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Controlling the optimal amount of resin in carpet back sizing with assessing its mechanical properties by image processing method

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ABSTRACT

Face to face is a kind of weaving carpet in which, the sizing step (back sizing) of carpet for connecting the pile yarn to substrate is inevitable. Failure to maintain the specified weight of applied latex (resin) compound can ultimately affect carpet properties as like as tuft lock, dimensional stability, the degree of firmness or stiffness accompanied by flexibility and anti fray properties. In this paper, a new method was presented based on bending stiffness of the sized carpet by measuring Radius of Curvature (R.O.C) via image processing to control and evaluate the optimum amount of resin by measuring and controlling the ROC index. The results show that controlling the radius of curvature, by the way, which was carried out in this paper can determine at least 10% fluctuation of the amount of resin with 99% confidence interval.

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INTRODUCTION

Due to the development of raw material, production process and usage of the carpet, many researchers have studied its physical performance [1,2]. Both mechanical and optical characteristics create the physical properties of a carpet and ultimately, influence its performance significantly [3]. Most of attentions to the evaluation of end-use performance of carpets have been focused on wear, colorfastness, and appearance retention [4], and most of the researches have focused on deformation of the appearance by thickness loss of pile yarn of the carpet. However, it is clear that there are other factors such as tuft binding, dimensional stability, resistance to water, reduced pilling, resistance to edge fraying and flattening are significant characteristics of carpet. Some factors that can affect these features are type, quality and the amount of resin in the back coating of a carpet. [5]

Figure 1 shows a typical method of applying a primary back-coating using a lick-roller or applicator. The carpet is passed over a tension roller before the lick-roller and it is back-brushed to remove loose fiber or any other contamination likely to prevent the application of the compound to the carpet. Upon passage over the lick-roller, which is rotating in the through of the latex compound, an excess of compound is applied, this excess is removed by the doctor-blade and returns to the trough. Control of the applied weight and penetration, provided the carpet speed constant, and they are influenced by the solids content of the latex compound, viscosity of the latex compound, the lick-roller speed and the position of the doctor blade against the carpet back. Viscosities of the latex compound are usually affected by shear forces and during processing these forces arise and they are dependent on the lick-roller speed, the speed of the carpet over the roller, the angle of contact of the carpet to the lick-roller, and the doctor-blade setting in relation to the carpet back. The effective viscosity changes at any of these points are not easy to establish, but cumulatively can considerably effect on the penetration of a compound into the carpet backing and also the applied weight. [6]

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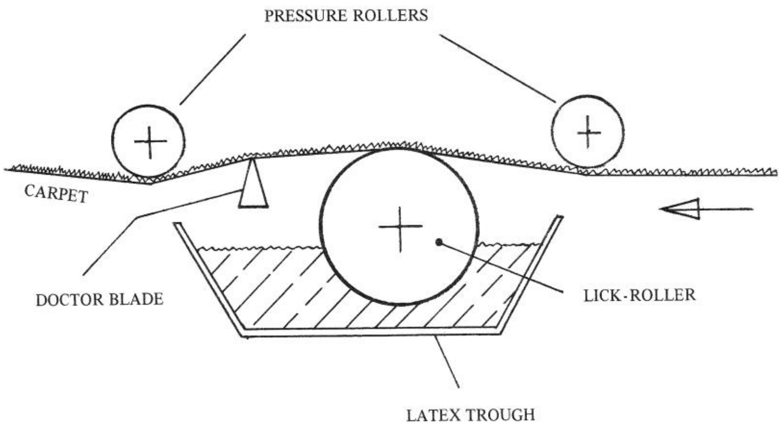

Fig. 1: A typical method of applying back-coating using a lick-roller [6]

Weight of applied backing compound may be checked by weighing a carpet before and after back sizing, but this could be a subject to be controlled by another system in a plant. These include the measure of the quantity of latex being pumped into the trough over a fixed time, and then can be compared by calculation the quantity of carpet processed in the same time period. This, however, requires an accurate means of ensuring that the quantity of the compound in the trough before checking is the same as that at the end.

An alternative method was used to mount the trough on a weighing device, and then calculated the weight of the used compound and compared this with the quantity of processed carpet over a fixed time. Again, there is a problem about establishing the amount of the pumped compound into the trough during the time period, in which the check is made. A possible combination of these two systems would provide a satisfactory means of monitoring the applied weight.

Stiffness, or 'handle' is another suggested way to control the coating and comparison of coating in similar type on the same or similar fabric and not as absolute method [6]. Because the carpet bending stiffness is one of the most effective properties, which is achieved by back carpet coating by resin. This process effects on handle, drape and wrinkle resistance characteristics. There are a lot of experimental methods to measure the indicators with quantitative assessment for bending stiffness of textile, which has been developed. They can be classified in two groups; the first group is concerned with the measurement of forces, moments or energy, while applying a prescribed bending deformation. These instruments are generally designed to produce the moment-curvature relationship of fabrics. The second group involves the measurement of fabric deformation under its own weight. The tests based on the second method are often simpler and faster. They can provide better control over the final product and even have the ability to be online [7].

Therefore, the purpose of this research is to replace a method of analyzing mechanical properties by image processing, which is flexible, low cost and can be replaced by a personal sense of optimal sizing.

Zhou and Ghosh (1997), have proposed four potential loop shapes in order to develop an on-line system to characterize fabric bending rigidity. Loop shapes are chosen such that they can be formed under dynamic conditions. The first loop is generated by hanging the fabric between two pairs of rollers in the horizontal plane and the second loop is formed when the fabric folds back on itself, but there is a separation plate between the two layers of the fabrics. Loop 3 and 4 are made by keeping the fabric between two clips with a specific shape. Each loop can be described with some parameters. The choice of a parameter as the “characteristic parameter” will depend on the relationship between that parameter and the bending rigidity of the fabric. In other words, the most sensitive (or most discriminating) parameters for a given loop will be picked as a characteristic parameter for a given loop. Then they used this parameter as a criterion to choose the right type of a loop, which was used to evaluate the bending stiffness of different fabrics. Their experiment represented that loop 2 is appropriate for fabrics with high bending stiffness and loop 3 and 4 are suitable for all kind of fabrics. The most important characteristic parameter for loop 2 is the length of folded fabrics, which do not contact with each other [8].

Before Zhou and Ghosh; for the first time Stuart and Baird (1966) used the method consists of folding a strip of fabric back on itself. They applied the height of a loop as a characteristic of that loop and announce Pierce bending length is 1.1 times of the length of the loop.

More recently, this method was applied by Cassidy et al. in developing their “bending box” in order to measure the bending property of knitted fabrics, which are usually difficult to measure by the Pierce cantilever method, due to their tendency to curl. The test results show that for knitted fabrics, the reproducibility of the results is significantly better for their method than for the cantilever method. But the physical meaning of the loop height, was not quite clear as they admitted [7]. Cassidy and et al. (1991) explained that the length and width of folded back fabrics on each other have little effect on the height of the loop [9].

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MATERIAL AND METHODS

In order to indicate optimal amount of resin in carpet back sizing by assessing its mechanical properties, we use a carpet with 4900 pile density (piles/dm ^{2}) (reed 700dents/m, weft density 1400ends/m) that was sized with normal amount of resin and %10-%20 less and more than normal situation. Other structural parameters are: two-shot weave, warp density, Ne 20/4 PET/cotton and Ne 20/5 PET/cotton 80/20; filling density, 4800 $\times$ 2 dtex jute; pile density Ne 12/2 Acrylic. And the resin is vinyl acetate homopolymer.

In this research, the researchers used the bending stiffness as a factor, which is affects by the amount of resin on the back of the carpet to control and determine the optimum amount of resin. The researcher used a method based on deformation among bending stiffness assessment methods, which is caused by the weight of the fabric. Since evaluation and quantification of deformation was used as a reference criterion; therefore, image processing was applied as a method with high accuracy and low cost. After accomplishing the finishing line, the carpet was placed on a smooth surface and the carpet was folded back onto itself and the analysis is done on obtained arc. In order to evaluate the bending stiffness of each carpet, Radius of Curvature of obtained arc (ROC) is measured in MATLAB. In previous research, determining the height of obtained arc of fabric or a length of fabric, which has no contact with each other were used [7,8]. But in the present research, the researchers compared the accuracy and sensitivity of that parameter and the ROC to bend rigidity by measuring this parameter for a sized carpet with normal resin and unsized carpet. This study shows that measuring the ROC is more accurate and more sensitive than other parameters specially measuring by image analysis method.

3- Data Collection:

Folded carpet image acquired by a CCD camera. Camera fixed in front of the folded carpet and working distance that means the distance between the objective lens and folded carpet was 60cm. Camera was fixed and the horizontal and vertical distance from the table that the carpet laid on it was constant. Because all parameters are the same for all pictures, the optical size of the image for all the pictures was constant; then the number of pixels for all pictures was equal.

The following steps are taken by MATLAB software in order to analyze the images and measuring the ROC of arc. At first, images changed to binary form by IM2BW function, then by using morphological operations, Dilation and Erosion and opening and closing operations the arc line in images were converted into a fine and continuous line. The program with point by point monitoring identified the arc and this is detected with the formula of a circle the center of an arc. The last step was choosing the best circle, which was fitted on the arc and its radius was expressed as Radius of Curvature (ROC) of arc.

A piece of carpet was divided into 5 equal sections with 60cm width and 180 cm length to prepare the sample for taking the images. One section was sized with a suitable and usual amount of resin and 4 remain sections were sized by 10 and 20% more and less resin than the normal range. images were taken from original raw material with 3 m width in order to investigate the effects of the width of the carpet on obtained arc. Comparing the ROC of obtained arc in unsized carpet with 60cm width and unsized carpet with 3m width revealed the same result as Cassidy and et al (1991) were achieved. It indicated that width of specimen had no significant effect on evaluating bending stiffness of the textile [9].

Samples of obtained images have been shown in Figure 2 and Figure 3. The circle was fitted on the arc of a folded carpet is shown for each image. Data obtained for ROC from image processing held certain assumption of one-way analysis of variance (ANOVA) test. ANOVA showed that the mean of unsized carpet ROC was 577 pixels and for sized carpet was 661 pixels, which showed a significant difference at the level of 99%. Therefore, calculating ROC with afore mentioned procedures were a good evaluation of bending stiffness. moreover, the carpet backing has a significant effect on it.

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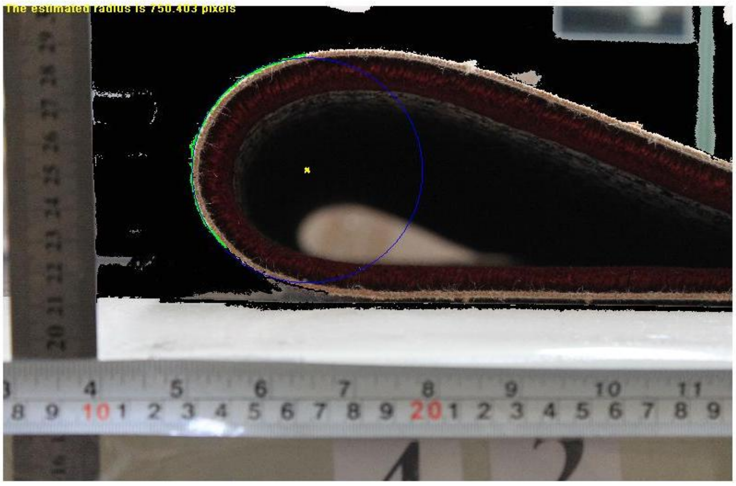

Fig. 2: Determining obtained ROC of arc for folded carpet before sizing

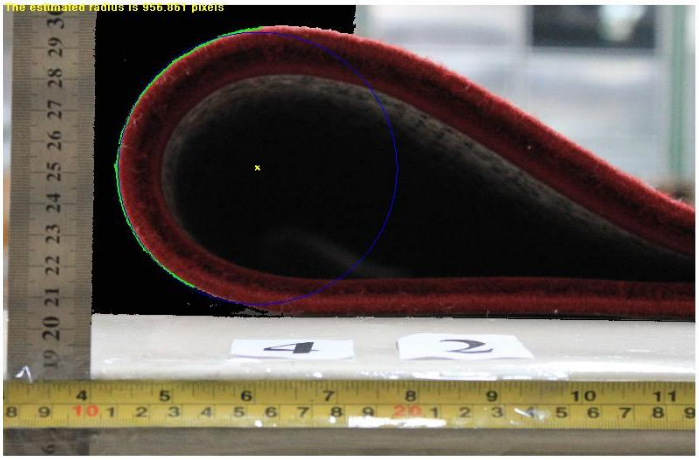

Fig. 3: Determining obtained ROC of arc for folded carpet after sizing

The optimum and usual amount of resin for achieving a suitable handle from the expert point of view was 135 gr dry materials per square meter. By comparing the images taken from specimen with desirable resin and the 4 sized samples with 10-20% less and more resin can be tested, if a 10% change in amount of carpet backing resin has a significant effect on bending stiffness and ROC of folded carpet arc. In addition, the researcher can achieve a reliable confidence interval from 95-99% level for carpet ROC with the adequate amount of resin and favorable mechanical properties. This confidence interval can be used in quality control of the produced carpet from this specific sample in terms of the amount of resin and suitable mechanical properties. Due to research limitation, applying resin on the back of carpet was carried out by hand, brush, and curing the resin was done by ironing back of carpet, which is not more uniform compared to sizing machine processes done in the carpet finishing line. Then two edges of prepared samples were folded on each other and 10 images were taken from different part of specimens. The ROC was calculated by a program written in MATLAB. The obtained data for ROC are presented in Tables 1 and 2 and Figure 4.

Table 1: Radius of Curvature of folded carpet in pixel

Radius Of Curvature (ROC)						
Sized by 20% more resin	Sized by 10% more resin	Sized by adequate resin	Sized by 10% less resin	Sized by 20% less resin	Unsized sample	Sample No.
781.99	675.51	657.60	648.02	589.01	560.50	1
762.38	666.81	643.05	618.78	633.63	559.64	2
750.74	698.98	662.36	610.65	615.68	558.80	3
819.65	697.15	646.66	614.61	627.63	567.26	4
780.27	712.50	681.64	627.80	606.68	604.71	5
764.85	690.98	659.37	601.72	642.03	578.36	6
812.02	690.45	657.10	625.59	600.54	588.29	7
769.73	674.31	653.56	640.03	609.79	572.21	8
750.39	719.40	662.88	643.28	612.21	582.75	9
790.75	696.72	683.64	663.44	609.65	596.31	10

Table 2: Descriptive of Radius of Curvature of folded carpet in pixel

Radius Of Curvature (ROC)	N	Mean	Std. Deviation	Minimum	Maximum
Unsized Sample	10	576.88	16.075	558.8	604.71
Sized by 20% less resin	10	614.69	15.826	589.01	642.03
Sized by 10% less resin	10	629.39	19.083	601.72	663.44
Sized by adequate resin	10	660.79	13.149	643.05	683.64
Sized by 10% more resin	10	692.28	16.635	666.81	719.4
Sized by 20% more resin	10	778.28	23.725	750.39	819.65
Total	60	658.72	67.168	558.8	819.65

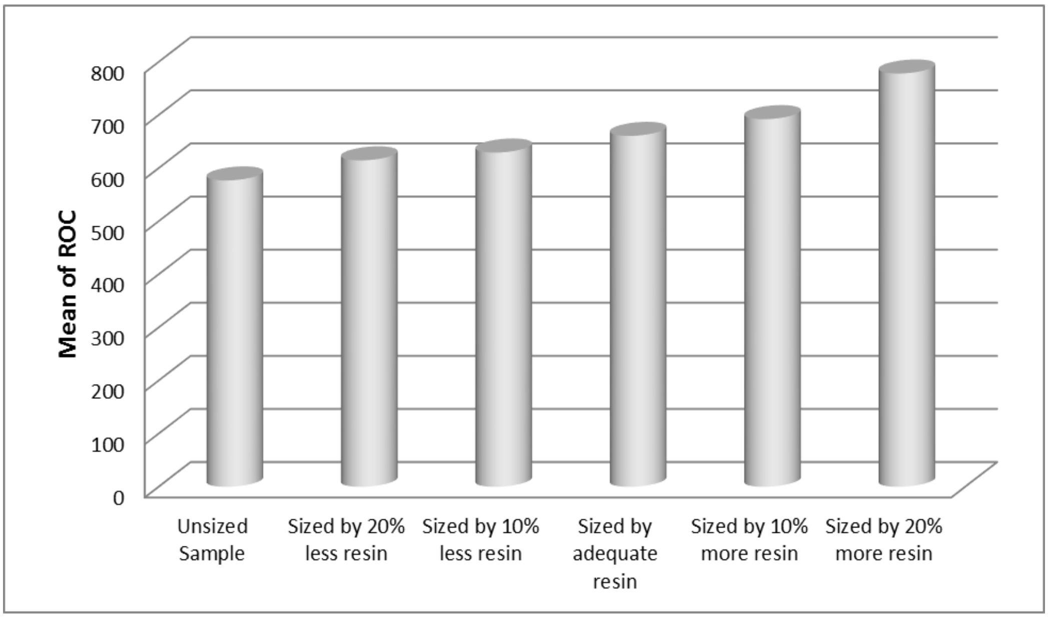

Fig. 4: Relationship between the amount of resin in carpet back sizing and mean of ROC.

According to Figure 4, the maximum radius of curvature (ROC) in samples sized by 20% more resin and minimum curvature radius without sizing can be seen in the raw sample.

RESULT AND DISCUSSION

First, equality and homogeneity of variances were tested to evaluate the inherent difference of the samples. Table 3 shows the results of Levene tests to evaluate the equality and homogeneity of variances.

Table 3: Test of Homogeneity of Variances

Levene Statistic	df1	df2	Sig.
.987	5	54	.434

According to Table 3, the significance level of test (Sig) was 0.434 and it is more than 0.50 and thus, variance measurement with 95% confidence for the studied samples in 6 groups with various amounts of sizing have no significant differences.

4-1 Analysis of data using analysis of variance (ANOVA):

ANOVA has been used in order to test whether ROC is different in various samples. For assessing the adequacy of obtained data for ROC to do ANOVA test, the normality and equality of variance assumption are tested with residuals in which, none of the hypothesis are rejected. Therefore, ANOVA is confirmed to compare the mean of ROC in a different kind of back sized carpet.

According to the adequacy of the linear model for testing the equality of the mean of the data, ANOVA has been done, and its results are shown in Table 4. As p-value test represented, there is a significant difference between data of ROC in the various sized carpet samples.

Table 4: The analysis of variance for testing the equality of ROC data

ANOVA

R.O.C

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	249283.6	5	49856.719	158.514	.000
Within Groups	16984.385	54	314.526		
Total	266268.0	59			

Multiple comparisons of means were applied to identify the various means. Tukey and Duncan's tests indicate that there is no significant difference between ROC of sized carpet with 10-20% less resin than usual, but there is a significant difference between ROC of other categories. Table 5 represents the result of calculating ROC with the mentioned method. Controlling the radius of curvature of the way in which, this research was carried out by at least 10% fluctuation of the amount of resin for carpet back sizing had a good accuracy. Due to the limitations of manually actions, carpet backing and curing of the resin may not be the same as sizing machine. Therefore, in case of producing specimens with sizing machine, and having more samples, the researcher could be able to do this test with better sensitivity.

At the end of finishing line, calculating of ROC and forming the control charts can determine if there is a significant difference between ROC of a desirable carpet and ROC of a new produced carpet. Either control charts that can show the tendency, may be lead deviation of desirable back sizing. It could be very useful because of irreversibility of sizing process. Fig. 3 indicated 99% confidence interval for ROC of all tested samples.

Table 5: comparing multiple means for ROC of samples

R.O.C

	Sample	N	Subset for alpha = .01 1	2	3	4	5
Tukey HSD[a]	befor	10	576.8380				
	-20%	10		614.6850			
	-10%	10		629.3920			
	Normal	10			660.7860		
	+10%	10				692.2810	
	+20%	10					778.2770
	Sig.		1.000	.441	1.000	1.000	1.000
Duncan [a]	befor	10	576.8380				
	-20%	10		614.6850			
	-10%	10		629.3920			
	Normal	10			660.7860		
	+10%	10				692.2810	
	+20%	10					778.2770
	Sig.		1.000	.069	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 10.000.

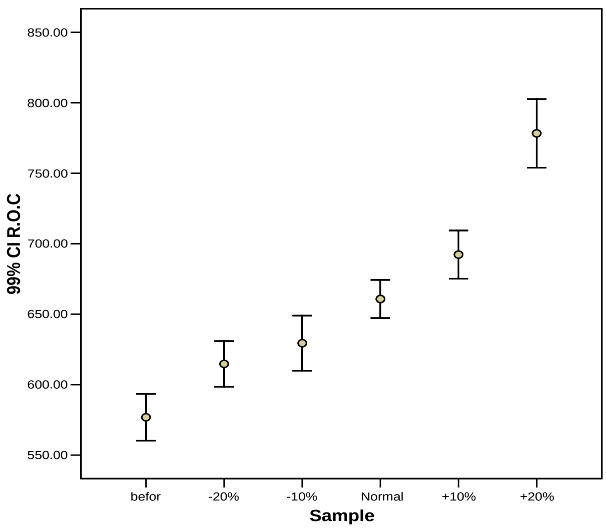

Fig. 5: Error bar chart data for ROC of samples in 99% confidential interval

4-2- Surveying the relationship between the amount of sizing and Radius of Curvature (ROC):

Simple regression analysis was used to investigate the relationship between the amount of sizing and Radius of Curvature (ROC) and presentation of the forecasts model. The results of this test are shown in Table 6.

Table 6: Regression results

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	T	Sig.
(Constant)	567.921	5.650		100.517	.000
Amount of sizing	36.319	1.866	.931	19.462	.000
F	378.768	Model Sig	.000	R Square	.867

According to significant level of model (Model Sig = 0.000), it is indicated that the fitted model on the data with 99% confidence level (1% error) is significant (Sig <0.01). Also according to the R Square in Table 6 (0. 867), it can be concluded that approximately 87% of the ROC is because of the changes in the amount of resin. Regression model (model forecast) is obtained as follows.

$$ROC = 567.921 + 36.319 \text{ (the amount of sizing)} \quad (1)$$

Finally, the results of the regression in Table 6, show that the amount of sizing in the ROC was important and effective (Sig <0.01), so that with increasing the amount of resin, the ROC has increased. In the presented regression model (formula 1), each unit that increases in the amount of sizing, caused 36.319 units increase in ROC.

The scatter plot in Figure 6 indicates the existence of a direct relationship between the amount of sizing and radius of curvature (ROC).

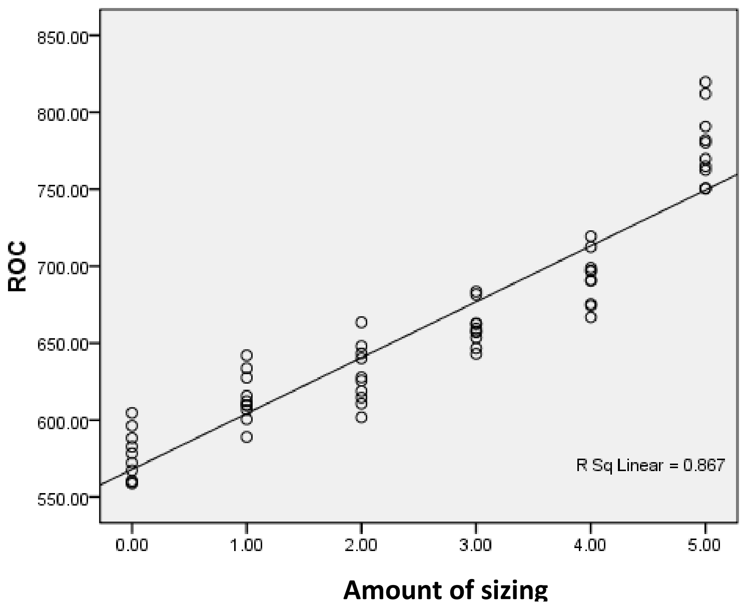

Fig. 6: Distribution diagram of a direct relationship between the amount of sizing and carpet's Radius of Curvature in the regression model

Conclusion:

We have developed a static bending model to evaluate the bending rigidity of carpet and a method for monitoring and controlling the amount of resin in back sized carpet. We have built an image processing system in order to evaluate the bending rigidity of back sized carpet. In this system, the carpet folded back on itself and the analysis is done on obtained arc. By increasing the amount of applied resin on the back of the carpet, the obtained Radius of Curvature of folded carpet arc is increased significantly as a characteristic of bending stiffness. So the proposed model in this research has the ability to evaluate bending stiffness as a characteristic of mechanical properties of machinery carpet.

According to the adequacy of deformation measurement method of textile, which was affected by its own weight mentioned in this research, conducted studies would be the basis for innovating a system of on-line bending stiffness control and optimal amount of resin in machinery carpet.

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