STRENGTH DISTRIBUTION OF ELEMENTARY FLAX FIBRES DUE TO MECHANICAL DEFECTS

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ABSTRACT

Flax fibres are finding non-traditional applications as reinforcement of both inorganic and polymer matrix composite materials. The tensile strength of fibres is an important factor in ensuring efficient reinforcement. The mechanical properties of fibres are affected by the natural variability in plant as well as the damage sustained during processing, and thus have considerable variability. This necessitates statistical treatment of fibre characteristics. The strength of elementary flax fibres, produced by different manufacturers, has been characterised at several fibre lengths by standard tensile tests. It has been demonstrated that the two-parameter Weibull distribution fails to capture the length dependence of natural fibre strength. Alternative strength distributions, based on the assumption that the presence of defects limits fibre strength, are considered and found to provide satisfactory agreement with test results.

KEYWORDS

Flax; fibre; strength; distribution.

INTRODUCTION

The efficiency of fibre reinforcement in a composite material is determined primarily by the mechanical properties of reinforcing fibres and their adhesion to matrix. While the scatter of fibre stiffness exerts limited effect on composite properties, fibre strength distribution affects both strength and toughness of a composite. Weakest-link character of fibre failure is reflected in the commonly used Weibull distribution of fibre strength (Weibull, 1939)

$$F(\sigma)=1-\exp\left[-\frac{l}{l_0}\left(\frac{\sigma}{\beta}\right)^{\alpha}\right] \tag{1}$$

where l stands for fibre length, l_0 is a normalizing parameter, σ is the tensile stress at fibre failure, and α, β designate Weibull shape and scale parameters, respectively. However, it has been shown that the two-parameter Weibull distribution, Eq. (1), does not comply with the experimental data of flax fibre strength at different gauge lengths (Andersons et al., 2005, Zafeiropoulos and Baillie, 2007). Instead, a modified Weibull distribution

$$F(\sigma)=1-\exp\left[-\left(\frac{l}{l_0}\right)^{\gamma}\left(\frac{\sigma}{\beta}\right)^{\alpha}\right] \tag{2}$$

is found to agree with elementary flax fibre strength (Andersons et al., 2005). The physical origin of the distribution Eq. (2) is related to inter-fibre variation of strength characteristics. It has been demonstrated theoretically (Curtin, 2000) and experimentally (Andersons et al., 2002) that the distribution [Eq. (2)] for fibre batch is obtained if each of the fibres possesses Weibull strength distribution Eq. (1), but the parameters of Weibull distribution for individual fibres differ. Berger and Jeulin (2003) attribute Eq. (2) to the presence of a large-scale fluctuation of the density of defects (flaws) in fibres.