FATIGUE OF FIBRES BY BIAXIAL ROTATION OVER A PIN

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INTRODUCTION

A simple method of rotation over a pin or wire has been successfully used to test fatigue properties of fibres, in the Department of Textile Technology of the University of Manchester. Goswami [1] originally used this technique and made some preliminary studies. Wong [2] developed the test method further and tested nylon, polypropylene and polyester fibres under different conditions of stress and chemical environment [3]. In this method, the fibre hangs over a pin with a weight attached to its free end (Figure 1). The opposite end of the fibre is rotated and the weight eventually rotates at the same frequency. The region which is bent over the pin undergoes a compression-tension action. Any given point on the surface of the fibre thus encounters an oscillating stress, increasing in magnitude with distance from the neutral axis.

The method is useful because of its simplicity and because the failures are similar in form to many failures in real use of fibres. However, it has the defect that the stress situation is complicated by the viscous drag on rotation of the weight.

BIAXIAL ROTATION OVER A PIN

The method of testing the fatigue properties of fibres by biaxial rotation over a pin is an improvement of the previous method described. An apparatus was designed and constructed in the Department of Textile Technology as a prototype and its principle is shown in Figure 2. Shaft 4 is driven at a constant frequency which is transmitted to shaft 1 through shafts 2 and 3. Therefore, the fibre which is bent over a pin and clamped in the shafts 1 and 4, has its ends rotating at the same frequency.

The system is built in a way that allows shaft 1 to move up and down freely. Consequently, the weight attached to its other end imposes a constant tensile stress in the specimen during the experiment. Once the fibre breaks, the weight drops on a switch stopping the system, and its fatigue life is measured in terms of cycles. Provisions are made so as to allow experiments to be made under different chemical environments.

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RESULTS

Medium tenacity polyester fibres were produced and tested to assess their fatigue life under different conditions. Table 1 shows the mean life-time, in cycles, obtained for polyester fibres of different linear densities, tested in air (21°C, 55 r.h.) under the same tension (41.2×10^{-3}N), frequency (15 Hz) and over the same pin (0.254 mm diameter, stainless steel wire).

The fatigue life tends to decrease as the diameter of the fibre and consequently the apparent strain amplitude (ε_{ap}) increases.

$$\varepsilon_{ap}(\%) = \frac{df}{df+D}\,100$$

ε_{ap} = apparent strain amplitude at the surface of the bent portion of the fibre,
df = fibre diameter, and
D = pin diameter.

Table 2 shows the mean life-time, in cycles, for a 0.8 tex medium-tenacity polyester fibre, under different values of tension, tested in water at the same frequency and over the same pin as the previous experiment.

As one would expect the fatigue life decreases as the stress increases. When higher values of tension were used early breaks occurred, partly due to an increase in the frictional force between the fibre and pin which grips the fibre in the region of contact with the pin.

For statistical study, about hundred runs were taken in water with the 0.8 tex polyester fibre, in the same conditions as before, under a constant tension of 69.6×10^{-3}N. Figure 3 shows the corresponding histogram for the fatigue life and some statistical parameters can be seen in Table 3.

An attempt was made to fit the Weibull distribution which has been successfully used to describe some types of fatigue failures, to results obtained from the present technique of fatigue.

This is illustrated in Figure 4 (not all points have been plotted) for a 0.84 tex polyester fibre. N(100) is the number of failures obtained and denoting by n_i the number of cycles to failure of the ith run, an estimate of the probability that an item will survive is given by $(N+1-i)/(N+1)$. By plotting $\ln (N+1)/(N+1-i)$ against n_i on log-log paper, the points will be on a straight line if the Weibull model is appropriate. Another parameter to be considered is the Weibull location parameter, an estimate of it can be obtained from the smallest failure, 1806 cycles in the given example. This is subtracted from all the other observations and the analysis carried out on the remaining readings, n_i will be in fact the (i-1)th failure after the location parameter. The points appear to fit reasonably well and there is evidence that this method does produce a Weibull distribution.

Another set of experiments has been carried out with the 4.2 tex medium-tenacity polyester fibre in which tests were stopped at regular intervals of 100 cycles, the specimen removed from the instrument and the bent portion of the fibre observed in the electron microscope. It was found that cracks began to appear on the fibre in the early stages of the test. This occurs approximately after the specimen rotates 10% of its mean life-time;

at this point the breaking extension drops considerably (from 30% to 12%). However, the tenacity decreases smoothly after the formation of the initial cracks.

Figures 5a, 5b, 5c and 5d show the sort of damage obtained in the fibre when this technique is used and compares it with fibres worn in normal use. Consequently this test seems to produce an action on the fibre similar to that encountered in worn fabrics.

CONCLUSIONS

Different fibres were examined in the biaxial rotation over a pin texter, in a variety of conditions using different tensions, pins of various diameters, different environments and the results were reproducible. This method is worth considering in any attempt to standardize fatigue tests in fibres.

REFERENCES

1. GOSWAMI, B. C. and HEARLE, J. W. S., Tex. Res. Journal, <u>46</u>, 1976, 55.
2. WONG, B. S., "A Comparative Study of the Fatigue of Some Synthetic Fibres in Various Environment", Ph. D. Thesis, University of Manchester, 1975.
3. HEARLE, J. W. S., "Contribution of Science to the Development of the Textile Industry", Joint Conference, Institut Textile de France - The Textile Institute, Paris, 1975, 69.

Table 1 Medium-Tenacity Polyester

LINEAR DENSITY (tex, i.e., g/km)	0.8	1.7	2.7	4.2
APPARENT STRAIN AMPLITUDE (%)	9.9	13.6	16.7	19.6
MEAN LIFE-TIME (cycles)	9046	5473	3019	2241

Table 2 0.8 Tex Medium-Tenacity Polyester

TENSION x 10^{-3} (N)	5.9	19.6	29.4	41.2	69.6
MEAN LIFE-TIME (cycles)	27402	11629	10187	7810	4019

Table 3 0.8 Tex Medium-Tenacity Polyester

MEDIAN	3834
MEAN-LIFE TIME	4019
STANDARD DEVIATION	1103
COEFFICIENT OF VARIATION	27.4%
SKEWNESS	0.776
KURTOSIS	3.621

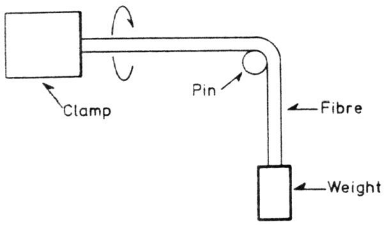


Figure 1 Rotation over a Pin

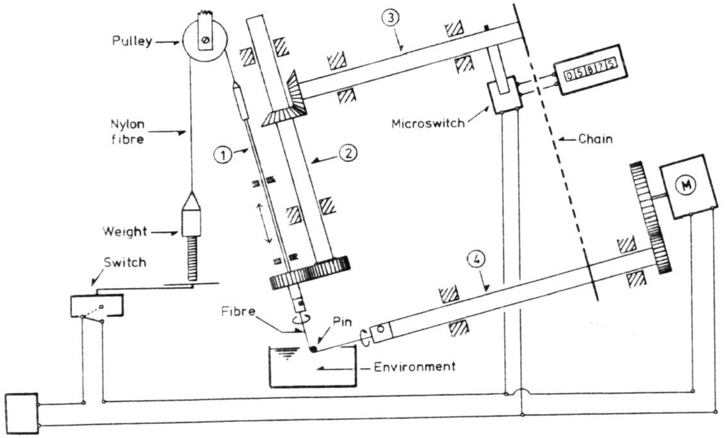


Figure 2 Biaxial Rotation over a Pin Tester

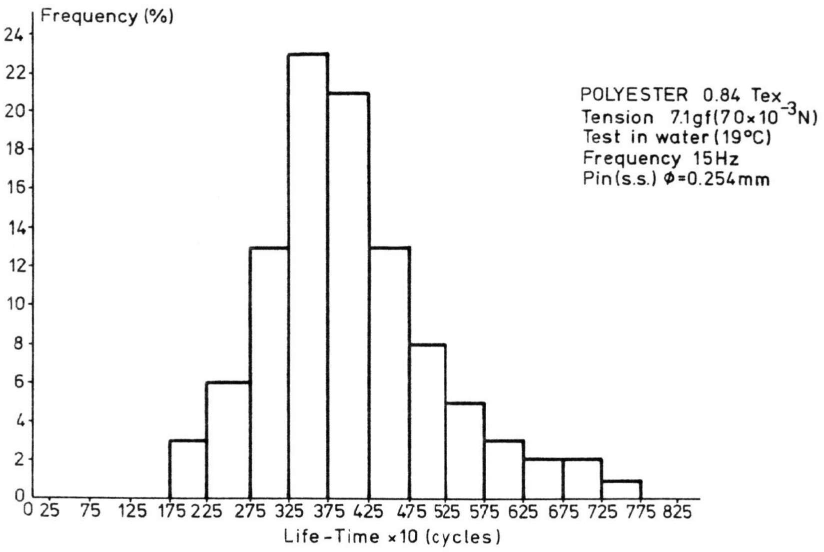


Figure 3 0.8 Tex Polyester Histogram

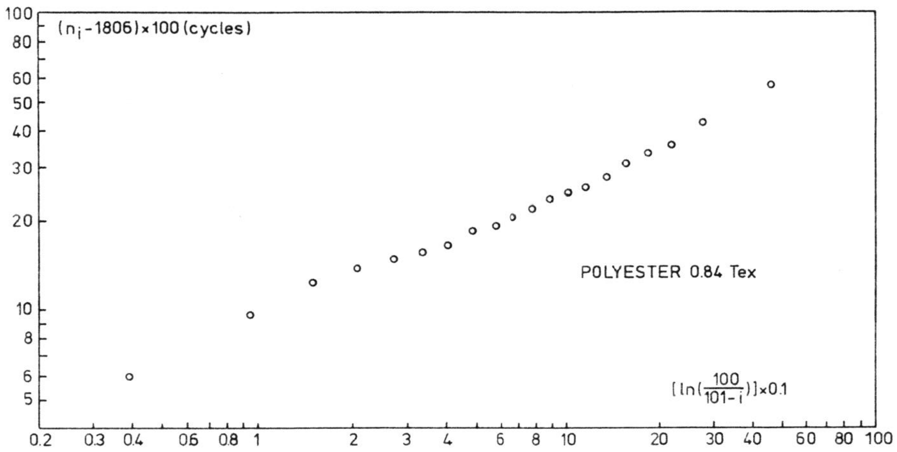
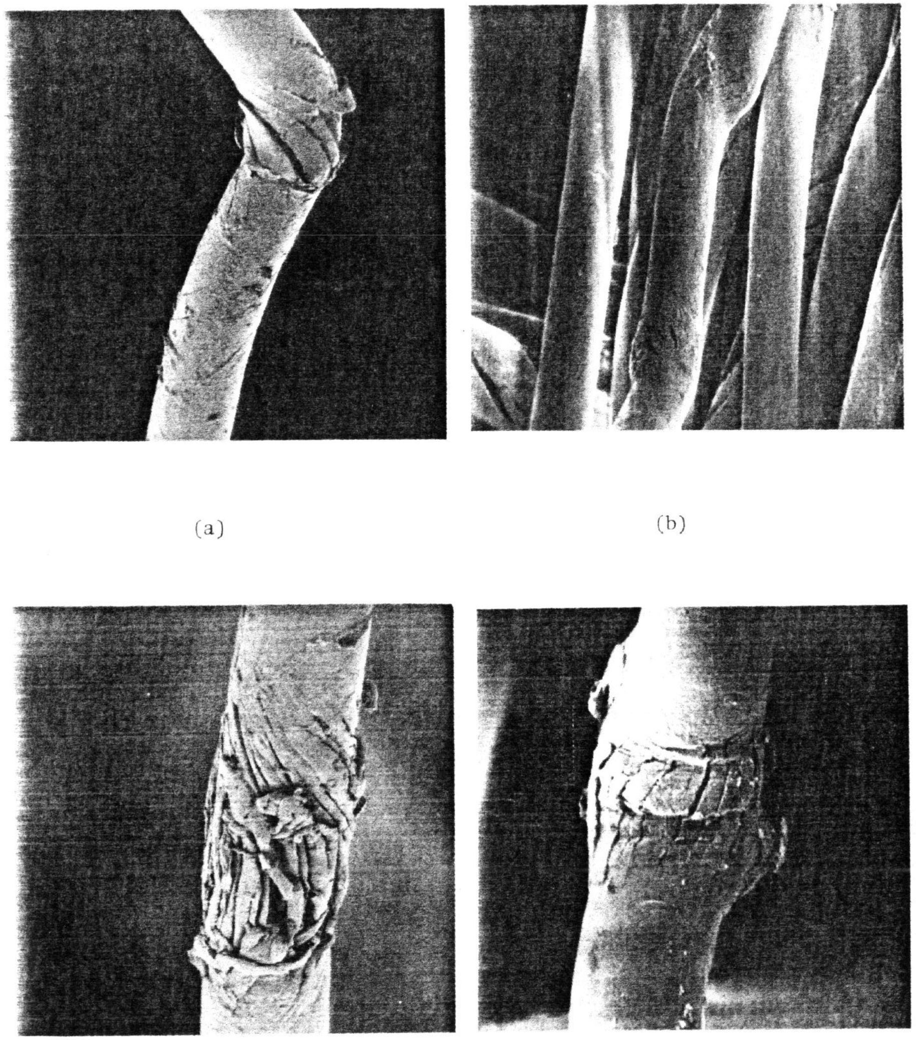


Figure 4 0.84 Tex Polyester: Weibull Distribution



(a) (b)

(c) (d)

Figure 5 (a) 2.7 Tex Polyester (3181 Cycles - 110X)
(b) Terylene/Cotton Shirt (Inside Shoulder Facing)
(c) 2.7 Tex Polyester (2032 Cycles - 1840X)
(d) Terylene/Cotton Shirt (Collar Fold)