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Studying Tensile Strength of Discontinuous Fibber Composites with Statistic Method

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Introduction

Comparing with continuous fiber composites, discontinuous fiber composites (DCFC) have more productions and applications. But the study on the properties of DCFC is very little. So far, in the literatures [1-10] on composite materials, the equations on strength of DCFC are too simple or too complex to be properly applied to engineering project or include some indefinite parameters not suitable to be used in practice. In this paper, by directly analyzing the stress and strain of DCFC and studying the effect of length, direction and position of fibers with statistic method, a group of useful equations has bee gotten, which are suitable to calculate or estimate the tensile strength of DCFC.

Mechanical Analysis

In DCFC, the critical length is

$$l_c = d\sigma_f /(2\tau_m) \tag{1}$$

Here d = diameter of fibers, σ_f = tensile strength of fibers, τ_m = adhesive strength of resin to fibers. If fiber length $l \le l_c$, fibers will be pulled out, when the specimen breaks. The average fiber length pulled out is l/4. The angle of a fiber to tensile direction is φ，which changes from $-\pi/2$ to $\pi/2$. In the section area of a DCFC specimen, the quality of fibers with the same length and angle is $n = \frac{8sV_f \cos\varphi}{\pi^2 d^2 l}$. Here s = section area of the specimen, V_f = fiber volume content. The force to pull out one fiber from a DCFC specimen is $f_1 = \frac{\pi}{4} dl\tau_m \cos\varphi$ and the total force can be calculated by

$$F_1 = \int_0^{l/2} dx \int_{-\pi/2}^{\pi/2} \frac{8sV_f \cdot \cos\varphi}{\pi^2 d^2 l} \cdot \frac{\pi dl\tau_m \cos\varphi}{4} d\varphi = \frac{sV_f l\tau_m}{2d} \tag{2}$$

The force to break the resin matrix is $F_2 = (1-V_f)s\sigma_m$. Here, σ_m = tensile strength of resin. Therefore, when $l \le l_c$, the tensile strength of DCFC is

$$\sigma_c = \frac{V_f l}{2d}\tau_m + (1-V_f)\sigma_m \tag{3}$$

There are N fibers in a DCFC specimen. If $l > l_c$, when the specimen is broken, N_1 fibers are broken and N_2 fibers are pulled out. Apparently, $N = N_1 + N_2$. If the fibers are unidirectional, they can be ranged as Fig. 1 and we can get

$$k_1 = N_1/N = \frac{2l - 2l_c}{2l - l_c} \tag{4}$$

There k_1 = position parameter. The angle effect to fibers can be seen in Fig. 2. Let

$$k_2 = 2\varphi_c / \pi = \frac{2}{\pi} arc\cos\frac{l_c}{2l - l_c} \tag{5}$$

There k_2 = angle parameter; φ_c = critical angle, which points out that fibers can be broken only in the range of $-\varphi_c < \varphi < \varphi_c$.

Analyzing as the same as $l < l_c$, the equation of tensile strength of DCFC for all length of fibers can be gotten as:

$$\sigma_c = \begin{cases} \dfrac{V_f l}{2d}\tau_m + (1 - V_f)\sigma_m & l \le l_c \\ \dfrac{kV_f}{2}\sigma_f + \dfrac{(1-k)l_c V_f}{2d}\tau_m + (1 - V_f)\sigma_m & l > l_c \end{cases} \tag{6}$$

There $k = k_1 k_2$. If $\sigma_m > \sigma_m^* = E_m \sigma_f / E_f$, σ_m should be changed to σ_m^* in (6).

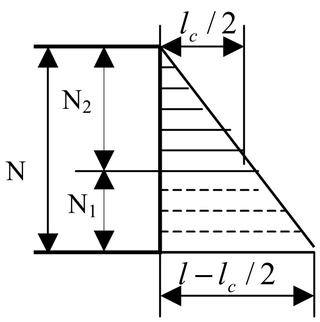

Fig. 1 Fibers range

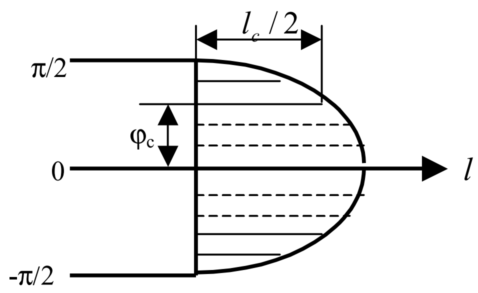

Fig. 2 Angle effect to effective fiber length

Example

As an example, the tensile strength of nylon 66 reinforced with fibers can be seen in Fig. 3. If the fiber length is longer than 0.5mm, the equation (6) should take with a correcting coefficient, which will be given in the full paper.

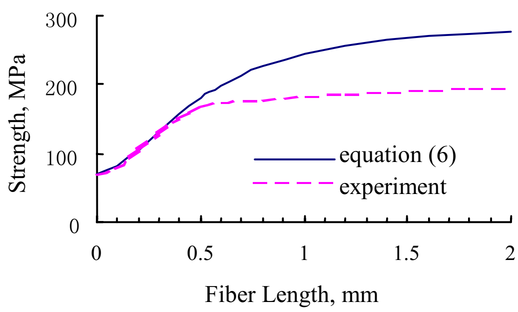

Fig.3 Fiber length to strength

References

1. Tsai, S.W., Composite Design, 4th Edition, 1988
2. Chen, P.E., Strength Properties of DCFC, Polymer Engng Sci., V. 11 N. 1, Jan. 1971
3. Derek Hull, An Introduction to Comp. Materials, Cambridge Univ. Press, 1981
4. Piggot, M.R., Load-bearing Fiber Composites, Pergamon Press, 1980
5. Richardson, M.O.W., Polymer Engineering Composites, App. Sci. Pub., 1977
6. Hukuda, H., et al, Probabilistic Approach on the Strength of Fib. Composites, JSCM, 1981
7. Lees, J.K., A Study of Tensile Strength of Short Fibers Reinforced Plastics, Poly. Engng Sci., NO. 8, 1969
8. Folkes, M.J., Short Fiber Reinforced Thermoplastics, Research Studies Press, 1982