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

by

ANINDYA GHOSH
DEPARTMENT OF TEXTILE TECHNOLOGY

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in yarn technology

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.

Dr. S. M. Ishtiaque
Professor
Department of Textile Technology,
IIT Delhi,
New Delhi- 110016,
India

R. S. Rengasamy
Dr. R. S. Rengasamy
Associate Professor
Department of Textile Technology,
IIT Delhi,
New Delhi- 110016,
India

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Anindya Ghosh

Anindya Ghosh

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.

CONTENTS

		Page No.
Certificate		(i)
Acknowledgements		(ii)
Abstract		(iv)
List of Figures		(ix)
List of Tables		(xiv)
List of Symbols		(xvi)
Chapter 1	**Introduction**	1
Chapter 2	**Literature Review**	
2.1	Mechanics of spun yarn failure	5
2.1.1	General outline of yarn failure mechanics	5
2.1.2	Theory of fibre slipping and gripping	6
2.1.3	Yarn and fibre tension relationships	8
2.1.4	Distribution of stresses on a fibre	9
2.1.5	Load sharing by surviving fibres	11
2.1.5.1	Equal load sharing	12
2.1.5.2	Local load sharing	12
2.1.6	Minimum length of fibre contributing to yarn tenacity	13
2.1.7	Yarn failure modes	16
2.1.8	Location of the weakest spot in the yarns	17
2.2	Modeling of spun yarn strength	18
2.2.1	The correlation between yarn strength and fibre bundle strength	32
2.3	Effect of testing parameters on yarn strength: gauge length and extension rate	33
2.3.1	Spun yarn strength as a function of gauge length	34
2.3.1.1	Theoretical considerations	34
2.3.1.2	Experimental studies on the relationship between yarn strength and gauge length	45
2.3.2	Spun yarn strength as a function of rate of extension	47
2.4	Effect of yarn structure on fabric strength	49

		Page No.
Chapter 3	**A Theoretical Analysis of Spun Yarn Failure and Translation of Strength from Fibre Bundle to Yarn**	
3.1	Introduction	51
3.2	A theoretical analysis of spun yarn failure	51
3.2.1	The distribution of tensile stress on a fibre	55
3.2.2	The conditions for gripping and slipping of a fibre	56
3.2.3	The relationship between axial and lateral stresses	58
3.2.4	The free body diagram of forces	59
3.2.5	The yarn as a successive link of fibre bundle	61
3.2.6	The condition of fibre break in the weakest link and ultimate yarn failure	63
3.3	Modeling of yarn tenacity	65
3.3.1	Theoretical yarn tenacity	66
3.4	Conclusions	69
Chapter 4	**Analysis of Structure-Strength Relationship of Different Spun Yarns and Tensile Failure of Yarn as a Function of Testing Parameters**	
4.1	Introduction	70
4.2	Experimental	75
4.3	Results and discussion	80
4.3.1	Structure of different spun yarns	81
4.3.1.1	Ring spun yarn	81
4.3.1.2	Rotor spun yarn	81
4.3.1.3	Air-jet spun yarn	84
4.3.1.4	OE friction spun yarn	85
4.3.2	Study of yarn tenacity at different gauge lengths	87
4.3.3	Study of yarn strength at different extension rates	93
4.3.4	Study of yarn failure zone at different gauge lengths and extension rates	97
4.4	Conclusions	105

		Page No.
Chapter 5	**Theoretical Prediction of Yarn Tenacity at Different Extension Rates and Gauge Lengths**	
5.1	Introduction	107
5.2	Theoretical yarn tenacity	108
5.3	Experimental	108
5.4	Validation of proposed model of yarn tenacity at different extension rates	109
5.5	Limitations of the model	114
5.6	Prediction of yarn strength at different gauge lengths	115
5.7	Conclusions	137
Chapter 6	**The Influence of Strain Rate and Gauge Length on the Characteristics of Stress-Strain Curves of Different Spun Yarns**	
6.1	Introduction	138
6.2	Experimental	139
6.3	Influence of strain rate and gauge length on stress-strain curves	140
6.4	Theoretical model for stress-strain curves of spun yarns	146
6.5	Conclusions	153
Chapter 7	**The Relationship Between Yarn Structure and Fabric Strength**	
7.1	Introduction	155
7.2	Experimental	155
7.3	Results and discussion	158
7.4	Conclusions	166
Chapter 8	**Conclusions**	167
	Reference	170
	Appendix	I