PROPERTY STRUCTURE CORRELATIONS IN SOME WOOL FIBRES

by

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CERTIFICATE

This is to certify that the thesis entitled "PROPERTY STRUCTURE CORRELATIONS IN SOME WOOL FIBRES", submitted by Mr. D. Ramarao to the Indian Institute of Technology, Delhi, for the award of degree of DOCTOR OF PHILOSOPHY is a record of the bonafide research work carried out by him. Mr. D. Rama rao has worked under my guidance for the submission of this thesis, which to my knowledge has reached the requisite standard.

The thesis or any part thereof, has not been submitted to any other University or Institution for the award of any degree or Diploma.

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ABSTRACT

The studies presented in this thesis attempt to seek correlations between mechanical properties and structure in three wool types, viz. Lincoln, Merino and Chokla in the native state. Limited amount of work was also done on these fibres after they had been set by stretch and heat treatment.

Fibre structure was characterised with the help of electron and optical microscopy, X-ray diffraction, thermo-analytical methods and nuclear magnetic resonance. Studies on load-elongation, creep and stress-relaxation behaviours were made under axial loading over a range of time, strain, stress, temperature and humidity. Similar studies were made on their torsional behaviour.

The electron micrographs of stained cross-sections showed that Merino fibre had a bilateral structure with the cortex having nearly 1:1 proportion of para and ortho cells whereas in the other two fibres, the cortical cells were predominantly para. Lincoln wool had the highest crystallite content and orientation, birefringence and thermal stability with Merino having the lowest and Chokla being intermediate. On the other hand, the mobility of water protons and glass transition temperature were the highest in Merino and lowest in Lincoln with Chokla again being intermediate. The torsional rigidity of Merino wool was the highest in the dry state and showed maximum reduction on going to the wet state. In tensile properties like Young's modulus, stress relaxation modulus and creep resistance, Lincoln fibres ranked the highest and Merino the lowest with Chokla being intermediate.

An analysis of these results led to an understanding of the

structural dependence of mechanical properties. In wool the tensile properties, viz. load-elongation, creep and stress relaxation behaviour, are known to be dominated by the characteristics of the α-helices in the ordered, oriented state, which form part of the fibrillar structure, with the fibril-matrix bonds also playing an important role. In the Lincoln and Chokla wools, the α-helix content is higher and they are present in a more ordered and oriented state than in Merino, thus leading to higher modulus and lower creep in the former fibres. On the other hand, the glass transition temperature (Tg) and torsional modulus are known to reflect matrix properties. The high Tg and torsional modulus of Merino fibres in the dry state, compared to Lincoln wool which had the smallest and Chokla wool which was intermediate, can be attributed to the presence of a much larger amount of bulky side groups in Merino wool compared to the other wools. In the dry state, under intense intermolecular bonding, the bulky groups contribute to rigidity. Moreover, Merino wool has a bilateral structure, with the bulky groups being concentrated in the ortho cortical cells. In the wet state, Merino fibres showed the highest Tg but low torsional modulus whereas Lincoln had the lowest Tg and high torsional modulus. Merino wool also showed high mobility of water protons and greater degree of visco-elasticity in the wet state compared to the other wools. It has been suggested that since the bulky side groups require more energy to achieve a mobile state, the wet Tg of Merino would be expected to be higher. However, once they are mobile, these bulky groups can generate more free volume and the mobility of water protons in Merino is therefore high and for the same reason its torsional modulus reduces in the wet state. In addition to the above, the fibril content and orientation would also make a contribution to the torsional properties.

The present studies have led to a better appreciation of the glass transition phenomenon in wool fibres. Tg has a less spectacular effect on the tensile mechanical properties of wool compared to that in other fibres because first the transition apparently involves motion of side groups and little large scale segmental motion in the matrix phase and second, the ordered and oriented helices continue to contribute substantially to the mechanical properties of the fibre even at large extensions and in the wet state. Torsional modulus is affected relatively more as the material transforms from the glassy to the rubber-like state.

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