

**A STUDY ON STRUCTURE-STRENGTH
RELATIONSHIP AND MECHANISM OF SPUN
YARN FAILURE**

by

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Submitted in fulfillment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

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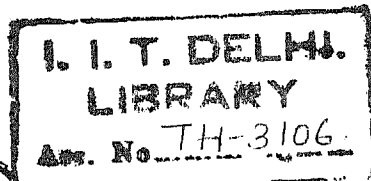
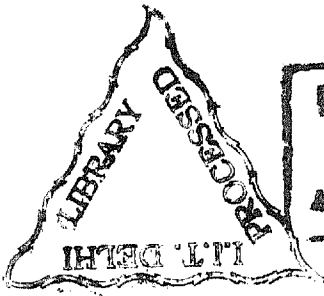
**INDIAN INSTITUTE OF TECHNOLOGY DELHI
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GHO-S



Dedicated
to
my parents

"I do not know what I may appear to the world; but to myself I seem to have been only like a boy playing on the seashore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, whilst the great ocean of truth lay all undiscovered before me."

-Sir Isaac Newton

"Equations are more important to me, because ... an equation is something for eternity."

-Albert Einstein

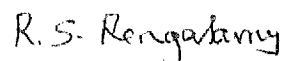
CERTIFICATE

This is to certify that the thesis entitled “A Study on Structure-Strength Relationship and Mechanism of Spun Yarn Failure” being submitted by Mr. Anindya Ghosh to the Indian Institute of Technology Delhi, for the award of the degree of Doctor of Philosophy in the Department of Textile Technology is a record of bonafide research work carried out by him. Mr. Anindya Ghosh has worked under our guidance and supervision and has fulfilled the requirements for the submission of the thesis. The results contained in this thesis have not been submitted, in part or in full, to any other University or Institute for the award of any degree or diploma.



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ABSTRACT

The tensile strength of spun yarn is one of the most important parameters of yarn quality. Strength of a spun yarn is mainly influenced by the constituent fibres and the structure of the yarn itself. To enhance the strength of spun yarn and to improve its processing performance understanding the structure of the yarn and its influence on tensile response of the yarn are very important.

Many researchers have investigated on the subject 'Mechanism of tensile failure of spun yarn'. However, the real mechanism of spun yarn failure is not yet fully understood because of the complexity of the yarns structure. Further, the failure mechanisms proposed are primarily concerned with ring spun yarns and in many cases idealized helical geometry of yarn is assumed. Therefore, in this thesis, an attempt has been made to explain the failure mechanism of spun yarns. A simple and generalized mathematical model for predicting the strength of spun yarns viz., ring, rotor, air-jet, and open-end friction is proposed. The predicted values of yarn tenacity for all the yarns are compared with measured tenacity and the deviations are explained. The limitations of the model have been discussed.

With the advent of rotor, air-jet, and OE friction spinning technologies and their acceptance in the market, study of the structures of yarns spun from these technologies and their influence on tensile strength and stress-strain characteristics and comparing them with ring spun yarns brings out better understanding of yarn engineering. Structure of different spun yarns is investigated in terms of fibre helix angle, fibre configurations (hook types and their extent), mean fibre extent, length of failure zone from broken ends of yarns, and percentage broken and slipped fibres. The tenacity and its CV of various yarns have been analyzed in relation to their structures.

Spun yarns are made from visco-elastic materials and the arrangement of fibres in them is random. These two factors make the strength of a yarn largely dependent on two important testing parameters viz., extension rate and gauge length. The tensile tests on spun yarns at different testing parameters have been the subject of study by many researchers. No significant literature is available on the tensile failure of ring, rotor, air-jet, and friction spun yarns encompassing the effects of wide range of extension rates (from 5 mm/min to 400000 mm/min) and gauge lengths (from 0 mm to 500 mm). Thus, in the present study these spun yarns are tested for tenacity over the range of gauge lengths and extension rates as mentioned above. The mode of yarn failure (catastrophic and non-catastrophic) is also investigated. The tensile responses of different yarns are explained in terms of their structures.

Using the Weibull distribution parameters of yarn tenacity at a particular gauge length and the classical weakest-link scaling theorem the yarn tenacity at other gauge lengths are predicted. The theoretical predictions of yarn tenacity at various gauge lengths are compared with the experimental data and the deviations are explained.

The effect of strain rates and gauge lengths on the characteristics of the stress-strain curves of different spun yarns is studied. A model is proposed to explain the stress-strain curves of spun yarns.

Finally, the strength of a fabric not only depends on the strength of the constituent yarns, but also on the frictional forces between warp and weft influenced by the surface structure of the yarns. The ratio of fabric strength per thread to single yarn strength is studied along with yarn friction and thread pulling force. The results confirmed that the surface structure of yarn plays a significant role along with yarn strength in influencing the fabric strength.

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