APPLICATION OF AN ANCIENT CHINESE ALGORITHM TO STAB PERFORMANCE OF WOVEN FABRICS

by

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Stab damage is a common failure mode for textile products, especially for the geotextiles and geotextile-related products which are widely used in the road, airport, pipeline, and so on. In this paper, an ancient Chinese algorithm is applied to predict the stab area and stab energy of woven fabrics under stabbing load according to the load-displacement performance of the single yarn. This research proposes a novel method to analyze the stab property of the textile products.

Key words: *ancient Chinese algorithm, stab performance, woven fabric*

Introduction

The *Nine Chapters* is the first mathematical work in Chinese history. It collected 246 actual problems faced by agriculture, business procedure, engineering, surveying, solution of equations, and properties of right triangles [1-3]. The *Ying Buzu Shu* which was listed in the *Seventh Chapter* and initially proposed to solve non-linear algebra equations is one of the most important methods in this work. Its basic idea can be extended to solve non-linear differential equations and non-linear wave equation with a great success [4-7].

Material's strength especially stab strength is an important factor for its products. Geometrical structure plays an important role in stability and security. For example, a steel truss in a bridge will greatly enhance its security and stability. Carbon nanotubes are also of Steiner structure, which greatly enhance its strength. Hierarchical structure of nanofibers also behaves excellently in thermal conduction and air permission [8-14], due to their Steiner structure of porosity.

In this paper, an ancient Chinese algorithm (*Ying Buzu Shu*) will be applied to analyze the stab performance of the textile materials with woven structure. With this method, the stab area and stab energy can be predicted during the stab process which will benefit for the design of textile products with high stab resistance.

Experiments

The tensile strength of the component warp yarns in the woven fabric is tested based on American Society for Testing and Materials D885-07. The load-displacement curves of the

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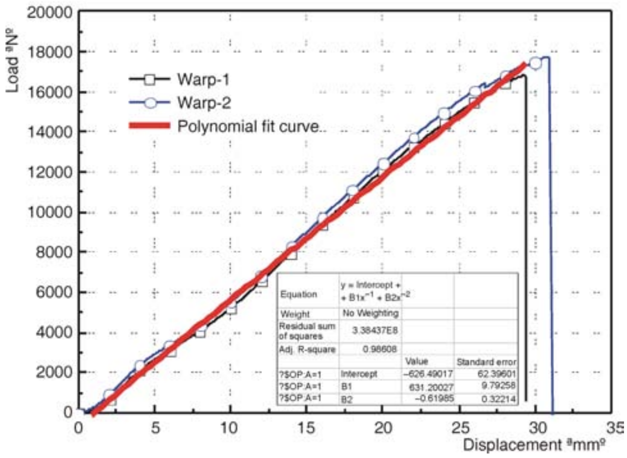

Figure 1. The load-displacement curves of the component warp yarns in the woven sample

warp yarns are shown in fig. 1. According to fig. 1, we can see that the tensile load increases steadily and smoothly with the increase of the displacement of the yarn sample. Therefore, a polynomial fitting equation, eq. (1), can be adopted to express the relationship between load and displacement on the yarn:

$$F \quad 631.2L - 0.62L^2 \tag{1}$$

where F is the load, and L is displacement of the yarn during the tensile process.

The stab performance of the woven sample is also tested. The experiment process and the shape parameters of the stabber are shown in figs. 2 and 3. The stab load-deflection curve of the tested woven fabric is illustrated in fig. 4. We can see from fig. 4 that in the initial phase, the stab strength increases slowly which means there are less yarns participate in the stab process. The

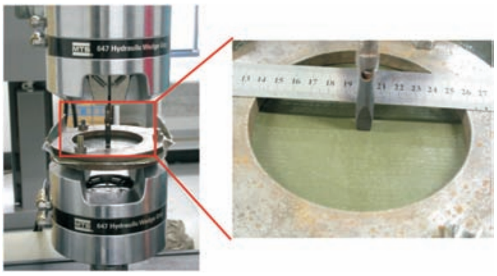

Figure 2. Stab process

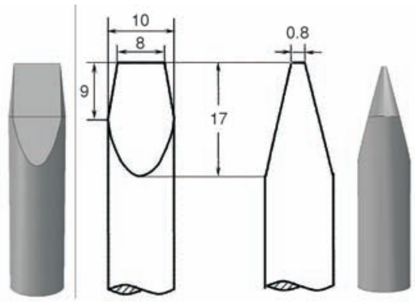

Figure 3. The shape parameters of the stabber

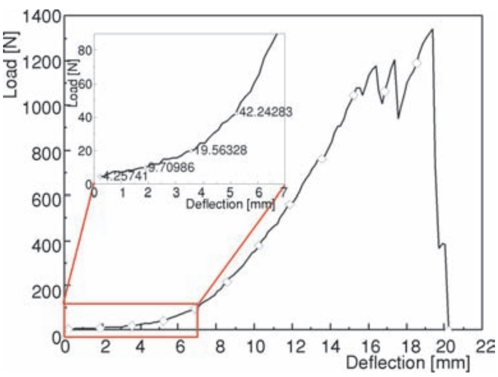

Figure 4. The load-deflection curve of the woven sample during the stab damage

stab load increases rapidly when most yarns are involved in the stab process. The main focus in this paper the initial stage of the curve with the displacement ranging from 0-7 mm which is magnified on fig. 4. Besides initial point, three load points 9.70986 N, 19.56328 N, and 42.24283 N refer to displacement points 1.88398 mm, 3.54699 mm, and 5.21626 mm, respectively, are selected for the following research.

Theoretical analysis

According to previous research [4] and the principle of ancient Chinese algorithm, we can have the following estimate root for a given non-linear algebra equation $F(x) = 0$ with given x_1 and x_2:

$$x_{\text{est}} \quad \frac{x_2 F(x_1) \quad x_1 F(x_2)}{F(x_1) \quad F(x_2)} \tag{2}$$

In present research, the final load strength of on the stabber can be expressed:

$$F \quad F_1 \quad F_2 \quad \cdots \quad F_i \tag{3}$$

where F_i represents the load on the i^{th} yarn which can be seen in figs. 5 and 6.

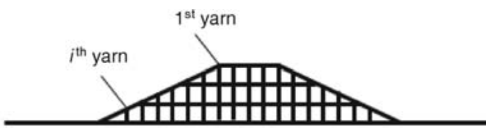

Figure 5. The diagram of stab process

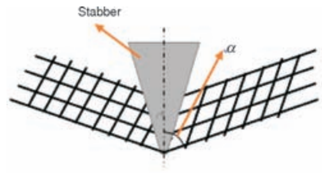

Figure 6. The side view of the stab process

With a set of estimated yarn number i_1 and i_2, we can get the residuals $R(i_1)$ and $R(i_2)$, respectively:

$$R(i_1) \quad \overset{i_1}{\underset{i\ \ 1}{}} F_i \quad F \tag{4}$$

$$R(i_2) \quad \overset{i_2}{\underset{i\ \ 1}{}} F_i \quad F \tag{5}$$

The estimated yarn number i_{est} can be deduced:

$$i_{\text{est}} \quad \frac{i_2 R(i_1) \quad i_1 R(i_2)}{R(i_1) \quad R(i_2)} \tag{6}$$

Take the first point with the displacement of 1.88398 mm and stab load of 9.70986 N in fig. 1 as an example, the elongation of the 1^{st} yarn can be expressed:

$$L_1 \quad 2[\sqrt{l^2 \quad (id)^2} \quad (id)] \tag{7}$$

where L is the elongation of the yarn, l – the displacement of the stabber, d – the space between the adjacent yarn.

The elongation of the i^{th} yarn can be illustrated:

$$L_i \quad L_1 \frac{i \quad 1}{i} \tag{8}$$

According to aforementioned analysis, the stab energy of the woven fabric can be deduced:

$$W \quad \overset{i_{est}}{\underset{i\ \ 1}{}} F_i L_i \tag{9}$$

Conclusions

This paper reports the theoretical analysis of the stab performance for the woven fabric using an ancient Chinese algorithm (*Ying Buzu Shu*). The number of participant yarns which contribute to the stab property of textile product can be predicted and the stab energy can be calculated subsequently. Stab energy is one of the essential parameters for the material design with textile structure.

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