Mechanical and dielectric properties of pineapple fibres

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Pineapple fibres are well known for their commercial uses in making fabrics especially in north-eastern India. Although other natural cellulose fibres like cotton, jute, ramie, hemp, etc., have been widely studied for their various properties [1–4], no work appears to have been reported on these industrially potential fibres. Hence a study of the structure and various mechanical and dielectric properties of the fibres was undertaken to help the users to better utilize this commercially cheaper variety of fibres. For this purpose a specimen of pineapple fibres from Manipur, India was selected. The fibres were first purified from fat, wax and lignin by successively treating them with an alcohol–benzene mixture and sodium chlorite solutions, respectively.

The purified sample was then first subjected to thermal and X-ray analyses. The differential thermal analysis (DTA) curve showed two endothermal peaks at 150 and 250° C, respectively, indicating a two stage dehydration of the fibres and an exothermal peak at 500° C which is due to the burning of the organic matter and possible emergence of some new phase. X-ray diffraction patterns were recorded with the help of a Philips X-ray diffractometer adopting the procedures as described by Mukherjee and Mitra [5]. The values of the lattice parameters obtained from the X-ray diffraction pattern after due correction are $a = 8.32$ A.U., $b = 10.3$ A.U., $c = 7.93$ A.U. and $\beta = 82.6°$. These data conform well with the structure of cellulose type-I [4]. An estimation of the degree of crystallinity $[I_{cryst}/I_{total}]$ was made from the X-ray diffractogram by applying the technique

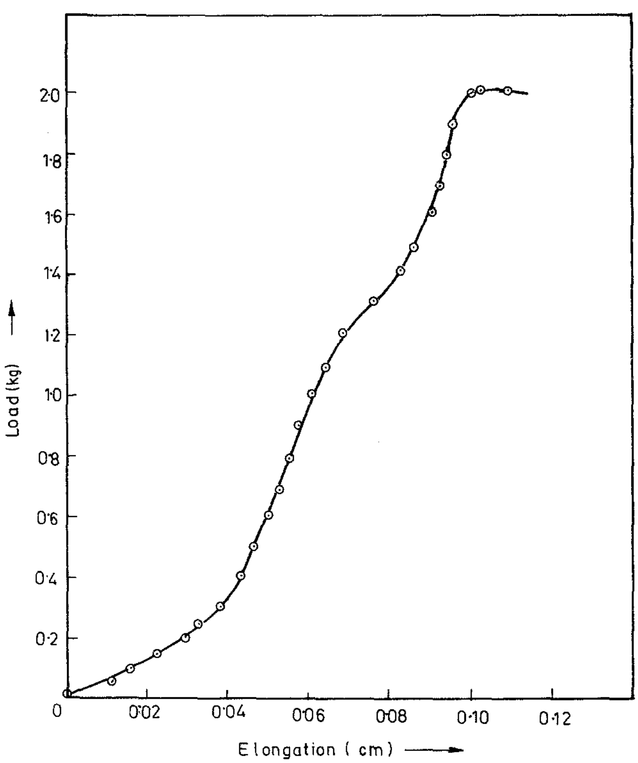

Figure 1 Load–elongation curve for pineapple fibre (length = 2.3 cm, diameter = 0.075 cm) at 70% r.h. and 25° C.

TABLE I Mechanical properties of pineapple fibre at 70% r.h. and 25° C

Properties	($kg\,mm^{-2}$)
Young's modulus	1750
Elastic limit	0.27
Tensile strength	0.45
Yield stress for 0.5% elongation	0.21
Extension at break	4.8%

of Ruland [6] and the values obtained are found to be in the range 0.63 to 0.68.

The mechanical properties of the fibres were studied with the help of an Instron table-model universal-testing instrument, Model TM-M at 70% r.h. and 25° C. The load–elongation curve is shown in Fig. 1. The observed values of the different parameters, as obtained from this figure, are given in Table I. It was observed that the load–elongation curve is fairly linear initially but becomes non-linear beyond a stress value of 0.27 $kg\,mm^{-2}$. The Young's modulus value of 1750 $kg\,mm^{-2}$ is quite high compared to 200 $kg\,mm^{-2}$ for wood, 750 $kg\,mm^{-2}$ for cotton and 2000 $kg\,mm^{-2}$ for jute [4]. However, the tensile strength is relatively low and is of the same order as those of polyesters, wood cellulose, etc. This low tensile strength as compared to other bast fibres of similar nature, such as ramie and jute, is most likely due to the randomness in the molecular configuration and existence of minute faults, fissures, etc., in the structure which initiates the breakdown at a comparatively low concentration of stress. Extension at breaking indicates the maximum strain that the material can withstand. The observed value of 4.8% compares favourably with 1.8%, 3.7% and 6 to 7% for ramie, jute and cotton, respectively [4].

A study of the dielectric property is of considerable importance as it gives information on the amorphous and crystalline contents of the fibre [7]. Earlier, Datta *et al.* [7] reported studies on the electric anisotropy of several other cellulose fibres. In the present case, samples were prepared and measurements were made with a precision capacitance bridge GR 716 up to 10 kHz frequency in the same manner as reported by Datta *et al.* [7]. The variation of dielectric constant, K, and dielectric loss, $\tan\delta$, with frequency along the longitudinal and transverse directions of the fibre is illustrated in Figs. 2 and 3. The variation of a.c. conductivity with frequency along the longitudinal and transverse direction of the fibre is calculated from dielectric measurement and is shown in Fig. 4.

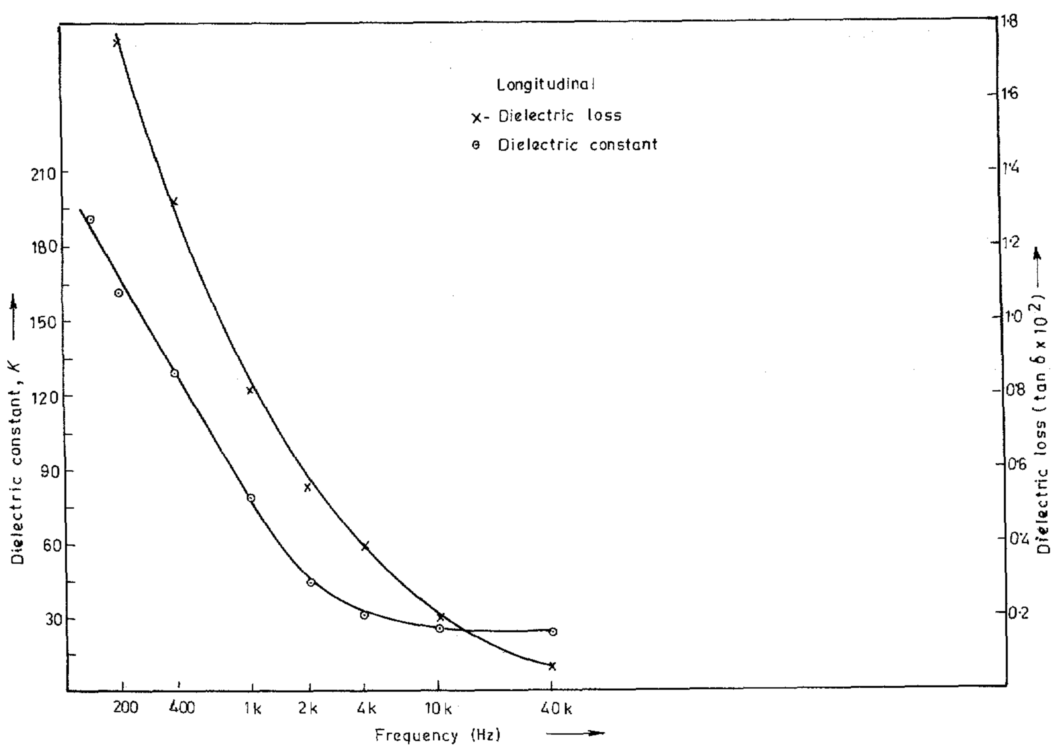

Figure 2 Variation of dielectric constant (K) and dielectric loss ($\tan\delta$) with frequency along the longitudinal direction.

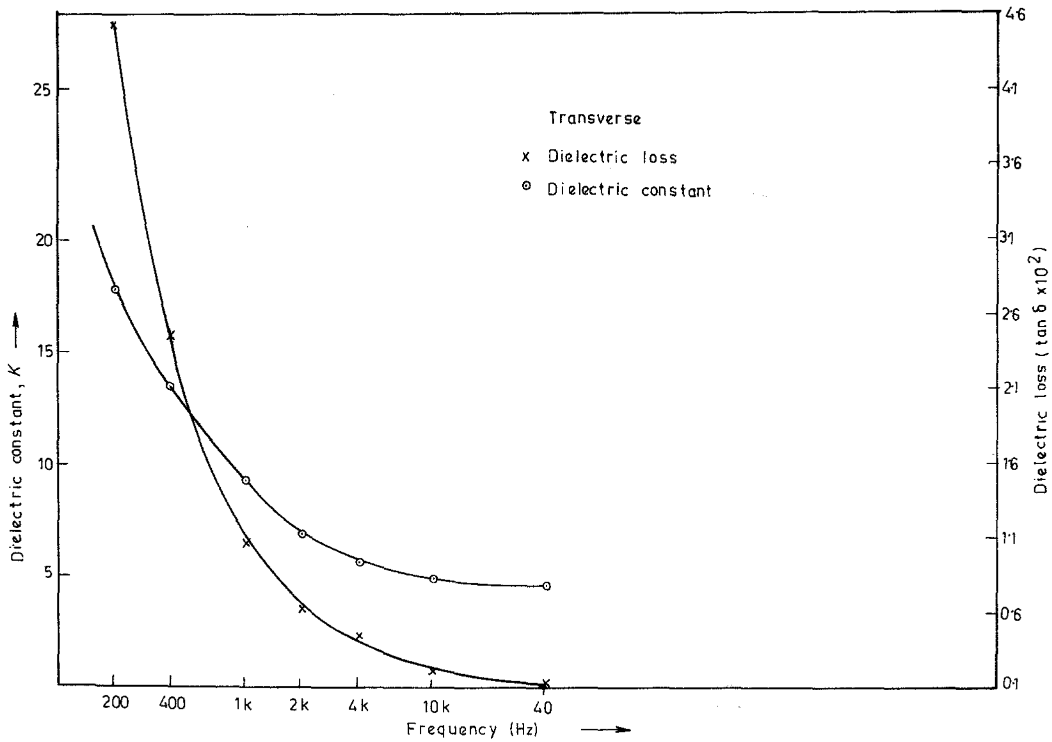

Figure 3 Variation of dielectric constant (K) and dielectric loss ($\tan\delta$) with frequency along transverse direction.

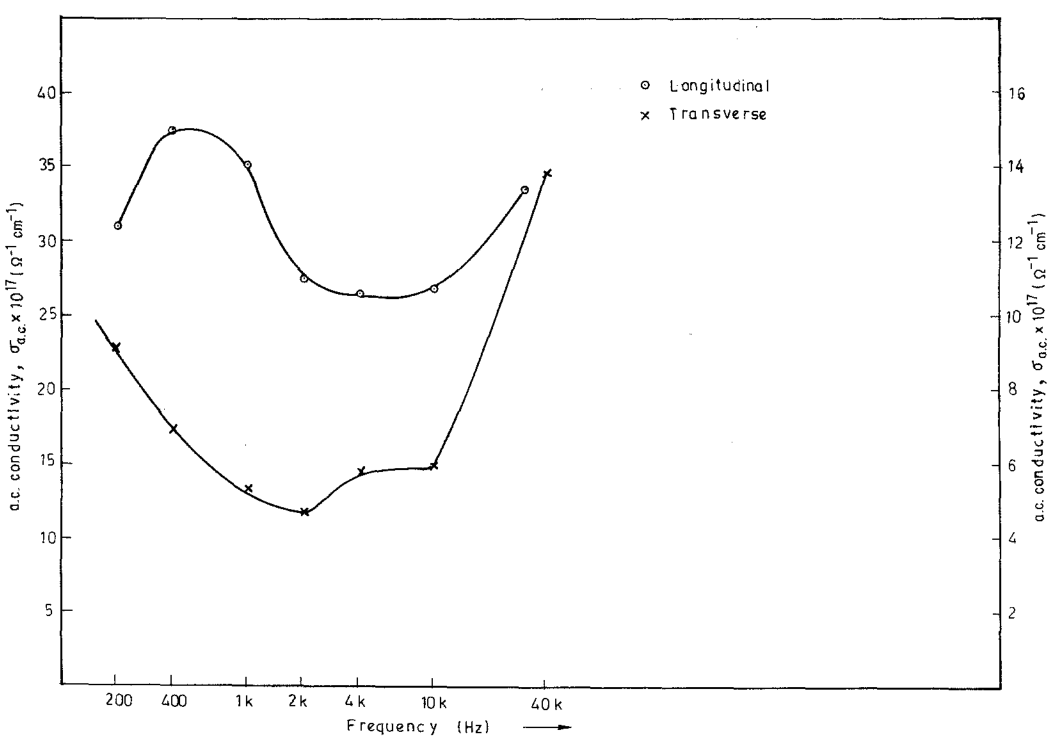

Figure 4 Variation of a.c. conductivity with frequency along longitudinal and transverse direction of the fibre.

The values of the dielectric constant and dielectric loss are nearly the same as that for jute reported earlier [7]. There is nearly a tenfold increase in the value of the dielectric constant and a fall in the dielectric loss along the direction of the fibre as compared to the transverse direction. This extent of increase is more pronounced as compared with other fibres [7]. This may be attributed to a greater orderly alignment of the dipoles along the fibre direction than across the fibre axis.

Thus, it can be concluded that pineapple fibres having cellulose type-I structure exhibit good elastic properties, can withstand high strains comparable with other similar fibres but have lower breaking stresses because of the high concentration of disorder. The electrical properties of these fibres show high anisotropy. A detailed study of the determination of the structural disorder by X-ray analysis is in progress and is expected to throw more light on the above properties.

References

1. H. MARK and A. V. TOBOLSKY, "Physical Chemistry of High Polymeric Systems" (Interscience, New York, London, 1950).
2. P. H. HERMANS, "Physics and Chemistry of Cellulose Fibres" (Elsevier, New York, 1949).
3. E. OTT, M. SPURLIN and W. GRAFFLIN, "Cellulose and Cellulose Derivatives" (Interscience, New York, 1954).
4. W. J. ROFF, "Fibres, Plastics and Rubbers, a Handbook of Common Polymers" (Butterworths Scientific Pub., London, 1956).
5. P. S. MUKHERJEE and G. B. MITRA, *Polymer* **21** (1980) 1403.
6. W. RULAND, *Acta Crystallogr.* **14** (1961) 1180.
7. A. K. DATTA, P. S. MUKHERJEE and G. B. MITRA, *J. Mater. Sci.* **15** (1980) 1856.

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