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Image Analysis Technique for Evaluation of Air Permeability of a Given Fabric

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Abstract—*The study of the effect of the air transmission through the fabric is an important factor in textile industries. Recent research trends suggest that a modeling and simulation technique to determine the quality and comfort of the fabric is still to be explored. Ahmet et al. (2005) have studied the concept of determining porosity in textile fabric using image analysis techniques.*

In this paper we have made an attempt to develop a Java and MATLAB based simulation software to determine brightness index using image analysis. The statistical models are also developed using regression techniques. The models are simulated through STATGRAPHICS software and the comparison with experimental results suggests that the results are in good agreement with the experimental matrix.

Keywords— *Air permeability, image processing, statistical techniques.*

I. INTRODUCTION

A woven fabric is made up of yarns wherein warp interlaces with the weft as seen in Figure 1. On critical examination of the fabric structure, it can be understood that the fabric is formed of yarns as well as air spaces and the distribution of air spaces can affect properties like warmth/protection in case of apparels and filtration efficiency (in case of industrial fabrics).

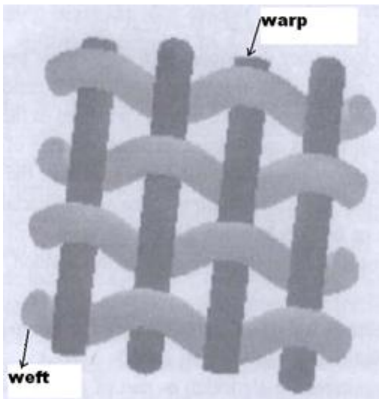


Fig. 1: Fabric warp and weft

The fabric properties can be put under various categories like mechanical, aesthetic, transmission, low stress mechanical and special properties. Just like the mechanical properties, the transmission (air or water) properties are also important and it occurs in the fabric like industrial filters, tents, sail cloths, parachutes, raincoat materials, shirting and airbags [1]. This work is concerned with only the air transmission (permeability) property of fabrics.

Porosity is the ratio of airspace to the total volume of the fabric which may be expressed in terms of percentage. Porosity is similar to permeability. Air permeability can be defined as the volume of air measured in cubic centimetres passed per second through one square centimetre of fabric at a pressure of one centimetre of water [7]. The air resistance of a fabric is the time in seconds for one cubic centimetre of air to pass through one square centimetre of the fabric under a pressure head of one centimetre of water. Air resistance is exactly opposite of air permeability.

Today technical textiles and composites are gaining popularity [4]. The geometry of the structure can affect the permeability of the fabric [5]. Even the finish of the fabric can have some influence on the permeability; however, the porosity of a fabric may remain unchanged [7].

The fabric properties such as ends/inch may affect the air permeability and the rate at which air flows through it. The ends/inch decides the openness of a given fabric and more open the structure; greater is the air permeability.

The cover of the fabric is defined as the ratio of fractional area covered by the yarns to the total area of the fabric. Openness of the fabric can also be judged in terms of cover and can be found out by using the empirical relations. It can be clearly under stood that greater is the area occupied by the constituent yarns lesser will be its cover. Hence, it may be concluded that a fabric with greater cover is expected to have lesser air permeability.

A textile is deformable and the pore size distribution in it is of non-uniform nature. In order to find out the pore size or its distribution using conventional methods like yarn diameter measurement and pore size would be very complicated and time consuming. These difficulties can be overcome by image analysis which is very popular tool in today's scenario [3].

Since woven fabric is porous, it allows light to pass through it, and the photographic image of a fabric shows the pore size distribution. Various image analysis techniques like grayscale conversion, thresholding and edge detection can be used.

II. EXPERIMENTAL SETUP, PROCEDURES AND RESULT

A. Experimental setup

Fig. 2: Air Permeability Tester

To obtain the air permeability of a fabric sample, the instrument Multiplex Air Permeability Tester is used, as shown in Figure 2. It consists of two rubber gaskets and a guard ring, between them a given sample (to avoid leakage) is clamped to ensure that the entire amount of air flows through the test area which is of 1 inch diameter [6]. The apparatus has four rotameter namely R_1, R_2, R_3 and R_4 to measure air flow in cubic centimetres per second and calibrated at 20° C and pressure of 760 mm mercury. These rotameters have a capacity covering different ranges of air flow such as $R_1 = 0.05\text{-}0.5$, $R_2 = 0.5\text{-}3.5$, $R_3 = 3\text{-}35$ and $R_4 = 30\text{-}350$. There are two knobs on the machine namely the fluid level and the suction level

B. Procedure

Nine fabric samples with different construction and composition are considered for the experimental purpose. Before placing the fabric in the clamp, the zero on the capillary of the pressure gauge (as seen on right side of the Figure 2) has to be set, with help of fluid level.

On clamping the fabric and opening the rotameter, the float rises. With the help of air suction knob the water in the capillary is set at 100 Pascal. If the float rises sufficiently in the rotameter then the reading will be noted or else the procedure is repeated until the most suitable value for the fabric under test is obtained. From the readings of rotameter either the air permeability or the resistance can be computed. The readings are given in $m^3/m^2/s$.

C. Experimental Results

Air permeability for the nine samples obtained is placed in the experimental matrix as shown below.

TABLE I: AIR PERMEABILITY USING EXPERIMENTAL METHOD

Sample	Air Permeability
S1	6800
S2	4100
S3	3200
S4	2600
S5	1950
S6	1850
S7	615
S8	500
S9	375

III. EXPERIMENTAL SETUP, PROCEDURES AND RESULTS OF FABRIC IMAGE PROCESSING

A. Experimental setup for taking images of fabric samples

Fig. 3: Computer Microscope

Computer microscope Intel play QX3 as shown in figure 3, was used to take the photographic images of the fabric samples. Arranging proper light and focus, images with 60X zoom factor were captured from the bottom. Five images for each fabric sample were taken having a maximum of 512x384 pixels.

The images of all the fabrics are shown in the figures 4(a) to 4(h).

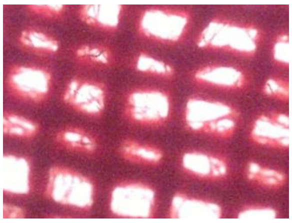


Fig 4(a)

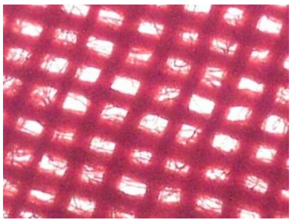
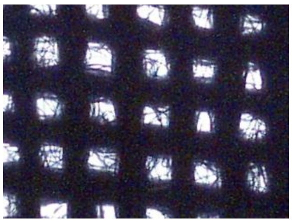


Fig 4(b)



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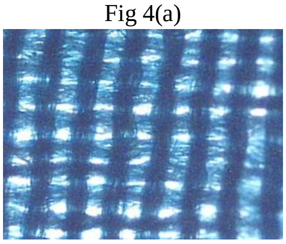

Fig. 4(d)

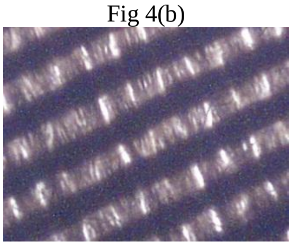

Fig. 4(e)

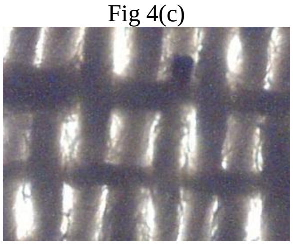

Fig. 4(f)

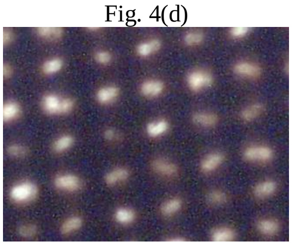

Fig. 4(g)

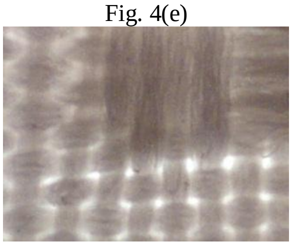

Fig. 4(h)

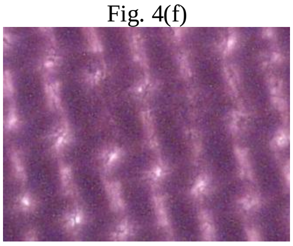

Fig. 4(i)

B. Image Analysis algorithm for estimating brightness index (Bi, i = 1…..9)

The images that were captured as above were colored and were converted to grayscale images. A common threshold was decided from our observations, to determine whether the pixel represents a brightness or non-brightness pixel. A count of such brightness pixels is obtained to determine brightness index of each fabric sample. Image processing algorithm, with implementation in object oriented programming language Java was used.

C. Results of image analysis

Table 2 shows the results for brightness index of the images of various fabric samples obtained using our algorithm.

TABLE II: BRIGHTNESS INDEX USING IMAGE ANALYSIS TECHNIQUE

Sample	Bi1	Bi2	Bi3	Bi4	Bi5	Average Bi
S1	20.403545	29.21906	22.84749	21.57237	26.56148	24.12079
S2	21.211243	27.95054	22.20306	27.03196	23.57686	24.39473
S3	10.9817505	10.09623	10.72795	9.970602	10.97209	10.54972
S4	18.0053	18.8385	23.08553	18.0308	18.82121	19.35627
S5	8.580526	10.19999	9.862265	10.41412	12.78992	10.36936
S6	17.597454	9.44.104	17.34212	12.7182	10.29358	14.48784
S7	3.3513386	6.654358	6.069946	9.621683	5.023702	6.144206
S8	19.163513	14.09607	18.09794	13.12714	23.12622	17.52218
S9	1.9922892	1.522827	1.205444	0.870768	1.900737	1.498413

IV. STATISTICAL SIMULATIONS

Nonlinear-regression linear analysis is used to predict brightness index and air permeability of a sample fabric.

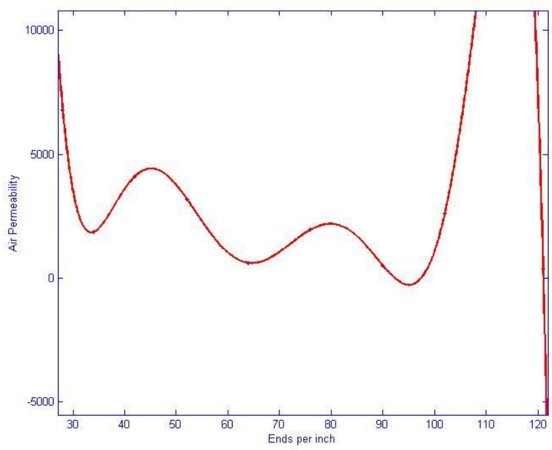

Fig. 5: Air Permeability versus Ends per inch

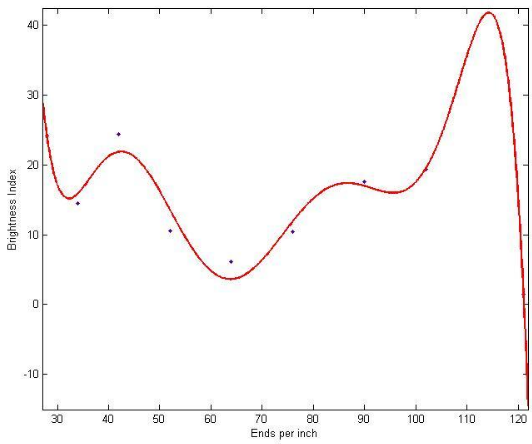

Fig. 6: Brightness versus Ends per inch

Figure 5 and Figure 6 shows the plots of ends per inch versus air permeability and ends per inch versus brightness index respectively from experimental observations and they are fitted by seven degree polynomials. The figure suggests that the air permeability and brightness index behaves nonlinearly as ends per inch increases.

Therefore, we may use the models of the form

$$B = ke^{ax} \tag{1.0}$$

where, B is the Brightness index, x is ends/inch while a and K are constants.

Similarly for air permeability index we may use

$$B_1 = k_1 e^{a_1 x} \tag{2.0}$$

where, B_1 is the air permeability, x is ends/inch while a_1 and k_1 are constants.

STATGRAPHICS software was used to determine the nonlinear regression coefficients.

V. RESULTS AND DISCUSSIONS

A. Regression analysis for equation brightness index and ends per inch

1) Nonlinear Regression:

Dependent variable: B
Independent variables: x
Function to be estimated: ke^{ax}
Initial parameter estimates:
k = 0.1
a = 0.1
Estimation method: Steepest descent
Estimation stopped after maximum iterations reached.
Number of iterations: 31

2) Estimation results:

Table III: ESTIMATION RESULTS

Asymptotic	**95.0%**			
		Asymptotic	**Confidence Interval**	
Parameter	**Estimate**	**Standard Error**	**Lower**	**Upper**
K	0.074201	0.968968	-2.21705	2.36545
A	0.0976832	0.100943	-0.141009	0.336375

3) Analysis of Variance:

TABLE IV: AOV RESULTS

Source	***Sum of Squares***	***Df***	***Mean Square***
Model	-1.0431E8	2	-5.21551E7
Residual	1.04313E8	7	1.49018E7
Total	2327.32	9	
Total (Corr.)	494.24	8	

R-Squared = 0.0 percent
R-Squared (adjusted for d.f.) = 0.0 percent
Standard Error of Est. = 3860.28
Mean absolute error = 1368.07
Durbin-Watson statistic = 0.930822
Lag 1 residual autocorrelation = 0.0473368

4) Analysis of the results:

The output shows the results of fitting a nonlinear regression model to describe the relationship between B (brightness index) and one independent variable x (ends/inch).
The equation of the fitted model is

$$B = 0.074201e^{0.0976832x}$$

In performing the fit, the estimation process was stopped before convergence due to the maximum number of iterations having been exceeded. To continue with the estimation process, set the initial estimates of the unknown parameters to the current estimates and start the estimation process again.

The R-Squared statistic indicates that the model as fitted explains 0.0% of the variability in b. The adjusted R-Squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 0.0%. The standard error of the estimate shows the standard deviation of the residuals to be 3860.28. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu. The mean absolute error (MAE) of 1368.07 is the average value of the residuals. The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in your data file.

The output also shows asymptotic 95.0% confidence intervals for each of the unknown parameters. These intervals are approximate and most accurate for large sample sizes.

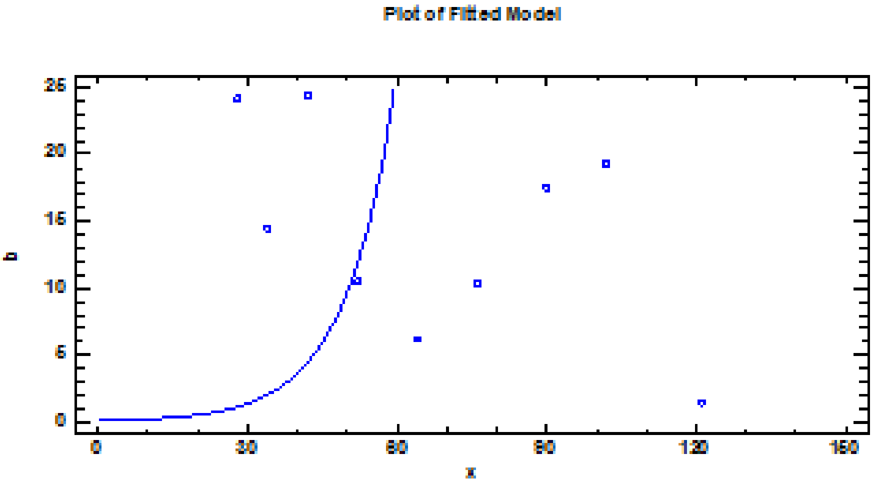

Fig 7: Plot of fitted model – Brightness Index Versus Ends per Inch

B. Regression Analysis for equation Air permeability and Ends per inch

1) Nonlinear Regression – B_1(air permeability):

Dependent variable: B_1
Independent variables: x
Function to be estimated: $k_1 e^{a_1 x}$
Initial parameter estimates:
k1 = 0.1
a1 = 0.1
Estimation method: Steepest descent
Estimation stopped after maximum iterations reached.
Number of iterations: 31
Number of function calls: 92

2) Estimation Results

Table V: ESTIMATION RESULTS

Asymptotic 95.0%				
		Asymptotic	*Confidence Interval*	
Parameter	*Estimate*	*Standard Error*	*Lower*	*Upper*
k1	0.0755225	1.26516	-2.9161	3.06715
a1	0.0978058	0.129588	-0.208623	0.404234

3) Analysis of Variance

Table VI: AOV RESULTS

Source	**Sum of Squares**	**Df**	**Mean Square**
Model	-9.39709E7	2	-4.69854E7
Residual	1.82015E8	7	2.60021E7
Total	8.80439E7	9	
Total (Corr.)	3.43149E7	8	

R-Squared = 0.0 percent
R-Squared (adjusted for d.f.) = 0.0 percent
Standard Error of Est. = 5099.23
Mean absolute error = 3260.83
Durbin-Watson statistic = 0.639991
Lag 1 residual autocorrelation = 0.276021

4) Analysis of Results

The output shows the results of fitting a nonlinear regression model to describe the relationship between B_1 (air permeability) and one independent variable x (ends/inch).

The equation of the fitted model is

$$B_1 = 0.0755225 e^{0.0978058x}$$

In performing the fit, the estimation process was stopped before convergence due to the maximum number of iterations having been exceeded. To continue with the estimation process, set the initial estimates of the unknown parameters to the current estimates and start the estimation process again.

The R-Squared statistic indicates that the model as fitted explains 0.0% of the variability in b1. The adjusted R-Squared statistic, which is more suitable for comparing models with different numbers of independent variables, is 0.0%. The standard error of the estimate shows the standard deviation of the residuals to be 5099.23. This value can be used to construct prediction limits for new observations by selecting the Forecasts option from the text menu. The mean absolute error (MAE) of 3260.83 is the average value of the residuals. The Durbin-Watson (DW) statistic tests the residuals to determine if there is any significant correlation based on the order in which they occur in your data file.

The output also shows asymptotic 95.0% confidence intervals for each of the unknown parameters. These intervals are approximate and most accurate for large sample sizes.

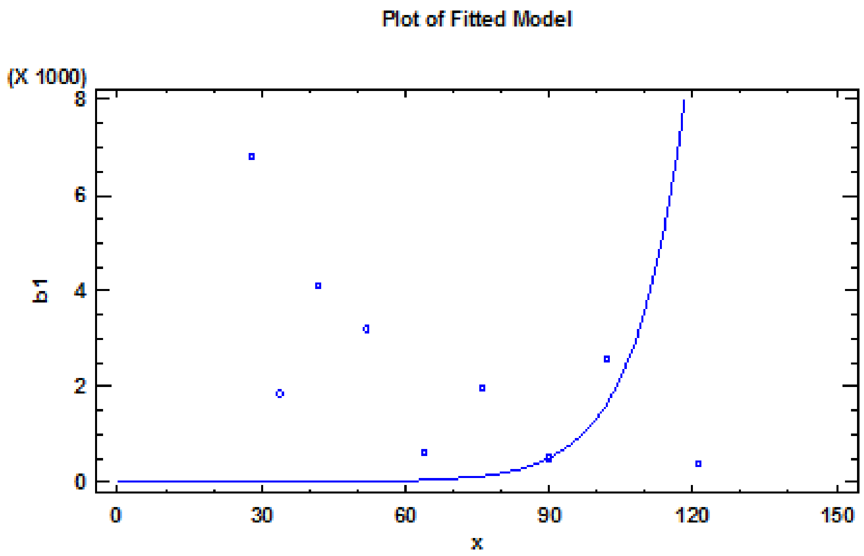

Fig 8: Plot of fitted model- Air Permeability Versus Ends per Inch

It is observed from the simulated results as shown in figure 7 and figure 8 that we have obtained best possible fitted model. The simulated results and experimental results are best fitted.

VI. CONCLUSIONS

The above study helps us to conclude that there is a definite relation between the physical and the transmission property of fabrics. The new technique that has been developed will be useful in determining air permeability of a fabric from its image.

REFERENCES

[1]. Ahmet ay, Savvas Vassiliadis, Maria Rangoussi, and Isik Tarakioioglu, “On the use of image processing techniques for the estimation of the porosity of textile fabrics, *World Academy of Science, Engineering and Technology*, Vol. 2, 2005.

[2]. Dipayan Das, S M Ishtiaque and Pankaj Mishra, “Studies on Fiber openness using image analysis technique”, *Indian Journal of Fiber and Textile Research*, Vol. 35, 2010, 15-20.

[3]. S. Benltoufa1, F. Fayala1, M. Cheikhrouhou2 and S. Ben Nasrallah1, ”Porosity determination of jersey structure”, *AUTEX Research Journal*, Vol. 7(1), 2007.

[4]. Boena Wilbik-Hagas,Remigiusz Danych, Bogdan Wicek, Krzysztof Kowalski, “Air and Water vapour permeability in double-Layered Knitted Fabrics with different raw materials”, *FIBRES and TEXTILES in Eastern Europe*, Vol. 14, 2006, No. 3 (57).

[5]. Ji Militk, Michal Vik, Martina Vikov and Dana Kemenkov, Influence of fabric construction on their porosity and air permeability, http://centrum.tul.cz/centrum/centrum/1Projektovani/1.2_publikace

[6]. B.P.Saville, “Physical Testing of Textiles”, Woodhead Publishing, 1999.

[7]. J.E.Booth, “Principles of Textile Testing”, 3rd Edition, CBS Publishers & Distributors, 1996.