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PREDICTING THE LIFE OF TEXTILE MATERIALS AS AUTOMOTIVE CAR SEAT FABRICS

Mohamad Faizul Yahya[a,*] and Abbas Deghami[b]

[a]*Department of Textile Technology, Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Malaysia.*
[b]*Department of Textiles, Faculty of Mechanical Engineering, The University of Leeds, UK.*

**Corresponding author: Tel: +603-5544 4625 Fax: +603-5544 4562 email: tex1mfy@salam.uitm.edu.my*

ABSTRACT

This paper describes the analysis of two important properties for car seat fabrics namely abrasion and tensile. The data obtained from the tests on these properties were reviewed and durability and energy coefficient (DEC) graphs were constructed for further analysis. Good relationship was found especially in warp direction. The understanding of the graph could become useful tool for fabric engineering and cost control for fabric manufacturing.

Keywords: automotive woven fabrics, abrasion test, tensile test, durability coefficient, energy coefficient

1. INTRODUCTION

The rapid growth of technical textiles has contributed to the development of high performance textile materials used in various applications and conditions[1]. Technical textile areas such as automotive textile, medical textiles, geotextiles, composites, sports and leisure and protective clothing have recorded significant growth in terms of its market demand[2]. One important study areas in textiles is on prediction of fabric durability based on its use. Durability prediction allows better fabric re-engineering so that it can meet the required performance with the production cost[3]. For example, expensive cars would normally require durable fabrics as their prices and car life expectancy can be extremely high. However for economical cars, fabrics must be manufactured by the most efficient methods so that car prices can become competitive. In addition, there is currently no specific research conducted to analyse the effect of several technical properties of automotive car seat fabrics[4].

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This work would then provide an opportunity to understand fabric mechanics in a scientific manner and also become a useful tool for fabric engineering as well as for fabric quality prediction.

Hamburger[5] was among the first researchers who conducted fundamental research in this area. In his work, he examined the abrasion and tensile loss of mechanically conditioned yarns. He explored initial work on energy and durability coefficients in his paper "The Mechanics of abrasion of Textile Materials". Based on his research, he found that to resist destruction, textile materials should be capable of absorbing energy being imparted during stress activity and then be able to release the absorbed energy without failure[5]. Hamburger appreciated that, immediate elastic or instantaneous and delayed deflection or time dependency should influence textile deformation under load. In his work, Hamburger[5] found some linear correlation between energy coefficients (from load elongation curve) and durability coefficients (from abrasion cycle with strength reduction) of various yarn types. Even though Hamburger's research concentrated on yarns, his approach was selected in this study as it offered a very useful mechanism to understand, relate and combine the surface and mechanical properties of many different fabric types[6-8].

2. EXPERIMENTAL METHODS

Five woven fabrics made by Malaysian automotive fabric makers were selected for this work. Some basic fabric analysis were done to obtain several fabric identification properties such as yarn linear density, fabric density and crimps. Upon completion of the analysis, each fabric specimen was cut according to 150 mm x 150 mm specimen dimension for abrasion test. Each of this fabric was abraded for five consecutive abrasion cycles namely 500, 1000, 1500, 2000 and 2500. Fifty samples of fabric were prepared for every abrasion cycles. The abrasion test was done according to Martindale-BS/ISO standard[9]. A total of 1500 specimens were required for this test. Then, the abraded images of these specimens were recorded after 2500 cycles using simple image analysis unit. This step was very important as it allowed visual record of fabric wear on its surface. Upon completion of the image processing work, the abraded specimens were then cut into smaller dimensions of 35 mm x 150 mm for tensile tests. Tensile tests were conducted in accordance with British Standard strip method test[10]. Graphical illustration is outlined in Figure 1 for clarification.

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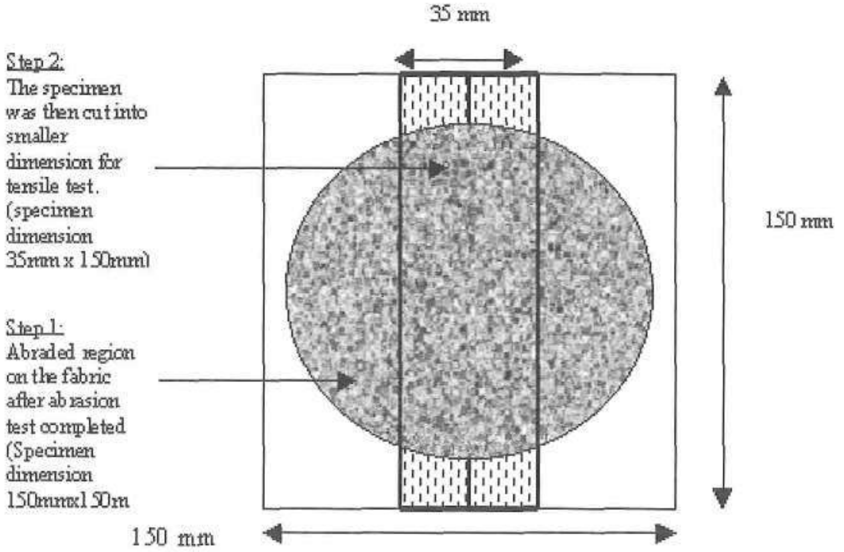

Figure 1: Specimen dimension for abrasion and tensile tests.

With abrasion and tensile strength results, durability and energy coefficient were calculated, and durability and energy coefficient (DEC) graphs were then constructed for analysis. Correlation analysis was also conducted to evaluate the strength of relationship that existed in the DEC graphs.

3. EXPERIMENTAL RESULTS

Abrasion and tensile strength analysis provide several useful data for interpretation. An attempt was made to calculate the durability and energy coefficient for all the fabrics used in this research. Durability and energy coefficient were determined by following equations.

$$\text{Durability coefficient} = \frac{A_{max}}{[\,\overline{T_L}\,]^{-1}} \qquad \text{eq. (1)}$$

$$\text{Energy coefficient} = \frac{E_{max} - E_{min}}{[\,\overline{T_s}\,]} \qquad \text{eq.(2)}$$

where;

E_{max} = Elongation maximum in mm

E_{min} = Elongation minimum in mm

$\overline{T_L}^{\,-1}$ = Mean tensile loss in % for warp or weft direction

A_{max} = Maximum abrasion cycle at 2500

$\overline{T_s}$ = Mean tensile loss in kg for warp or weft direction

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Table 1. Warp Durability and Energy (DEC) coefficient summary.

Coefficients	1	2	3	4	5
Durability Coefficient	5.130	5.174	5.141	5.220	5.343
Energy Coefficient	0.154	0.522	0.417	1.258	2.313

Table 2. Weft Durability and Energy (DEC) coefficient summary.

Coefficients	1	2	3	4	5
Durability Coefficient	5.137	4.995	5.22	4.475	5.284
Energy Coefficient	1.786	0.827	2.373	1.186	4.754

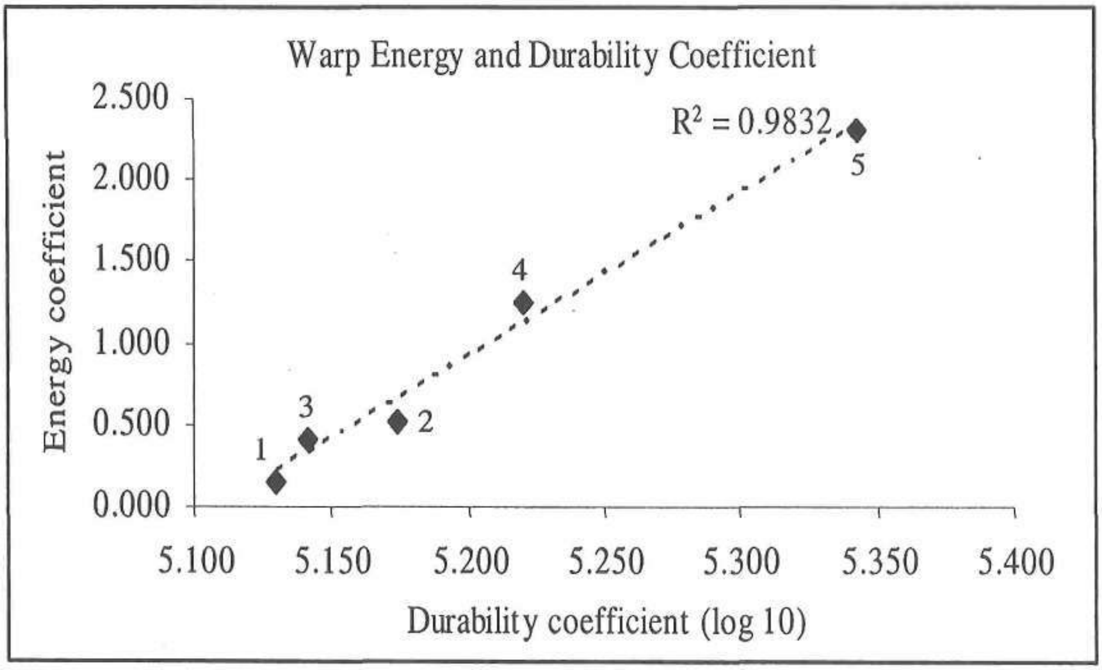

Figure 2: Warp DEC graph.

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The durability and energy coefficient results for both warp and weft direction are shown in Tables 1 and 2.

Two "Durability and Energy Coefficients" (DEC) graphs for both warp and weft directions were then constructed so that the correlation of these factors would be further examined and understood. These are shown in Figures 2 and 3.

4. DATA INTERPRETATION AND DISCUSSION

An attempt was made to locate the relationship between durability and energy coefficients (DEC) in both warp and weft directions in the fabrics. The primary interest of the analysis was to establish initial understanding of this relationship and to see if warp DEC values could be linearly related to each other and whether the same behavior could be found in weft direction. Generally, DEC values in warp and weft directions in fabric are reported to have moderate to strong linear correlation. From Figure 2, it is very clear that, there is a linear relationship of DEC in warp direction. It was found that, R^2 or coefficient of determination value was 0.9832, which indicates that 98.32% of variability in energy coefficient can be explained by durability coefficient. Taking the square root of R^2 would yield coefficient of correlation or Pearson correlation r-value. Again, the value is 0.992, which indicates that, there is a very strong positive correlation between warp DEC. In contrasts, weft DEC graph in Figure 3, presents somewhat lower R^2 value than warp direction. R^2 value of weft DEC is found to be 0.3836 or in other words, only 38.36% of variability in weft energy coefficient can be elucidated by durability coefficients while the remaining percentages were unexplained. Again, by taking the square root of R^2, r-value is 0.62, which denotes a moderate positive correlation between energy and durability coefficients.

The finding is important as it relates the fabrics (warp and weft) DEC values and permits quantitative comparison to be carried out. Hence, initial prediction of fabric life in car can be predicted by evaluating tensile strength test of abraded fabrics. By referring to eq. 1, durability coefficients can be expressed as destruction rates. The greater the degree of tensile loss, the higher the durability coefficient values would be and less time ie required to destroy the specimen during abrasion cycle. Also, high energy coefficient values, as described in equation 2, was attributed to massive differences between elongations values (in mm) divided by low tensile strength mean. In other words, high energy coefficient fabrics were usually weak fabrics that simply elongate as uniaxial load is applied. Therefore, by referring to warp durability coefficient of samples five and one, it will be evident that sample five which scored the highest value for durability and energy coefficient, would have faster rate of destruction compared to sample one. It was very clear, the behavior in warp DEC of sample one clearly indicates the lowest

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destruction rate manifested from its ability to resist energy imparted during abrasion.

For the purpose of highlighting initial prediction of specimen life as car seat fabrics, it is estimated that sample one, two and four would have medium to longest usage period. Sample three is anticipated to have only medium life cycle. Most importantly, it is predicted that, sample five would have higher chance to wear out both warp and weft direction and most likely be the first sample to destruct during its usage period. The image taken after 2500 abrasion cycles confirmed the above analysis.

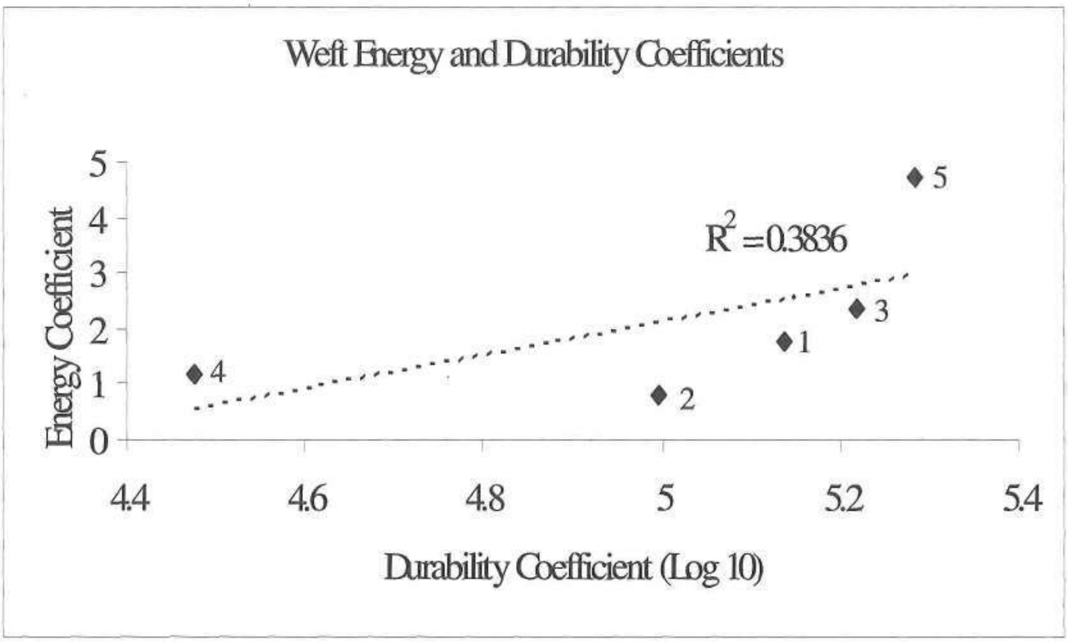

Figure 3: Weft DEC graph.

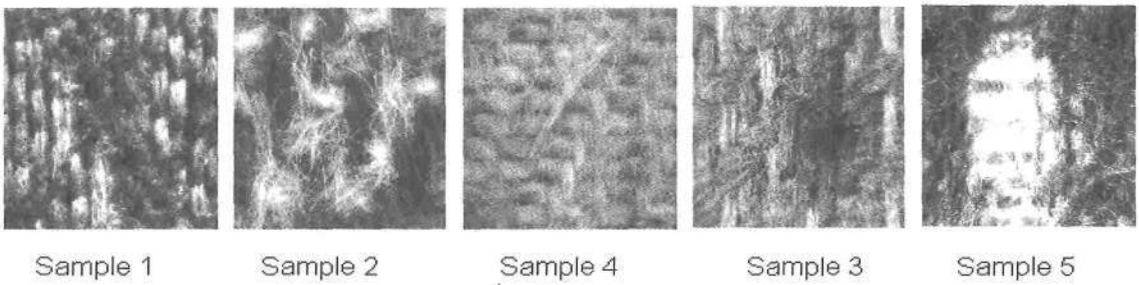

Figure 4: Image Processing for Abraded Fabrics (after 2500 abrasion cycles).

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In this work, it is concluded that destruction of car seat fabrics can be predicted using load elongation data of an abraded fabrics. Abrasion and tensile deformation process can be brought together for quantitative analysis. Hamburger's concept on the ability of textile materials especially yarn to absorb energy imparted during abrasion can be related to its ability to resist destruction and now it can be extended to fabrics. The findings suggest another method of interpreting load elongation curve and ability to counteract the accuracy. By combining both tests together, comprehensive analysis can be done on multiple samples, in terms of how much tensile force is required to meet abrasion standards. One can reproduce DEC data, review how much variability in energy coefficients which are explained by durability coefficients and decide which fabrics possess the highest destruction rate and vice versa. From there, the decision of which fabric possess the longest predicted life can be established. Such information is important for car seat fabric manufacturers because the fabrics would be abraded and subjected to extreme load during their usage period. This analysis is also useful for car seat manufacturers, as it offers the simplest analysis tool for understanding and improving fabric performance as well as comfortable basis to work out costs and process control.

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