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STRUCTURAL AND THERMAL STUDIES ON SISAL FIBRE

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Mechanical characteristics of sisal fibre, such as UTS and Young's modulus, have been determined. The thermal degradation of sisal fibre has been observed by running its DSC and TG/DTG.

Sisal is an important leaf fibre and its production is quite high [1]. Sisal is creamy-white to yellowish in colour. The average fibre length varies from 0.6 to 1.2 m, the diameter being about 0.24 mm. When sisal is added as a filler in suitable proportions to cement, it gives increased flexural strength. Sisal is light, it has good insulating properties and it is highly resistant to bacterical damage [2, 3]. The chemical constituents of the fibre are cellulose 66–72%, lignin 10–14%, hemicellulose 12%, and moisture 10% [4–5].

The fibre has the following physical properties: true density 1.45 g/cc, apparent density 1.26 [6] and spiral angle 23° [6]. The physical properties of these natural fibres vary from source to source [6–8] and it was therefore necessary to study the structure and thermal behaviour of sisal fibre from Madhya–Pradesh (M.P.).

In this paper, the physical properties and thermal behaviour of M.P. sisal fibre have been studied and are correlated with the structural changes occurring during heating of the fibre.

Materials and methods

The sisal fibre sample used in this study was from the Bilaspur region of M.P. and was obtained through the Khadi Village and Industries Commission (KVIC),

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Bhopal. For optical microscopy, the fibre was embedded in a polyester block and, after polishing, photographs were taken. The tensile behaviour of a large number of samples was determined by using an INSTRON at a testing speed of 0.02 m/min. Fractured samples were observed on a scanning electron microscope (SEM).

Samples for thermal study were prepared by chopping the fibres to a length of 2 mm.

TG and DTG runs were carried out on a Stanton Redcroft thermal analyser model TG 750, in the temperature range 30 to 500°, at a heating rate of 20 deg/min in static air. DSC runs were carried out on a Perkin–Elmer DSC–2, using aluminium pans, in the temperature range 50–520°, at a heating rate of 20 deg/min. An inert atmosphere was maintained with argon. The sample weight for all runs was about 5 mg.

Results and discussion

The average ultimate tensile strength (UTS) and modulus of 100 samples measured by means of a load-elongation curve obtained with an INSTRON are 445.0 MN/m^2 and 10.0 GN/m^2, respectively. Initially the curve is linear elastic up to a certain percentage of elongation, after which it displays plastic behaviour. Figure 1 depicts the cross-section of sisal fibre, which shows the cell size ranging from 5 to 40 μm. Sisal has elongated, elliptical cells [7].

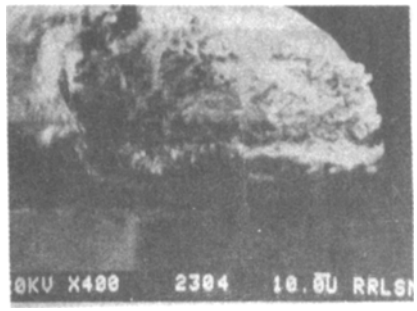

Fig. 1 Optical micrograph of a cross section of sisal fibre at a magnification of 120×

Figure 2 shows the fractured cross-section of sisal fibre at a speed of 0.02 m/min, which reveals that the cells have fractured after pulling out.

Figure 3 illustrates DSC scans of sisal fibre as received, and heated at 60° for 1/2 hour and 1 hour under an inert atmosphere. The baseline of the equipment was normalized between 323 and 773 K, using the procedure recommended by the

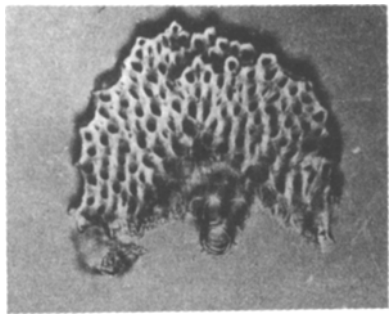

Fig. 2 SEM micrograph of a fractured cross section of sisal fibre at 0.02 m/min speed × 400

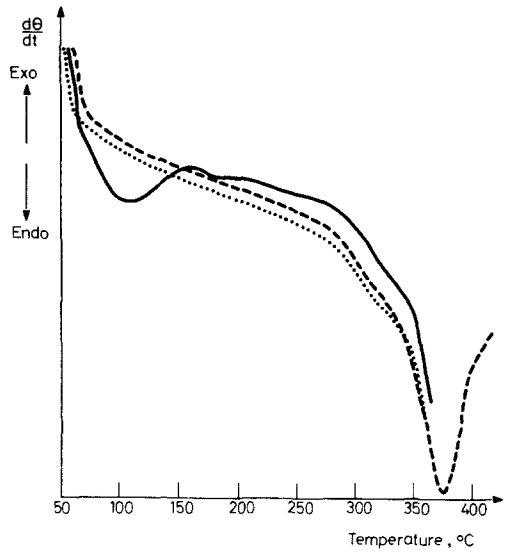

Fig. 3 dQ/dt *vs.* temperature plot of sisal fibre. —— untreated; --- 1/2 hour; .... 1 hour

manufacturer. The temperature axis was calibrated by using indium and potassium chromate, which have melting points of 429.8 and 943.7 K, respectively.

Figure 4 gives the residual weight and rate of weight loss *vs.* temperature plot of a dried sisal fibre. The plot indicates a two-step degradation process for sisal fibre.

It is observed that, after a small change in weight up to 100°, the main initial weight loss begins at 200° to 310°. The rate of weight loss dw/dt is very high. The peak at 310° corresponds to the decomposition of lignin; this temperature is similar to the 270–290° observed by Smith [9]. After 310°, dw/dt attains a plateau region up to 328°, after which the rate of decomposition becomes very high up to 347°. This degradation is similar to the degradation reaction of cellulose in the case of wood, observed by Levin and Belikova [10].

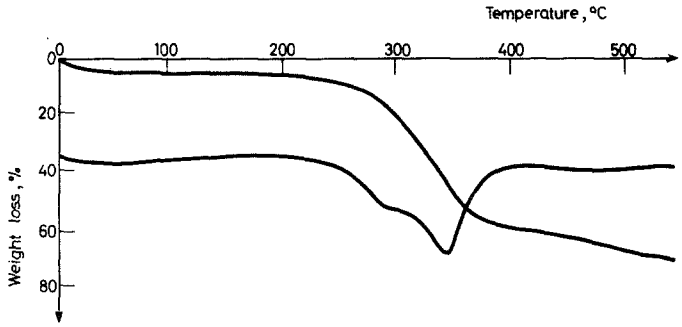

Fig. 4 Weight loss and dw/dt *vs.* temperature of sisal fibre

The untreated fibre exhibits an endothermic transition, with a maximum at 107°. This is attributed to the removal of absorbed moisture from the fibre matrix. A similar endothermic transition has been reported by Tang [11] in a different plant material. Fibres treated at 60° for 1/2 hour and 1 hour do not exhibit this type of transition as their absorbed moisture is removed during heat treatment.

The softening of lignin starts from 207°, and the decomposition of lignin continues up to the temperature range 270–290°. The continuous endothermic shift change in the enthalpy is very fast at nearly 315°, from which temperature the decomposition (dehydration) of cellulose starts. The DSC scans of heat-treated sisal fibre samples were continued up to 425°. A well-defined endothermic transition near 375° is observed in both cases. This may be attributed to the dehydration and splitting of hydroxyl groups of the cellulose molecule, resulting in the evolution of water. The dehydration of cellulosic material during its decomposition has been reported elsewhere [12].

Conclusions

The stress-strain curve and the fracture of typical sisal fibre have been observed by means of the INSTRON and SEM. The fibre has a Young's modulus of 10.00 GN/m^2, an ultimate tensile strength (UTS) of 445.0 MN/m^2 and a percentage elongation at break of 9%. The cell arrangement has been observed by taking photographs on a stereomicroscope. The thermal analysis shows that the fibre liberates water at 107°. Two steps of degradation were observed in the temperature range 250–310°, corresponding to the degradation of lignin and cellulose.

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Zusammenfassung — Die mechanischen Kennwerte (UTS, Young's Modul) von Sisalfasern wurden bestimmt. Der thermische Abbau von Sisalfasern wurde mittels DSC und TG/DTG untersucht.

Резюме — Для волокон сизальской пеньки определены такие механические характеристики, как ЮТС и модуль Юнга. Методом ДСК и ТГ/ДТГ изучено термическое разрушение волокон.