DESIGN AND CONSTRUCTION OF A BENDING TESTER FOR TEXTILES

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ABSTRACT

Bending rigidity is an important physical parameter measured in Textiles. The drape and handle qualities of a textile are governed mainly by its bending and torsional characteristics. These can be changed only by using suitable softeners or various finishing agents. Many attempts have been made to develop instruments to measure the bending rigidity of textiles using various principles. The aim of some research activities is to relate the bending properties of constituent fibres and yarns to fabric properties. According to one school of thought properties such as bending, torsion, strength, friction and compression are measured to predict the overall drape and handle qualities of fabrics. Much work is being done in the objective evaluation of properties of textile structures which should replace subjective evaluation methods. Upto now there is no standard instrument to measure each of these parameters including the bending rigidity.

Although there are several commonly used methods for measuring the bending rigidity of yarns and fabrics, not all satisfy the desirable condition that a pure bending couple should be imparted to the test specimen. Such a method has an advantage over other methods in that the specimen experiences only a bending moment. The apparatus described in this work has been designed to impart an almost pure bending to the specimen under consideration over its entire length. Also it was attempted to ensure that the equipment is made versatile in as many aspects as possible.

A cyclic bending tester was designed and constructed to achieve the above mentioned aims. Unlike the earlier versions this tester was controlled by computer. The principle employed was that of the cloth bending tester designed by Livesey and Owen [1], later improved and extended by Abbott[2], Grosberg[3], Chapman[4] and Grey[5]. This tester was made with more precisely controlled movement and with greater sensitivity, adjustable to measure yarns and fibres and with overall control using an IBM Personal Computer.

DESIGN OF THE INSTRUMENT

In the design of the instrument, three main parts were put together to make up the composite apparatus. The three units are the rotating unit, the load measuring unit and the computer for overall control of the system.

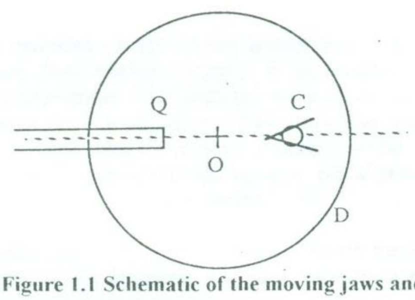


Figure 1.1 Schematic of the moving jaws and disc

Many problems arose in the construction of the instrument and each of these are discussed. The bending unit consists of two sets of jaws, one stationary(Q) and the other able to rotate(C). The stationary set of jaws are fixed to the end of a very light lever, suspended at its centre by a wire that hangs from the load measuring unit. The movable jaws are fixed to a metal disc(D) with the nip of the jaws half the length of the sample away from the centre of rotation(O) of the disc. The disc is attached to the shaft of a stepper motor which drives the shaft. If the shaft and disc are concentric, then one end of the sample moves in an arc of a circle.

THE ROTATING UNIT

The Stepper Motor

The stepper motor rotates in finite steps and the motion is not strictly uniform. A matching gear box was used to produce nearly uniform speed of rotation. The software controlling the instrument was designed so that the rate of rotation of the shaft which is proportional to the rate of change of curvature in the specimen, can be fixed before the start of a test.

The curvature of the specimen at any given time is proportional to the angular position of the shaft and is calculated precisely by the step counter in the programme. Automatic and instantaneous reversal of the direction of bending was made possible by manipulating the software. The maximum angle of rotation can be set to any value in the range ±90° which enables a specimen of 5 mm length to attain a curvature of ±3 cm^{-1}, which is the usual limit in these experiments. If the specimen size was reduced, the maximum curvature can be increased further.

The Disc

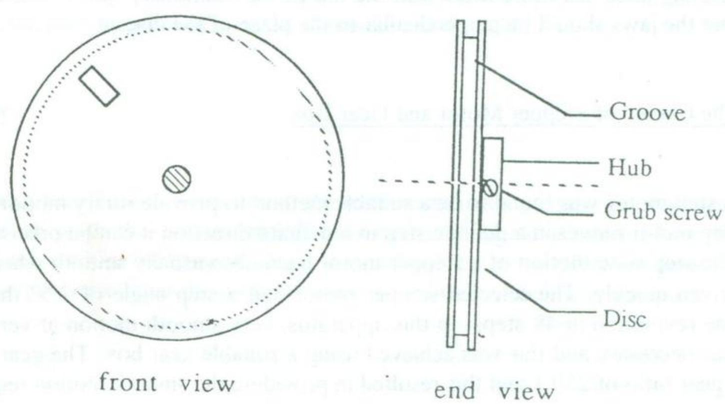


Fig 1.2 Slot and the groove in disc

A circular metal disc was used to fix the rotating jaws which are fitted on the shaft of the stepper motor. This is concentric with the disc and the distance from the centre of the disc to the nip point of the jaws is half the length of the test specimen. The disc has a slot in one place and a groove round its perimeter, the purposes of these features will be seen later.

The Movable Jaws

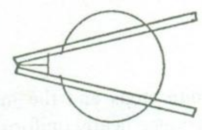


Fig. 1.3 Rotating jaws

The movable jaws consist of a bulldog clip which has been slightly modified by filling up the angle at its nip so that the specimen is mounted in a simple and effective way. The rotating jaws are rigidly attached to the circular disc by a bracket on which the jaws are fixed. A second slot is made in the disc and the bracket is fixed in it using two screws. Slight movement is possible within the slot in the unscrewed state in order to adjust the sample length as well as the height of the nip when required. The nip of the rotating jaws has to be level with the nip of the 'stationary' jaws. It is also necessary that the jaws should be perpendicular to the plane of the disc.

The Choice of Stepper Motor and Gear Box.

A step motor was found to be a suitable method to provide rotary motion and since the step motor moves in a definite step in a definite direction it can be precisely controlled. The step-wise motion of a stepper motor becomes virtually smooth when the motor is driven quickly. The selected stepper motor had a step angle of 7.5° thus completing one revolution in 48 steps. In this apparatus, very smooth motion at very slow speeds was necessary and this was achieved using a suitable gear box. The gear box used had a gear ratio of 250:1 and this resulted in providing the smooth motion required.

Overcoming the Backlash in Gears

As expected, it was found that the gear box used with the stepper motor produced a considerable backlash. To overcome this problem the gears were biased by means of a string wound round the disc and sitting inside the groove at its rim mentioned earlier. One of the ends of the string is knotted through a hole let into the groove, and the string, on leaving the disc is passed over a fixed pulley and then allowed to hang freely with a small weight at the end. This weight is about 50 grams which would keep the string taut and therefore suited the purpose. This arrangement counteracts the backlash produced by the gears. With the correct length of string there will be no problems of fouling the pulley nor striking the base, within the extremes of the test limits, which is a quarter of a revolution in either direction from the rest position.

Verifying the Rest Position

The rest position is defined as the situation when the two nip points of the jaws, the specimen, the lever and the centre of the rotating shaft all lie on the same horizontal axis. At the rest position, the angle of rotation is zero which in turn corresponds to a zero curvature. The rest position of the rotating jaws is determined by the zero position of the shaft which is verified by means of an optical sensor fixed in the slot in the disc mentioned earlier.

This enables the shaft to be driven in any direction and to be stopped at the geometrical rest position, which is determined by the optical sensor. When the lever(carrying the specimen in the jaws) is suspended the load cell reads a force. This is cancelled out by balancing electronically. When the specimen is inserted between the moving set of jaws, the load cell reading is checked and the shaft and specimen adjusted until the original reading is obtained.

Since the expected record of moment s curvature is a hysteresis curve, it was therefore decided to set the starting point of a test at the middle of the scale.

Optical Sensor

An optical sensor was fixed to the frame of the instrument in such a position that when the slot passes through the sensor, an optically activated signal is received by the computer and the rotation is stopped. Then the disc will be at its reference position. The slot was so positioned that the rotation was not inhibited while a test was on.

THE LOAD MEASURING UNIT

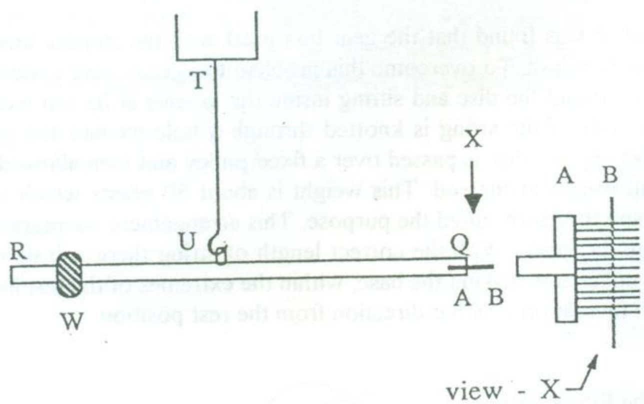


Fig 1.4 Arrangement for measuring the force on the load cell

This unit consists of a load cell type of transducer to measure the strain. In this case a load cell of an Instron Tensile Tester was used. A long lever is suspended from the hook which carries at one end the "fixed" jaws, and at the other a movable counter weight. At the rest position, just before a test is carried out, the lever, the jaws and the specimen should be horizontal. When the shaft rotates and bends the specimen, the balance of the system is upset, and the load cell will immediately measure the change in force that takes place. The change in the force on the load cell measures the changes in bending moment that occur with changing curvature. This force in analogue form is amplified and converted to a digital value and recorded by the computer. An A/D converter was used to convert the analogue signal produced by the load cell into a digital signal.

Strain-Gauge Amplifier

The strain-gauge amplifier was a precisioned, purpose built amplifier with low drift characteristics and with stable amplification.

The Lever

The theoretical analysis suggests that the lever should be as light as possible and that the distance from the specimen to the point of suspension should be more than 10 times the length of specimen. If not the error due to the moment produced by the weight of the lever becomes significant. This is a very critical feature of this apparatus as there is a possibility of the centre of gravity of the system moving slightly forwards or backwards during a test.

Hooks and Connections

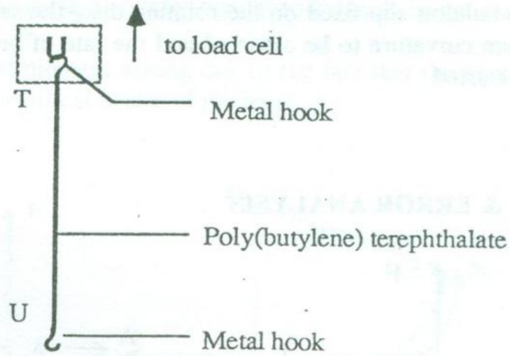


Fig. 1.5 Hooks and the lever arrangement

The top end of a long hook is rigidly fixed to a hook that exists on the strain gauge within the cell. The arm of the hook is a string made up of poly(butylene terephthalate) which has an insignificant moisture regain and very low creep characteristics.

THE CONTROLLING DEVICE

An IBM PC is used to control the motor. The motor can be rotated, at the required speed, in both clockwise and anti-clockwise directions. In the cyclic bending test, the motor is rotated until a pre-determined maximum curvature is reached and then driven in both directions until the cycle is completed.

While the test proceeds, a Load - Curvature curve can be plotted on the video display unit of the computer. By manipulating the software, initial bending rigidity could be calculated.

The computer is used to calibrate the instrument, store and retrieve information and data associated with experiments and to calculate the results of the experiment.

Test procedure

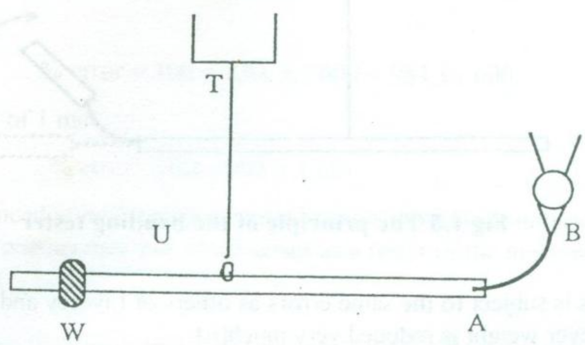


Figure 1.6 Bent sample during the course of the test

When the specimen is inserted into the jaws attached to the tube with the other end held by the bulldog clip fixed on the rotating disc, the sample is ready for test. When the maximum curvature to be assumed and the rate of bending have been decided the test can be started.

THEORY & ERROR ANALYSIS

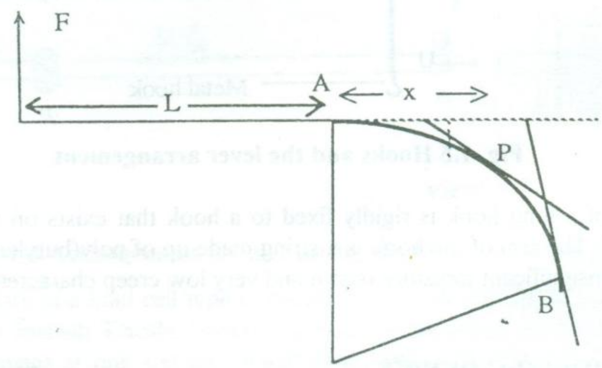


Fig 1.7 Representation of forces in specimen while bending

AB is the specimen and P is a point situated at a horizontal distance x from A. Assume that the specimen AB bends to form an arc of a circle having a radius of r, then,

$$\text{Moment}(M) \text{ about } P = F(L + x)$$

where F is the resultant force on the load cell. From this we see that, if $x \ll L$, M will be nearly constant along the length of the specimen.

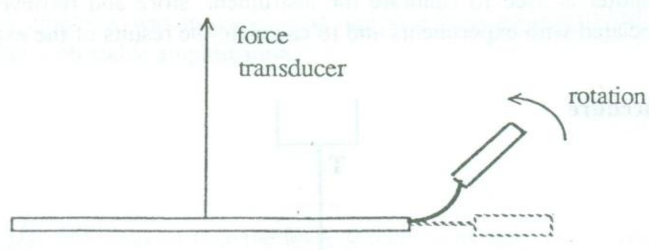
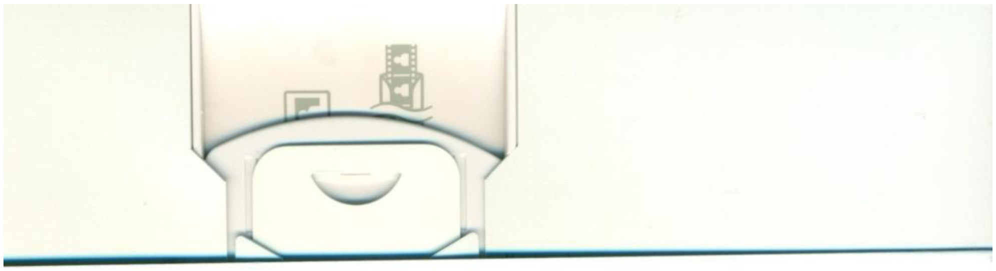


Fig 1.8 The principle of the bending tester

This apparatus is subject to the same errors as others of Livesey and Owen type but the effect of the lever weight is reduced very much[6].



If the lever was uneven and the centre of gravity did not coincide with the geometrical centre, this was overcome by using a counter-weight to balance the lever at its point of suspension.

There could be an unwanted moment arising due to the fact that the centre of gravity of the lever is not at the geometrical centre of the lever.

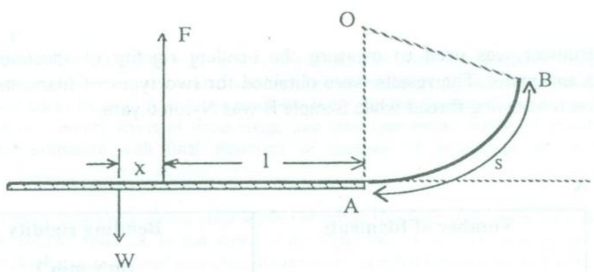


Fig 1.9 Lever with centre of gravity not in the geometrical centre

Suppose the centre of gravity is at a distance ***s*** from the geometrical centre. Then, taking moments about B,

$$M = F(l + \rho\sin\alpha) - W(x + l + \rho\sin\alpha)$$

$$= (F - W)(l + \rho\sin\alpha) - W.x$$

When x = 0, the "correct" moment is

$$M_c = (F - W)(l + \rho\sin\alpha) = B/\rho$$

$$\therefore \ \%\text{ error} = W.x.100/M_c$$

$$= 100W.x/(F - W)(l + \rho\sin\alpha)$$

$$= 100\,W.x.\,\rho\ /\ B$$

If W = 9.81 mN ($\equiv$ 1 g)

M_c = 600 mN mm

$$\%\text{ error} = 100 \times 9.81.\,x / 600 = 981\,x / 600$$

If x is in the order of 1 mm,

$$\%\text{ error} = 981 / 600 = 1.6\%$$

If the lever is balanced at its suspension point, using a movable counterweight, there will be another erroneous moment which arises as a result of the movement of the lever, during a test

It can be shown that this movement is normally less than 1/4(specimen length) which is = 0.25 ***s***.

When the lever is balanced, it can be shown that the maximum moment of this force about the specimen is approximately 0.16 mN mm when W = 1 g. This is very small in comparison with M.

RESULTS

The instrument was used to measure the bending rigidity of specimens made of filaments and yarns. The results were obtained for two types of filaments. Sample A was Nylon 6.6 sewing thread while Sample B was Nylon 6 yarn.

Sample A

Number of filaments	Bending rigidity ($mN\ mm^2$)
20	929
10	464

Sample B

Number of filaments	Bending rigidity ($mN\ mm^2$)
20	384
10	192

The instrument was calibrated using a specimen made of shim metal and within the limits of the experiment, the results obtained were very promising. Further the results obtained for sample filaments were compatible with calculated values for bending rigidity.

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