ANALYSIS OF CERTAIN FACTORS AFFECTING TENACITY OF ROTOR YARNS

by

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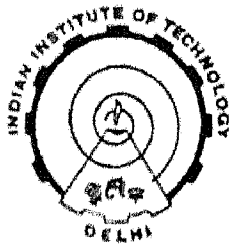
A thesis submitted
in fulfilment of the requirements
for the award of the degree of
DOCTOR OF PHILOSOPHY



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CERTIFICATE

Certified that the dissertation entitled "ANALYSIS OF CERTAIN FACTORS AFFECTING TENACITY OF ROTOR YARNS", which is being submitted to the Indian Institute of Technology, Delhi, by P. Balasubramanian in fulfilment for the award of the Degree of DOCTOR OF PHILOSOPHY is a record of the student's own work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any Degree or Diploma.

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To
the
living
memories
of my sister
and
to
my
mother
and sister
for their patience,
understanding
and affection

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"- - - - the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favour to men of skill; but time and chance happenth to them all".

Ecclesiastes

Just as every man is an omnibus in which his ancestors ride, so every work is the progeny and common property of a community of ideas in which there are no real owners, but only contributors and custodians. My primary acknowledgement then, must be to every writer I have read and every one who have conveyed me some ideas. I bow to all of them with a deep sense of gratitude for having taken immense pains to provide the necessary background which enabled me to initiate the present task.

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A true friend is one who unbosoms freely, advises justly, assists readily, adventures boldly, takes all patiently, defends courageously and continues a friend unchangeably. Almost all MY FRIENDS met this definition very closely. Any attempt to thank them would defy the greatness of the contribution rendered by them.

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Inspite of my best efforts, it is quite likely that any omission or mistake could be present in this work for which I sincerely apologize.

Just like a wheel can not rotate without an axis, the present work could not have been completed without the grace of MOTHER NATURE to whom, the foremost acknowledgement should go. I bow to Her with a sense of emptiness and humbleness.

(P. Balasubramanian)

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ABSTRACT

"Reading maketh a full man, conference a ready man and writing an exact man"

Francis Bacon

Since the advent of a commercial rotor spinning machine in 1967, a lot of research work has been done to improve the yarn quality and machine performance. This has resulted in significant design modifications and automation in the rotor frame. The rotor yarn has proved to be superior to ring yarn in many aspects like lower irregularity, higher breaking elongation, greater bulk, less imperfections etc. This yarn is, however, 10-15% weaker than the ring yarn. Considerable research work, using factorial design approach, has been carried out to study the influence of machine parameters on the tenacity and various other parameters of yarn quality. However, in some experimental plans, this approach is either not applicable or results in an increase in the size of the experiment.

It is generally accepted that the failure of rotor yarn during a tensile test occurs predominantly due to the slippage of fibres. The arguments advanced for this type of behaviour are purely qualitative as no quantitative information is available to support this. In this regard, it is important to recall the classical work of Tallant et al., who estimated the minimum length of fibre that breaks in a tensile failure and thus contributes to the yarn tenacity. They estimated this minimum fibre length for ring yarn to be 3/8 inch irrespective of the twist level.

However, this estimated value remained to be substantiated with experimental evidence. Further, no investigation has been made so far to find the comparative values of the minimum fibre length and the percent fibre rupture for ring and rotor yarns to corroborate the forementioned view.

Another factor which can throw some light on the comparative tenacity values of ring and rotor yarns could be the study of the effect of rate of yarn extension in a tensile test as it substantially influences the yarn tenacity. Though some information on this aspect is available for ring yarns, there is practically no such work reported on rotor yarns.

The present work, therefore, attempts to bridge these gaps and provide reliable information on these aspects. The work has been divided into five distinct phases.

The first phase of the work deals with the assessment of the influence of rotor machine parameters such as rotor speed, rotor diameter and opening roller speed on yarn characteristics. According to the experimental combinations of a rotatable central composite design, cotton yarns were spun on a Suessen OE Spintester. The response surface equations for various yarn quality characteristics were obtained. It is observed that with an increase in rotor speed, the tenacity progressively decreases for yarns spun from a semi-high production

carded material while it increases to a certain level and then decreases for tandem carded material. This differential response of yarn tenacity to increasing rotor speed, depending upon the carding technique, has been explained on the basis of changes interalia in fibre packing in the yarns. With an increase in rotor speed, the yarn diameter, which is an indirect measure of fibre packing, is seen to decrease for tandem carded material while it is hardly affected for semi-high production carded material.

The second phase of the work deals with the estimation of minimum length of fibre that breaks during the tensile failure of rotor yarn. Twelve cottons, differing widely in fibre properties, were spun with varying twist densities on a Suessen OE Spintester. To estimate the minimum fibre length, different fibre bundle strength parameters viz., S_0 (at 0 gauge), S_1 (at $\frac{1}{8}$ inch gauge) and $\sqrt{S_0 \times S_1}$ were used. The product of function of fibre length distribution and the fibre strength parameter was correlated with the maximum yarn tenacity irrespective of the yarn twist density for different assumed values of the minimum fibre length. The minimum fibre length at which the maximum z-transformation value occurs, was considered as an estimate of the minimum fibre length. It is seen that the fibre strength parameters S_0 and S_1 indicate a minimum fibre length of 12 mm while $\sqrt{S_0 \times S_1}$ of 9.5 mm. Further,

with an increase in twist density this minimum fibre length is found to decrease irrespective of the fibre strength parameter used.

An experimental technique, using tracer fibres, was developed in the third phase of this work to measure the minimum length of fibre that breaks during the tensile failure of yarn. The method consisted of mixing a small amount of dyed fibres of known length, to act as tracers, with undyed cotton so that only one tracer was observed in a given yarn segment. The broken ends of a yarn, subjected to tensile failure, were observed on a projection microscope for the tracer fibres after optically dissolving the undyed fibres. Thus, the minimum length of fibre that broke during the tensile failure of yarn was determined for both ring and rotor yarns. It is found that the minimum fibre length for rotor yarn is comparatively higher than for ring yarn. With an increase in twist density, the minimum fibre length is observed to decrease for both ring and rotor yarns.

The fourth phase of the work deals with a new experimental technique to find out the percentage of fibres that rupture during the tensile failure of yarn. First, the fibre rupture was found out experimentally for different fibre lengths for both ring and rotor yarns. Then assuming a linear relationship between the fibre length and the fibre rupture and considering the fibre length distribution, the overall fibre

rupture for yarn was calculated. The percentage of fibre rupture for rotor yarn is seen to be much lower than for ring yarn.

The last phase of the work is concerned with the influence of strain rate on yarn tenacity. The study was carried out on the Instron Universal Strength Tester with strain rates of 1,10,20,50 and 100 cm/min. Contrary to the view held so far that the higher the strain rate the higher the breaking load, the maximum yarn tenacity is observed at a strain rate of 20 cm/min. (values at 50 cm/min being only marginally lower) irrespective of yarn structure, cotton type and twist density. The reason for observing this phenomenon for the first time seems to be that most of the earlier researchers considered the relationship between the yarn tenacity and the strain rate as a logarithmic one and hence the strain rates were chosen in such a way that the ratio between the successive strain rates was 1:10. The strain rates commonly used were 0.1, 1, 10 and 100 cm/min., thus completely missing the intermediate ones between 10 and 100 cm/min. In order to identify the factors responsible for this phenomenon, yarns were strained to break-point with differential strain rates in the initial and the final stages. These results alongwith those on fibre rupture provide a plausible explanation for observing maximum tenacity at intermediate rates of straining mentioned earlier.

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