SONIC MODULUS – A UNIQUE CHARACTERISATION METHOD

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Physical and Chemical characterization methods can be used to analyze the polymeric materials with reference to their molecular arrangement, degree of crystallinity, crystalline orientation, thermal degradation, melting and other transitions related behaviours. Many of the characterization methods involve degradation or destruction of the samples for analysis purpose. Sonic modulus is a unique characterization technique which does not involve destruction or degradation of the specimen but gives a measure of overall orientation, useful analyses of many of the mechanical properties.

Key words: *Amorphous, Crystalline, Modulus, Orientation, Sonic Velocity.*

INTRODUCTION

The structure and properties of the man-made textile fibres are, mainly, decided by the spinning conditions and post spinning operations, besides the chemical nature. Though many auxiliary materials are used during the manufacturing operations, some additives like pigments are added in the dope to impart value addition to the material. The effects of these pigments on the structure and the properties of the fibres produced are of practical significance since they also affect the subsequent processing performance, physical properties and ultimately end use applications. Characterisation of polymers and textile fibres plays a major role in analyzing the properties and deciding the applications for different end uses. Spectroscopic methods, x ray diffraction, thermal characterisation methods are widely used in analyzing the structural aspects and properties of the fibres. However, these methods involve degradation or destruction of the samples for analysis purpose. Sonic modulus, a unique characterization technique involving sonic pulses, does not require the destruct or degrade the specimen but is of great use in analyzing structure and properties of the fibres.

SONIC MODULUS

Young's modulus of elasticity applies only to the perfectly elastic materials, limited to the initial portion of a stress-strain curve where a material exhibits essentially elastic behaviour without any plastic flow or permanent deformation. In fibre testing, the modulus over the initial part of the stress-strain curve, over first percent or two, is calculated as the initial modulus of the fibre. Synthetic fibres are the aggregation of different micro-structural elements, some of which behave as elastic components of the structure (recoverable) and other as plastic components (non-recoverable). The effect of creep and recovery cannot be ruled out in testing the polymers for their modulus value using the normal mechanical methods that employ very low rate of loading. The behaviour of these structural elements on a time scale is spread over a spectrum of relaxation times of several orders. Mechanical methods of testing always involve a significant time element such that when a fibre is stretched, a certain amount of plastic or non-recoverable deformation takes place during the test time itself and those elements do not return back even after releasing the stress or partially do after very long intervals. High rate of loading can be achieved by the use of longitudinal vibrations of relatively high frequency and the method is based on the expression for the velocity of sound in media which are free to shrink laterally when extended longitudinally and expand laterally when compressed longitudinally i.e.

$$V = \sqrt{E/d}$$

When E is the Modulus value, d is the density of substance and V is the velocity of the sound. Dynamic modulus values obtained are higher than those obtained by static means and the modulus values are higher in the case of highly oriented specimen. In the case of sonic vibrations the strain in the form of sonic pulses is applied over a very low time interval, 0.001 sec and due to this shorter duration, the effect on the structural element with longer relaxation times (longer than pulse time) can be eliminated.

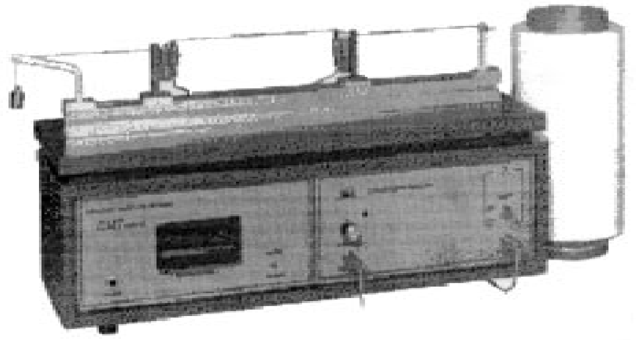

Fig. 1. Dynamic Modulus Tester.

Dynamic Modulus Tester, shown in Fig. 1, employs piezo-electric crystal transducer with the natural frequency of 5 KHz. The samples were tested with a tension level of 0.1 g/den. The slope of the transit time of the sonic pulse with the distance traveled i.e. sonic velocity was calculated from the resultant graph. The graphs obtained in the testing are used to calculate the sonic velocity by measuring the slope of the sonic pulse transmission.

The mechanism of transmission of sonic energy involves the stretching of intermolecular bonds when the sonic pulses are transmitted across an array of fibres and while stretching of chemical bonds of the backbone of the polymer molecules when sonic pulses are transmitted along the length of parallel arrangement of the polymer molecules. In textile fibres, partially oriented polymeric materials, molecular motion due to sound pulses takes place along and across the direction of molecular axis.

In the case of partially oriented polymeric molecules, the molecular motion due to sound transmission is presumed to have right angle components, along and across the direction of molecular axis. The magnitude of either of these two components is taken to be a function of the angle between molecular axis and the direction of sound propagation. It has been observed in the past[1] that sonic modulus values are independent of crystallinity so long as observations are carried out at temperature significantly below the second order transition point of the polymer and for a oriented polymer with a transition well above the room temperature the sonic modulus values are significantly influenced by the orientation and are greater in the direction of orientation. The fact that sound velocity is independent of crystallinity means that sonic modulus is also independent of crystallinity when it is expressed in units of force per unit linear density. Apart from the above factors, the relative humidity, that decides the moisture content, also influence the modulus value while measurement[2].

When linear density is used as a basis, the dynamic modulus of different fibres from the same polymers can be compared on the basis of an equal number of molecules passing through the fibre cross section rather than on the basis of unit cross sectional area i.e. the internal molecular and intramolecular force constants, which control fibre stiffness are not measurable by different crystalline and amorphous state.

The two experimental quantities used to calculate the molecular orientation are the velocity of sound in the direction of fibre axis and the velocity in a randomly oriented sample. The orientation parameter computed from these two velocities is identical to Herman's Orientation Factor and is a measure of the total molecular orientation.

Dependence of sonic velocity on orientation

The unoriented (randomly oriented) fibres have low sonic velocities ranging from about 1-2 km/sec, which is comparable to those found in liquids where the mechanism of sound transmission is largely intermolecular. The following table shows the sonic velocity in the polymeric materials of different states.

Table - 1: Sonic Velocity in Textile Fibres

Fibres	Sonic Velocity (km/sec)	
	Randomly Oriented	Highly Oriented
Polyester	1.4	3.4-5.9
Nylon	1.3	2.3-5.7
Viscose	2.0	3.5-6.1
Acrylic	2.1	4.2-5.1

The lower level of sonic velocity in the highly oriented state, in the above table, indicates the velocity measured with the tension of 0.1 g/den while higher values were obtained after stretching the samples near the breaking load. In the case of highly oriented fibres obtained from linear PE, the experimental sonic velocities of 11 km/sec approach the theoretical maximum values.

In order to develop an equation, it is necessary to make two assumptions, namely,

- Any fibre deformation which occurs during sound transmission is the sum of the intramolecular and inter-molecular deformations. This assumption results in a series of addition of the intramolecular and intermolecular force constants, weighted by an average orientation function.
- Any force on fibre resulting from a sound wave is the sum of the forces exerted on the intermolecular and intra-molecular bonds. This assumption results in parallel additions of the intramolecular and intermolecular force constant, weighted by an average orientation function.

- The orientation parameter calculated from sound velocity is taken to be a measure of the average orientation of all molecules in the samples regardless of the degree of crystallinity. So, this parameter is called the total molecular orientation as contrast to crystalline orientation and amorphous orientation. Orientation parameter (a) of the fibrous materials varies from 0-1 and this can be calculated from

$$\alpha = 1 - (Cu^2/C^2)$$

For theoretically completely oriented sample, the value of C^2 will be finite and a will not be 1. Cu can be measured from as spun fibres but is advisible to check the orientation before measurement. The sonic modulus in g/d is directly given by

$$E = 11.3\ C^2$$

Where C is the given in terms of km/sec and the orientation factor is given by

$$\alpha = 1 - (E_u / E)$$

When E_u sonic modulus of unoriented specimen

Advantages of Sonic Modulus Testing

The sonic modulus testing offers many advantages over the other physical characterisation techniques. Some of the advantages include

- It is non-destructive test method
- Instant results can be obtained
- Test can be performed while stress-strain tests, while wetting/drying
- Test method is faster than x ray, birefringence tests
- Possibility of segregating good and bad samples

Points to be remembered!

Sonic modulus measures the overall orientation, which is contrast to the x ray orientation that measures only crystalline orientation. Also, x ray technique measures the orientation in a short length whereas sonic measurements are carried out in a longer length of the specimen.

CONCLUSION

Sonic modulus, which offers a quick way of testing the specimen, is highly reliable and has been used by researchers to analyse the orientation parameter and related mechanical properties. As discussed in this paper, the method has many advantages over the other characterization techniques, which gives an edge to this technique.

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• THE SOUTH INDIA TEXTILE Research Association

International Seminar

SITRA recently conducted an International Seminar on "World Trade Scenario of Textiles" on 1st December 2006. Experts from the International Trade Centre, Geneva and also scientists from SITRA presented papers at the half-day seminar. Four papers concerning trade issues related to the textile industry were presented to a group of 250 delegates gathered on the occassion.

Shri Sarath Chandran, Chairman, SITRA inaugurated the seminar after Dr. Arindam Basu, Director, SITRA welcomed the gathering. The speakers were - Mr. Matthais Knappe, Chief, Market Development Section, International Trade Centre, Geneva, Mr. Daniel Torres, Consultant-International Trade Competitiveness in Cotton, Textile and Clothing, ITC, Mrs. Beatriz Rodriguez, ITC and Dr. K. P. Chellamani, Deputy Director, SITRA.

International Training Programme

SITRA recently conducted an International training pro-gramme on "Cotton Cultivation, commerce, quality aspects and value addition" during November 20 - December 1 2006 for the benefit of African nationals. The participants were a diverse group of farmers, ginners, spinniners and cotton traders totalling 22. The programme, held in association with ITC, Geneva and Ministry of Textiles, GOI was sponsored by the Ministry of External Affairs, GOI. The programme included classrom lectures, laboratory sessions and field and industrial visits. The sessions were handled by experts from SITRA; South India Cotton Association (SICA), Coimbatore; Tamilnadu Agricultural University, (TNAU), Coimbatore, experts from the industry and also the International Trade Centre, Geneva.

The programme was inaugurated by Ms. Indra Doraiswamy, Adviser, SITRA on 20th November 2006. The Valedictory was held on December 1 2006, on the occassion of which Dr. Arindam Basu, Director, SITRA distributed the Course Completion certificates to participants.

COMPANY NEWS

Clariant Chemicals achieves a Net Profit of INR 102.7 million

Clariant Chemicals (India) Limited (formerly known as Colour-Chem Limited) has reported Net Sales of INR 2294 million and Profit after Tax of INR 102.7 million for the quarter ended September 30, 2006. Its Net Sales and Profit after Tax for the six month period ended September 30, 2006 amounted to INR 4588.4 million and INR 254.6 million respectively.