The Tensile Behavior of E-glass fibers

E.J. Parra-Venegas, A. Rodríguez-Miranda, K. Campos-Venegas, R. Martínez-Sánchez, J.M. Herrera-Ramírez

Glass fiber is a mineral fiber made from silica, lime, alumina and magnesite. The glass fibers are fairly isotropic, the Young's modulus and coefficient of thermal expansion are the same along the fiber axis and perpendicular to it. This of course is the result of a three-dimensional array structure [1]. Glass fibers are used in a number of applications which can be divided into four basic categories: (a) insulations, (b) filtration media, (c) reinforcements, and (d) optical fibers. More than 99% of continuous glass fibers are spun from an E-glass formulation. E-glass is basically a calcium aluminum-borosilicate glass [2]. These fibers have a low density and at the same time a very high resistance; the Young's modulus, however, is not so high. Thus, while the relationship weight- resistance is very high, the relationship weight-module is only moderate [1]. E-glass fibers can be converted into a number of forms for reinforcement of resins, rubbers or polymers to give durable structural composites, with a wide range of application; this is due to their wide availability, good mechanical properties and low cost [2]. The purpose of this investigation was to determine the tensile mechanical properties of E-glass fibers. Single E-glass fibers have been subjected to tensile tests at room temperature using a Universal Fiber Tester [3], equipped with a load cell of 250 g calibrated from 0 to 100 g, with a precision of 0.01 g. The specimen gauge length was 30 mm and the fiber was gripped between two sets of jaws. Data acquisition used a PC linked to the fiber tester via a National Instrument interface card and WinATS 6.2 software from

Sysma. In order to normalize the stress, the diameter of each fiber was systematically measured before each test by using a Mitutoyo LSM-500S laser apparatus, with an accuracy of 0.01 µm.

The E-glass fibers had simple Hookean stress-strain curves, that is, they remained linear up to failure. The mechanical properties were calculated from these curves, whose values are shown in Table 1 together with the diameter; 30 fibers were broken and mean properties were determined. The standard deviation indicates there is considerable variability in the strength of these fibers. The fiber strength depends partly on the inherent structure but is also critically dependent on the state of the fiber surface, with the strength decreasing as damage leads to deeper surface cracks. The surface appearance of the untested E-glass fibers in the scanning electron microscope is smooth (Fig. 1a), although some stretch marks have been observed (Fig. 1b). The tensile fracture morphology presented for all the fibers tested was a classical brittle fracture; images of the fracture surface are shown in figure 2. These brittle fractures, in consort with the linear stress-strain curves, demonstrate that the material strain is everywhere elastic with no plastic yield. The failure is usually initiated by surface flaws and when tension reaches a given level, the deepest crack starts to propagate radially until it exceeds the local tensile strength of the material and a catastrophic failure occurs [4]. Although breaks perpendicular to the fiber axis are the simplest form and are frequently observed, eventually it is possible to find cracks at other angles, or even two separate cracks linked by a plane of high shear stress.

Table 1. Mechanical properties e of the E-glass fibers.

Tensile strength (GPa)	2.89 ± 0.69
Breaking strain (%)	1.99 ± 0.61
Young´s modulus (GPa)	73.18 ± 10.76
Diameter (µm)	19.01 ± 1.38

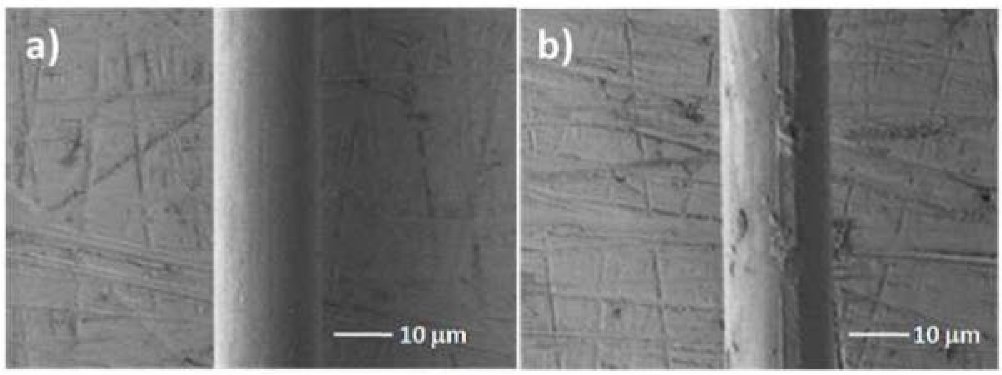

Fig. 1 SEM micrographs showing two E-glass fibers with: (a) a smooth surface and (b) the presence of stretch marks on the surface.

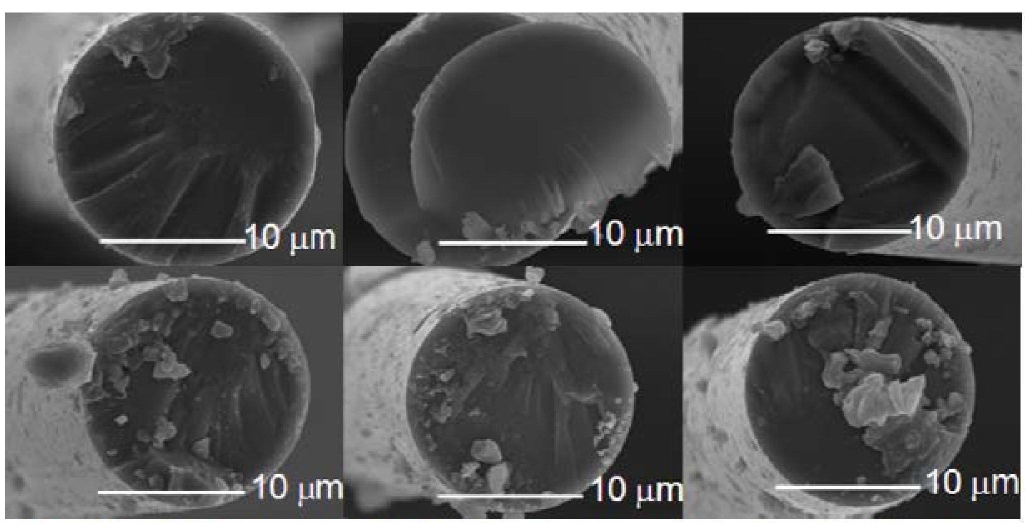

Fig. 2 SEM images of some E-glass fiber fracture surfaces. E-glass fibers exhibit a brittle fracture.

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