in the hidden layer is characterised by the highest correlation coefficient between the values of air permeability observed and predicted for all sets: training, selection and test (***Table 3***). ANN 2 is characterised by slightly lower values of the correlation coefficient in comparison with ANN 1; nevertheless the prediction errors for the training and selection sets are significantly higher in the case of ANN 2 than in that of ANN 1. The lowest quality of prediction occurred for ANN 4.

Figure 7 present a comparison of values of the air permeability of woven fabrics observed and those predicted by means of the ANNs elaborated.

The quality of predicting the air permeability of woven fabrics using the ANNs generated was assessed by external validation done on the basis of results for 9 variants of cotton woven fabrics different from those applied in the generation of the ANNs. All fabrics taken for external validation were chosen randomly. They were purchased on the market, but selected from the same kind of woven fabrics used in the first part of the experiment to design the ANNs. The ANNs designed were dedicated for such kinds of woven fabrics. Fabrics 2 and 9 are in the range of parameters occurring in the set of data used to design the ANNs. The difference in weft density (sample 2) and thickness (sample 9) are in the range of the measurement error.

Characteristics of the woven fabric variants taken for external validation are presented in ***Table 4***.

The analysis of prediction quality included a comparison of observed and predicted values of air permeability as well as values of statistical measures:
- correlation coefficients between the values observed and predicted,
- mean square error - *MSE*:

Table 4. *Characteristics of woven fabric variants taken for external validation.*

No.	Weave	Linear density of wrap, T_{tex}	Linear density of weft, T_{tex}	Mass per square meter, gm^{-2}	Warp density, dm^{-1}	Weft density, dm^{-1}	Thickness, mm
1.	Twill 3/1 S	50	50	225.0	317	116	0.70
2.		60	60	241.0	321	72	0.91
3.	Plain	15		151.8	271	170	0.53
4.			20	101.5	278	260	0.34
5.			40	133.6	276	210	0.44
6.			30	85.9	268	146	0.37
7.			40	148.7	304	232	0.29
8.	Twill 3/1 S	30	50	132.0	242	111	0.54
9.		50		279.0	326	139	1.32

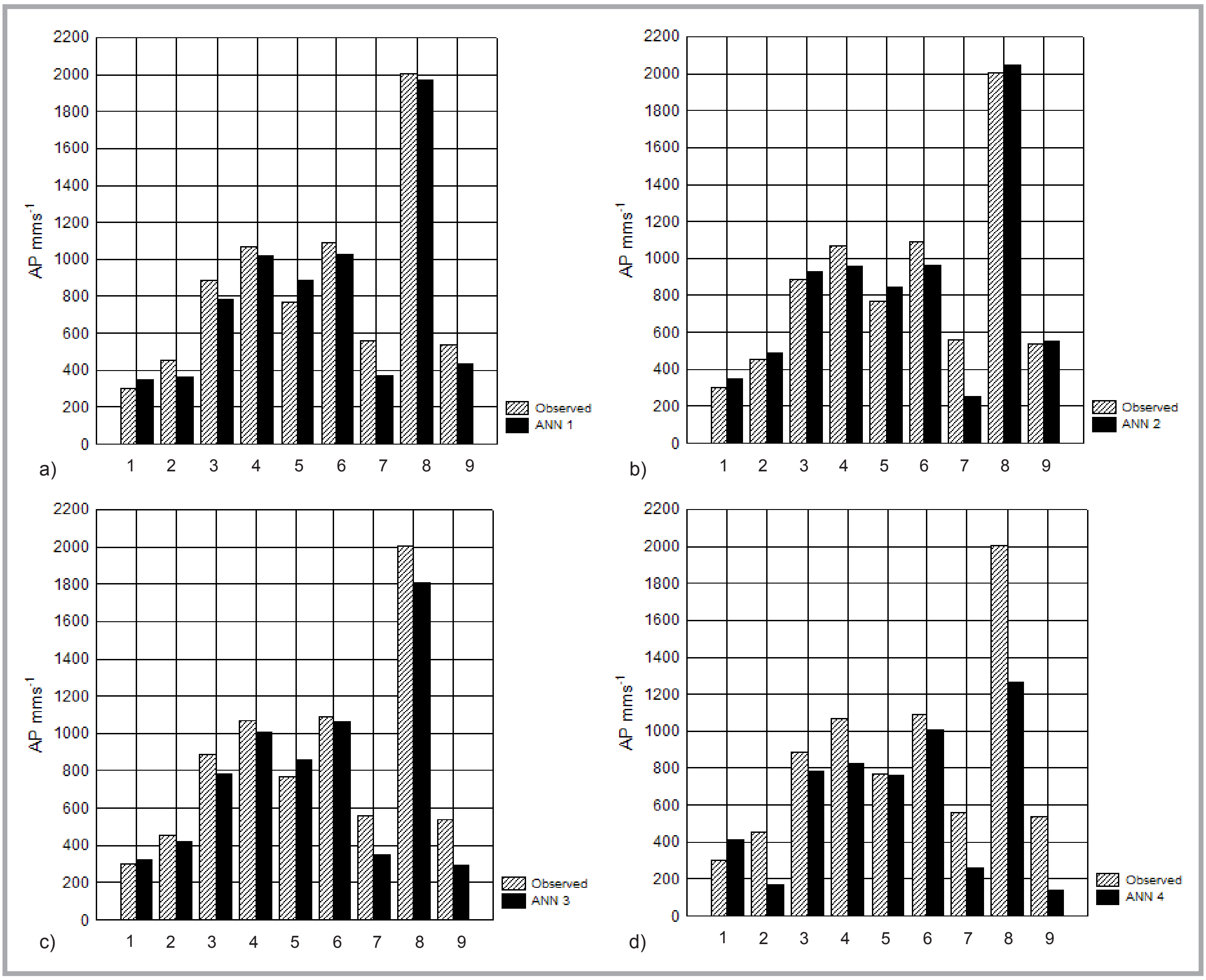


Figure 8. *Comparison of observed values of air permeability measured by the standardised method and those predicted using: a) ANN 1, b) ANN 2, c) ANN 3, d) ANN 4 elaborated.*

$$MSE = \frac{1}{m}\sum_{i=1}^{m}\left(y_i - y_i^P\right)^2 \quad (3)$$

- root mean squared error - *RMSE*:

$$RMSE = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(y_i - y_i^P\right)^2} \quad (4)$$

- mean absolute error - *MAE*:

$$MAE = \frac{1}{m}\sum_{i=1}^{m}\left|y_i - y_i^P\right| \quad (5)$$

- mean percentage squared error - *MPSE*:

$$MPSE = \frac{1}{m}\sum_{i=1}^{m}\left(\frac{y_i - y_i^P}{y_i^P}\right)^2 \quad (6)$$

- mean absolute percentage error - *MAPE*:

$$MAPE = \frac{1}{m}\sum_{i=1}^{m}\left|\frac{y_i - y_i^P}{y_i^P}\right| \quad (7)$$

where:

m – number of cases,
y_i – observed value of i^{th} case,
y_i^P – predicted value of i^{th} case.

A comparison of the observed values of air permeability measured by the standardised method [34] and those predicted using the ANNs designed is presented in ***Figure 8***.

Values of statistical measures calculated characterising prediction quality for the external set of fabrics are presented in ***Table 5***.

Correlation coefficients between the values of fabric air permeability measured and predicted for ANN 1 – ANN 3 are higher than 0.97. Even in the case of the worst ANN taken for comparison – ANN 4, the correlation coefficient is quite high – 0.88. Nevertheless the values of air permeability predicted with ANN 4 (the worst one) differ significantly from the air permeability of the fabrics measured in the external set (***Figure 8.d***). The errors of prediction with ANN 4 are also much higher than those for the rest of the ANNs designed.

Table 6 presents values of the prediction errors for each variant from the external set of woven fabrics. The prediction error was calculated according to the following formula:

$$\Delta p = \frac{\left|y^p - y\right|}{y^p} \quad (8)$$

where:
Δp – relative prediction error,
y^p –value predicted,
y –value observed.

The lowest values of relative prediction error can be observed in the case of ANN 1 and ANN 2. For ANN 1 the values of the prediction error are in the range

0.02 – 0.25, with exception of variant 7. For ANN 2, in majority of cases (8 cases in 9) the values of the relative prediction error do not exceed 0.15. In the case of variant 7 all values predicted using the ANNs designed differ significantly from the value of air permeability measured. It is difficult to determine the reason for such big differences. They may be caused by the fabric finishing. The woven fabrics for external validation were purchased on the open market and we do not have any data concerning fabric finishing.

The biggest differences between the values of air permeability observed and predicted were noted for ANN 4, which is according to expectations. In the first step of the investigation ANN 4 was assessed as the worst among all ANNs generated and saved taking into consideration the quality of prediction. ANN 4 was included in further consideration in order to compare it with selected ANNs: ANN 1 – ANN 3. The results presented in table 6 confirm that ANN 4 is characterised by the lowest quality of prediction. In 3 cases the relative prediction error is higher than 1.0, and only in 2 is the value of the prediction error lower than 0.25.

In general, we can state that the results obtained confirm the good quality of the ANNs designed for predicting the air permeability of cotton woven fabrics. In the majority of cases the values predicted with the ANNs are close to those measured for the air permeability of woven fabrics from the external set. We can also observe some cases with significant differences between values of air permeability observed and predicted.

The results obtained confirmed that the ANNs can be successfully applied to predict the air permeability of woven fabrics on the basis of their basic structural parameters. According to the Author's opinion, the ANNs can be implemented in industrial practice. However, some researchers consider that ANNs are not of practical value, and presently this method has basically been abandoned. I disagree with this opinion. Establishing the basic structural parameters: weave, warp and weft linear density, and the number of picks and ends is the starting point for designing woven fabrics and their manufacturing process. Moreover in daily industrial practice the above-mentioned basic structural parameters are measured within the framework of intermediate and final quality control. As a result, the

Table 5. *Values of statistical measures calculated characterising prediction quality for the external set of fabrics.*

Parameter	Value			
	ANN 1 MLP 7-4-1	ANN 2 MLP 7-3-1	ANN 3 MLP 7-2-1	ANN 4 MLP7-2-1
Mean squared error in $(mm\ s^{-1})^2$	10128	15200	18924	108330
Root mean squared error in $mm\ s^{-1}$	100.64	123.28	137.56	329.14
Mean absolute error in $mm\ s^{-1}$	90.10	89.44	111.39	254.56
Mean percentage squared error	0.0488	0.1722	0.1231	1.4948
Mean absolute error	0.1714	0.2063	0.2242	0.8034
Correlation coefficient	0.9848	0.9719	0.9748	0.8770

Table 6. *Values of prediction errors for each variant from the external set of woven fabrics.*

No. of variant	ANN 1	ANN 2	ANN 3	ANN 4
1.	0.14	0.14	0.06	0.27
2.	0.25	0.07	0.08	1.75
3.	0.14	0.04	0.14	0.14
4.	0.05	0.12	0.07	0.30
5.	0.14	0.09	0.11	0.00
6.	0.06	0.13	0.03	0.08
7.	0.50	1.22	0.59	1.19
8.	0.02	0.02	0.11	0.58
9.	0.25	0.02	0.84	2.91

technical staff of a weaving mill have a huge amount of data, many times bigger than those possessed by the researches, which can be used for the elaboration of ANNs, especially for a specific weaving mill. Of course, it should be done with the help of a scientist dealing with artificial intelligence.

The investigations presented are based on a relatively small number of data, which is a common problem for researchers. Nevertheless by performing the investigations presented, the author has demonstrated the possibility of ANN application for modelling the air permeability of woven fabrics on the basis of their basic structural parameters, commonly measured in industrial practices.

In my opinion, now is an appropriate time to put research results in the area of ANNs into practice instead of abandoning this promising and easy-to-use prediction method.

Conclusions

The complexity of relationships between the air permeability of woven fabrics and their structure justifies the purposefulness of the application of ANNs to predict fabric permeability. Investigations carried out in the work presented confirmed that ANNs can be successfully applied to predict the air permeability of woven fabrics. The statistical analysis of prediction errors, the comparison of observed and predicted values as well as the validation based on the results of the external set of fabrics confirmed the good quality of air permeability prediction using the artificial neural networks elaborated. Nevertheless analysis of the results separately for particular fabric variants from the internal set of fabrics showed that there are some cases characterised by a high value of relative prediction error, which can be caused by factors connected with the kind of finishing of the fabrics investigated. This factor was not taken into consideration while designing the ANNs.

Cotton woven fabrics were manufactured in order to perform the investigation presented. The fabrics were finished in the same way – classical starch finishing. Thus the ANNs designed can be applied to predict the air permeability of such a kind of fabric. It is possible to prepare an ANN for the prediction of the air permeability of cotton woven fabrics finished in different ways. But in order to do this it is necessary to have an appropriate set of input data based on the measurement of a bigger number of fabric variants with different finishing. Such a set of necessary data is available in the textile industry.

In order to apply the ANNs successfully it is necessary to have knowledge of ANNs, especially in the range of the kind of ANN, its topology, learning algorithm and functions of activation. However, knowledge and ability to work with the ANN is only the starting point for further investigation. Understanding the phenomenon investigated is equally important for correct work with ANNs and reliability of results.

Very important is the proper preparation of a set of input data, especially in the aspect of representativeness and the number of data as well as appropriate categorisation of data from the point of view of a uniform number of cases in each category.

The choice of the best ANN from among all ANNs generated and saved has to be based on the analysis of many factors, such as prediction errors, even the influence of particular input data on the model, and results of prediction for the internal set of data.

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