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STRENGTH OF OPTICAL FIBRES UNDER COMBINED STRESSES AND AGING IN VARIOUS ENVIRONMENTS

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Abstract. This paper is an overview of the various parameters determining the mechanical behaviour of the optical fibres. Some recent results are presented and discussed in the light of fracture mechanics, Weibull statistics and surface fractographic analysis.

Lifetime evaluations under various service environments are presented as a function of the mechanical properties of the fibre. The combined stress configuration analysis is tied to the realistic assumption that the fibres will be subjected in operation conditions to a complex stress field. The results together with those of short and long term stability of fusion splices, are particularly important to engineering field installations.

As low-loss fibres are now routinely produced in many laboratories, the interest is being shifted towards the mechanical resistance and other properties whose knowledge seems necessary for use of the waveguides in a practical system.

The influence of the surface state on the fibre strength has to be particularly studied in order to avoid premature aging of the fibers and to choose the appropriate outer protection of them.

Few data have been published on this field, most of them reporting statistical results of breaking tensile strength tests of fibers with different plastic protections.

In this paper we present statistical results concerning the breaking strength, under combined torsional and tensile stresses, of various fibres are presented on Weibull plots. The relative resistance loss due to torsion is in good agreement with the theoretical calculations. On the other hand, static and dynamic fatigue experiments on a large number of fibre samples simultaneously, are described and lifetime predictions are made from these results.

A variety of coatings was tested with respect to the permeability to water, by measuring the fracture stress of a large number of randomized samples previously placed in vacuum, hot moisture and laboratory atmosphere.

One of the starting points of fracture mechanics is the concept of the stress intensity factor $K_i$. Using Paris equation: $K_i = \sigma \sqrt{\pi a}$ and the appropriate values for silica: $K_i = 0.798$ MPa.m$^{1/2}$ and $Y = 1.24$, we can plot the stress to failure versus the initial flaw depth (FIG.1).
The fibre lifetime is essentially determined by the first part of the \((V, K_I)\) plot, (FIG.2), the flaw propagation time for the second and third parts being too short to be taken into account. We have reported an experimental method for recording the flaw size as function of the applied stress in optical fibres (1). Nevertheless, indirect techniques like static and dynamic fatigue are mostly used to obtain mechanical strength and durability data.

During cabling and eventually in service as well, fibres will undergo combined torsional and tensile stresses. In this case, the equivalent tensile stress \(\sigma'\) can be expressed as a function of the number of tours per unit length \(N\), the fibre diameter \(D\), the corresponding pure-tensile breaking stress and the shear modulus \(G\):

\[
\sigma' = \frac{\sigma^0}{\left(\frac{G \cdot D \cdot N}{\sigma^0}\right)^2}
\]

Hence, the loss of mechanical resistance due to torsional stress is showing the influence of the initial tensile strength (FIG.3). The Weibull plots for different levels of additional torsional stress are reported in FIG.4 in comparison with the plot corresponding to pure tensile stress.

The fracture surface of some fibre samples tested under combined stresses were examined on the scanning electron microscope (FIG.5). The results presented clearly show some important departures from the pure tensile stress case. The failure origin is determined whenever possible and the mechanical behavior of the fibres under combined stresses is discussed. The experimental set up for static and dynamic fatigue operates with 34 samples simultaneously (FIG.6). The static fatigue behavior of different CVD fibres was studied for three different elongations (2). The failure probability is plotted versus the time to failure using a linear regression. (FIG.7). The slope of this curve is \(N_n\) and knowing the value of \(m\) from the Weibull plot, we can calculate the stress-corrosion susceptibility constant \(n\), and make possible lifetime predictions for various conditions:

\[
t_f = \frac{\sigma^0}{\sigma_a} \cdot \left(\frac{N_n}{m}\right)^{\frac{n}{2}}
\]

Lifetime evaluations of an average CVD fibre are shown in FIG.8. The parameters \(n\) and \(B\) are given by static or dynamic fatigue statistical tests. Lifetime depends on the service permanent stress \(\sigma_a\) and the fibre initial strength \(\sigma^0\).

**REFERENCES**


Fig: 6

**STATIC FATIGUE**

- \( \sigma = 1.5 \) 0.001
- \( \sigma = 3.5 \) 0.001
- \( \sigma = 2.5 \) 0.001

**TIME TO FAILURE (T)**

- 20.3
- 24.2
- 26.1