CHAPTER 1

GENERAL INTRODUCTION

1.1 INTRODUCTION

A nineteenth century philosopher and reformer is reputed to have commented on the work of earlier philosophers by saying: "The philosophers have explained the world; the problem, however, is to change it". This aptly fits into Ring spinning area in that the spinning process has been explained by many, and now it is changed for improving the quality of the yarn produced.

In every field of scientific endeavour, there appear eras marked by the genius of a few individuals whose investigative abilities were guided by freshness of thought and a revolutionary approach and whose efforts inspired and motivated several research workers. It was thought at one time that the ring frame had reached saturation point, and no further development work was needed. To day, ring frame design has been modified to such a level that the machine has come out with unprecedented technological innovations thanks to the pioneering work carried out by enthusiastic team of research workers.

Air-jet spinning technology has been extensively studied and the published literature is large; this is because the results of research in this field are of obvious technical as well as scientific interest. Much of the published work, however, deals with specific aspects of the subject, and a large amount of data exists of a more general and comprehensive nature. Air-jets are introduced in the Ring frame with a view to producing a somewhat similar yarn to air-jet spun yarn; these are becoming popular. The work of Wang, Miao and How\textsuperscript{(190)}, Sawhney and Kimmel\textsuperscript{(154)} and Chellaman\textsuperscript{i(37)}, who studied the use of air-jet nozzle in Ring frame and cone winding machine, is the most
comprehensive work to date, but is limited in two respects. First, there is lack of information on yarn properties such as bending, compression, tensile, abrasion resistance and friction. Second, the yarns were not studied for their structure such as packing density and migration. All other published work deals with the yarn hairiness only. Moreover, the collection of data from different workers in an attempt to form a more comprehensive body of results is unsatisfactory since, as is well realised, the differences in the method of spinning of yarn, their testing, and in the experimental techniques employed, render such comparisons of limited value.

One aim of the work described in this thesis is to help make good this deficiency, i.e. to provide data on yarn structure and low stress mechanical properties such as bending, friction, abrasion resistance twist liveliness and wicking. An attempt has also been made to study the effects of these yarns on spirality of weft-knitted fabrics. It is considered that such a body of results should be useful for reference purposes; an extensive investigation of this kind also seemed to be an essential first step towards a better understanding of the role of air-jets in ring frame.

Ring spinning is the most versatile and widely used method of yarn manufacturing in the world today. In this process, the twisting and winding of the newly formed yarn are combined as shown in Fig. 1.1. The wound on package i.e., the ring tube is rotated at very high speeds (12,000 to 16,000 rotations per minute). With a great deal of improvements in the machinery design, productivity in ring spinning has increased by over 60% during the period 1960-80. There was a speculation that the potential of ring spinning had reached a near-saturation point (with regard to achievable speeds) due to various mechanical, metallurgical and above all economic limitations. Many research workers felt that there was nothing to do further research in ring spinning except varying the break draft, cot diameter, apron spacing, apron design, nose bar setting and studying their effects on yarn characteristics. Also, in recent times modern methods of spinning such as rotor, wrap, and air-jet spinning have been introduced. Rotor spinning, although with the technological improvements achieved through intensive research, which has
Fig.1.1 Ring Spinning System
resulted in a phenomenal increase in spinning speeds and improved performance, is not suitable for producing yarns finer than 30s; also delivery speeds higher than 150 mpm were not possible. Air-jet spinning, which is the most recent, promises to be more versatile in terms of production rates as well as the range of counts capable of being produced.

It is well-known in the textile industry that the limits of conventional ring spinning have been reached in terms of production rates, and since the 1970's there has been considerable activity in the development of alternative spinning systems. Although initially, a major part of the development work was directed towards the short staple sector because of the large numbers of ring spindles in this sector of the market, recent work has involved new technologies for the production of long staple, woollen and worsted type yarns.

Each alternative spinning system has its advantages. These include the elimination of some of the fibre preparation processes and/or the subsequent winding stage; higher yarn delivery speeds, reduced power consumption and improved working conditions. Most of the new spinning systems have carved a niche for themselves with regard to a particular end product and a particular count range. However, the characteristics and appearance of conventional ring spun yarns have not been completely reproduced by any of the new technologies. Because of this and because of its versatility and flexibility in producing yarns over a wide count range, ring spinning still remains the predominant system for the manufacture of staple yarns.

Air-jet spinning is essentially a pneumatic spinning method which consists of passing a drafted strand of fibres through two fluid nozzles situated between the front roller of a drafting system, and a take up device. Air is injected into these nozzles at high pressures forming swirling air streams. Fibres protruding from the main fibre strand are made to wind around the strand by the swirling air currents in the first nozzle thus giving the strand
cohesion and strength. The second nozzle enhances the cohesion of the strand to give the final strength to the yarn.

The major difference between air-jet spinning and rotor spinning is that the former method is a false twist process and does not involve "open end technology". Air-jet spinning is claimed to be more economical than ring spinning in medium and fine count ranges. Based on 100% output, air-jet outproduces ring by a 7:1 margin. In comparison with rotor spinning, air-jet system starts to exhibit economic advantages in the count range finer than 30 tex. Santjer\(^{152}\) has reported on the cost comparison of polyester/cotton blend (50/50) for Air-jet, Rotor and Ring spinning systems.

While air-jet spinning was becoming popular and a number of developments such as MVS (Murata Vortex Spinner) principally for spinning 100% cotton yarn had occurred, interest aroused in combining air-jet spinning and ring spinning together to produce yarn.

Wang, Miao and How\(^{190}\) introduced the concept of jet ring spinning, a new spinning technique that incorporates features of both ring and air-jet spinning systems. In jet ring spinning, a single air-jet is used below the yarn-forming zone of a conventional ring spinning system; this jet acts in a way similar to the first jet in air-jet spinning. The swirling air currents in the jet wind the protruding fibres around the yarn body, S nozzle loosening of tightening two stretch and touching of protruding hairs, Z nozzle sweeping to binding protruding fibres, thus reducing yarn hairiness. The pressure applied to the jet in this study is 0.5 bar which is much lower than that of the pressure used in air-jet spinning. This development is something similar to converting a conventional ring frame to a doubler and comparing its performance in terms of yarn characteristics with conventional doubler. It can be also called as quasi air-jet spinning machine.

The yarn manufacturing cost is lower for air-jet spinning in finer counts and for rotor spinning in coarser counts. For all the counts, the power consumption for air-jet spinning is less, and the difference increases with yarn
count. Automatic yarn knotting or splicing and doffing on the air-jet spinner permits labour cost reductions to a level between 25-33% of those for a ring spinning system. Comparison of running costs shows a distinct advantage for air-jet spinning over other spinning systems (Tamura 1993) and improved versions show advantages over earlier versions.

Indira Doraiswamy and Chellamani have stated that for the techno economic conditions prevailing in India, the cost of production in air-jet spinning has been found to be higher than that in ring spinning by about 5% when new machines are considered for both the systems to spin polyester viscose blended yarns. Even though the wages cost is lower in air-jet spinning, this is more than offset by higher power costs plus maintenance and depreciation costs. This may be due to the higher interest rates and lower wages in India when compared with many developed countries. Consideration also must be given to downstream economics in weaving and knitting for air-jet yarns. When air-jet spun yarn is used as warp due to less weak spots and lower hairiness of these yarns, the weaving efficiency in air-jet looms has been found to be generally higher.

A number of research workers such as Kalyanaraman, Wang and Miao, Sawhney and Kimmel, Basu and Oxenhara, Basu, Chellamani, Chattopadhyay and Kumarasamy have been concerned with the design and development of air-jet nozzles in ring frame and winding machine, and work is still in the offing.

Thus, although the ring frame with the air-jet nozzle is not similar to the air-jet spinning, it can be a via media to the technology and the chief objective of using it was to reduce the yarn hairiness. Much importance nowadays is attached to hairiness of the yarns. Also, with the reduction in yarn hairiness, it is clear that processing performance after spinning will improve and lead to higher efficiencies in weaving. The use of air-jets in spinning and winding machines has led to significant reduction in hairiness. However, the effects of air-jets on other properties such as yarn structure,
friction, bending, abrasion resistance, compression and torque have not been investigated.

The present research has been undertaken to fill up the gaps existing in the literature, and to have a better understanding of the introduction of air-jet nozzle in ring spinning.

In India sometime around 1992 air-jet yarns started penetrating into the textile industry. A few industries were started specifically for spinning air-jet yarns from polyester and viscose blends. It was felt that this type of yarn could only be used as weft in the fabrics in view of their higher bending rigidity. Many research institutions such as I.I.T. (Indian Institute of Technology) Delhi, NITRA (Northern India Textile Research Association) and VJTI (Veeramata Jijabhai Technical Institute) commenced research on this air-jet spun yarns. SITRA (South India Textile Research Association) was concerned with the study on the techno economics of air-jet spinning and also on the handle of knitted fabrics produced from air-jet and ring spun yarns. It is now learnt that air-jet spinning could be used for spinning cotton yarns also and recently Balasundaram\textsuperscript{(13)} has discussed the potential of MVS system.

Chasmawala, Hansen and Jayaraman\textsuperscript{(31)} were the first to show how the air-jet yarns could be characterised in terms of the component fibre configuration. An analysis of wrapper, core, wild core-wild, wrapper-wild in terms of the first nozzle and main draft in air jet yarns has been made by Chasmawala\textsuperscript{(30)}.

The credit for carrying out a detailed analysis of the structure and properties of air-jet fascinated yarns, doubtless, goes to Lawrence and Baqui\textsuperscript{(64)}; they investigated the effects of machine variables such as nozzle pressure, production speed, thread tension, draft and inter jet distance on the structure and properties of air-jet spun yarns. The approach made by these authors in classifying the structure of air-jet yarns into different classes is quite different from the methodology followed by Chasmawala\textsuperscript{(30)}. 

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1.2 AIR JET SPINNING

About six decades ago, DuPont introduced a method of spinning using air-jets to "twist" the yarn. The original DuPont claim was for a texturing process for filament yarns involving the use of a heat setting process, or a system of producing composite yarn in which filaments and staple were combined. An obvious extension of the latter idea was to dispense with the filament and to spin staple fibres into a "sheath yarn" in which the core fibres were "tied together" at intervals along the yarn length by means of wrapper fibres.

Some years later, the same company (DuPont) introduced a slightly different method of spinning, and named it as the fasciated yarn system. Miao\(^{(106)}\) has reported that, although the fasciated yarn system was claimed to be able to spin from filaments and from staple fibres, in the latter respect this was intended to be a "direct spinning system", i.e., tow-to-yarn spinning technique.

The Murata Company\(^{(112)}\) introduced the Murata twin Jet Spinning System (M.J.S). Apart from claims by the manufacturer which report that 100 percent cotton can be spun, it is generally agreed that the most suitable fibres for the Murata jet spinning are polyester and polyester rich blend.

The production sequence of M.J.S is as follows: the sliver is drafted (between back rollers aprons and the front rollers). The drafted material, emerging from front rollers is drawn into the first jet by the suction caused by the air injected to the air orifice. The orifices are angled in such a way as to rotate (twist) the yarn as it passes through. The second yarn twisting device is constructed similar to the first air-jet twisting device. However, the air injection orifices of the second air-jet are arranged in such a way to inject the compressed air to make air vortex in a contrary direction to the first twisting jet. The construction of the air twisting jets (first and second air-jets) is similar except for the orifice direction. The jet orifices are angled in such a way that they create forces both to twist the "yarn" and to exert a tension in order to...
pull the yarn through the jet. The angles of the orifice are critical and for practical purposes a compromise must be made so that an adequate consideration of twisting and "suction" is achieved.

It has been reported by Miao\textsuperscript{[10]} that if the yarn structure from Murata jet spinning is compared with that of the DuPont Rotofil system, there is no substantial difference between them. However, the quantity and tightness of wrapping fibre with the M.J.S yarn is better than Rotofil yarn. Mahmoudi\textsuperscript{[10]} has used the system for imparting bulk to worsted yarns.

Figs. 1.2 and 1.3 illustrate the DuPont and Murata principles of producing fasciated yarns. The only basic difference between the Murata and other systems is the presence of two jets B1 and B2 between the front rollers and the take-up. Although the Murata air-jet spinner was considered to be basically a form of open-end spinning unit, it is generally regarded as an improved fasciated yarn system. Atkinson and Henshaw\textsuperscript{[12]} have shown that, if a fibre does not converge with the main twisting strand at a fixed position but instead joins at a point that travels along the strand, it will receive less or more twist than the main bundle depending on the direction of movement of the convergence point.

Grosberg, Oxenham and Miao\textsuperscript{[55,56]} have conducted a pioneering work on the air-jet spinning system in which they have investigated the effects of the number of jets on yarn quality, distance between the front roller nip and the position at which the edge fibres contact on fascination and on twisting efficiency. They have formulated a generalized equation for twist changes and analysed the twist flow in the steady state. Their contribution to the area of air-jet spinning is a very significant one as it unravels all the important factors which affect the structure of air-jet yarn. The year 1987 seems to be a very important one for air-jet spinning technology, as many investigations on air-jet spinning were carried out during this period by research workers.

Yu\textsuperscript{[201]} has described an open end jet spinning using air twisting and open end spinning concepts.
Fig. 1.2 The Du Pont principle of producing Fasciated yarn with a single jet

Fig. 1.3 Murata principle of producing Fasciated yarn with two jets B₁ and B₂
Jeon\textsuperscript{(80)} has conducted studies on the effect of an air suction nozzle on yarn hairiness and quality.

The thesis is divided into 17 Chapters. Chapter 1 is a general introduction to the study. Chapter 2 contains the literature review and Chapter 3 research objectives of the project, Chapter 4 contains the materials and methods.

Included in Chapter 5 are the design particulars of air-jet nozzles and their optimization. Chapter 6 discusses the fibre migration in air-jet ring spun yarns. In Chapter 7, the radial packing density of air-jet ring spun yarns has been discussed. In Chapter 8 the wicking behaviour of air-jet ring spun yarns has been discussed. In Chapter 9 the installation of air-jet nozzle in the ring frame and its effect on the yarn characteristics has been discussed. Chapter 10 the low stress mechanical properties of yarns have been discussed. Chapter 11 discusses the application of air-jet nozzle for reducing hairiness of jute yarns. Chapter 12 discusses application of air-jet nozzle in cone winding.

The extension of air-jet nozzle in rotor spinning for producing a compact yarn is discussed in Chapter 13.

Included in Chapter 14 are the spirality of weft-knitted fabrics. Chapter 15 discusses the fluid modelling of air-jet nozzle and simulation of airflow pattern in the air vortex ring spinning system using computational fluid dynamics techniques.

Chapter 16 contains the on-line measurement of twist in the yarn in ring frame with the air-jet nozzle.

A general summary of the overall study reported in this thesis is given in Chapter 17 which consolidates the experimental results given in different chapters of the thesis.