

**STUDIES ON REDUCTION OF YARN HAIRINESS USING
AIR NOZZLES DURING RING SPINNING AND
YARN WINDING**

by

ASIS PATNAIK

DEPARTMENT OF TEXTILE TECHNOLOGY

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

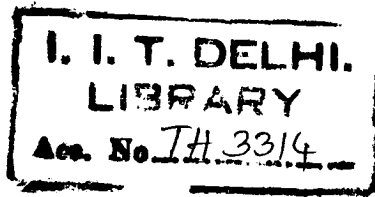
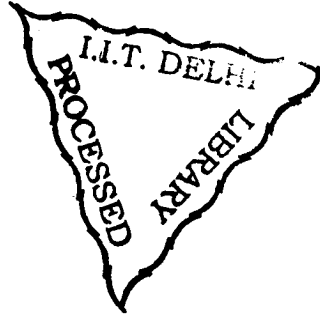
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ber - Ring Spinning
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*Dedicated
to
My Parents*

CERTIFICATE

This is to certify that the thesis entitled “Studies on Reduction of Yarn Hairiness Using Air Nozzles during Ring Spinning and Yarn Winding” being submitted by Mr. Asis Patnaik 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 original bonafide research work carried out by him. Mr. Asis Patnaik has worked under my guidance and supervision and has fulfilled the requirements for the submission of thesis. The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

R.S. Rengasamy

Dr. R. S. Rengasamy

Associate Professor

Department of Textile Technology,

I I T Delhi,

New Delhi-110016,

India

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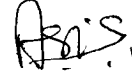
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ABSTRACT

The hairiness of yarns is one of the most important quality parameters. It affects the appearance of staple yarns and the resulting fabrics and the efficiency of processes involved in converting the yarns into fabrics. Fabric properties such as handle and thermal insulation are also influenced by yarn hairiness. In majority of cases, yarn hairiness is undesirable like in formal wears, but in some cases it is desirable like in case of some winter garments or fashion clothes. Yarn hairiness is one of the most serious causes of inefficiency in sizing, weaving, and knitting.

Yarn hairiness depends on factors such as fibre parameters, yarn structure, and processing variables during yarn forming processes. Among these processes, spinning plays a vital role in the formation of yarn hairiness. Yarn hairiness increases during winding, causing end breaks during warping and sizing. Because of the disadvantages associated with the yarn hairiness, many methods are developed to reduce it. Traditional methods of reducing yarn hairiness are: sizing in short staple sector and two-folding in the long staple sector. Higher costs due to additional machine elements and time consumption are the disadvantages associated with these methods. In recent years, several technologies have been developed to reduce yarn hairiness during spinning and winding, of which few have been commercialized. Compacting the fibre strand during drafting at ring frame (Compact Spinning), placing an air-nozzle below the spinning triangle on ring frame (JetRing spinning), and on winding machine (JetWind) are the recently developed techniques to reduce yarn hairiness. The main disadvantages of Compact Spinning is the cost of the spinning machine, chocking of the compacting

elements (i.e. perforated drums, aprons) by fibres, and faster wearing of top roller cots and aprons.

Use of air-nozzles during ring spinning and yarn winding, referred as 'Nozzle-Ring spinning' and 'Nozzle-Winding' respectively is in nascent stage and may become a cheaper alternative to Compact Spinning in reducing yarn hairiness. Nozzle-Ring spinning combines the features of both ring and air-jet spinning technologies. The single nozzle placed below the yarn formation zone, acts in a way similar to the first nozzle in air-jet spinning. Nozzle-Winding is the process of winding the yarn with help of nozzle placed at a suitable position on winding machine.

Most of the research works done on Nozzle-Ring spinning to reduce hairiness are mainly confined to worsted system. Works done on yarn winding with an air-jet attachment or false twisting rollers were carried out up to winding speed of 600 m/min, whereas the commercial winding speeds are in the region of 800-1200 m/min. Studies on application of Nozzle-Winding to reduce hairiness of different spun yarns such as ring, rotor, air-jet, and dref (OE-friction) have not yet been carried out. There is a lack of comprehensive research work reported on short staple Nozzle-Ring spinning and Nozzle-Winding with respect to nozzle parameters, fibre parameters (fineness), linear and rotational direction of airflow, and air pressure. For better understanding the principles of hairiness reduction by nozzles, simulation of airflow is essential to get velocity profiles such as axial, tangential, and resultant velocity of air acting on yarn surface and hair for nozzles used in Nozzle-Ring and Nozzle-Winding. There is no published information available on these aspects.

In this backdrop, an attempt has been made in this thesis to study the air-nozzles to reduce the hairiness of yarns during ring spinning and winding to understand the generation of airflow pattern and velocity profile of air along and across the nozzle with various nozzle parameters, and role of this and other parameters on the efficiency of hairiness reduction. Literature relevant to generation, control, and measurement of yarn hairiness is discussed.

In this study, a range of nozzles with few nozzle parameters are selected and on these nozzles, airflow simulation has been carried out by using CFD (Computational Fluid Dynamics) to obtain air velocity profile. Drag forces acting on yarn and hairs are also computed. Angle of impinging of drag forces on hair is calculated and its role is discussed. Techniques of mounting the nozzles on ring spinning and winding machines are developed. The effect of placement of the yarn inside the nozzle with respect to nozzle axis on hairiness reduction is investigated and discussed.

A comprehensive study is carried out to reduce the yarn hairiness in Nozzle-Ring spinning. Positioning of nozzle with respect to front roller nip (distance), directions of airflow (linear and rotational), influence of air pressure, nozzle parameters viz. axial angle of air inlets, and yarn channel diameter on hairiness reduction are investigated. A mechanism of yarn hairiness reduction is proposed. Optimization of nozzle parameters, fibre linear density, and air pressure for yarn hairiness reduction has been carried out for polyester yarns spun from fibres of different linear densities. Hairiness, tensile, and evenness properties of nozzle spun yarns are compared with conventional ring yarns.

Similarly another study is carried out on reduction of yarn hairiness in Nozzle-Winding. The distance of the nozzle from the balloon bracket, linear direction of airflow,

optimization of nozzle parameters, winding speed, yarn linear density, fibre linear density, and air pressure are carried out. Nozzle-Winding technique is also applied to reduce hairiness of different technology spun yarns viz., ring, rotor, air-jet, and friction-OE yarns. Hair-length distribution and hair-types present on different technology spun yarns at various stages viz., as-spun, yarns wound without, and with nozzles are reported. An empirical equation has been proposed to characterize the hair-length distribution present on different technology spun yarns.

A comparative study on Nozzle-Ring and Nozzle-Winding processes are presented. The results of the study are discussed. The major conclusion arrived out of all the above works are presented.

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