

**INFLUENCE OF SOME PARAMETERS ON INTERNAL
STRUCTURE OF OPEN-END AND CORE-SHEATH
FRICTION SPUN YARNS**

by

PRASHANT

DEPARTMENT OF TEXTILE TECHNOLOGY

Submitted

in fulfillment of the requirements of the degree of Doctor of Philosophy

to the



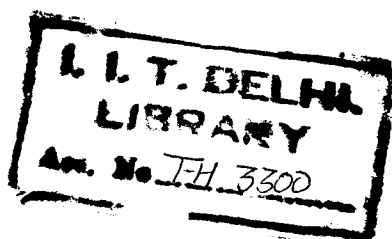
Indian Institute of Technology, Delhi

MARCH, 2006

1. Spun yarn 2. Friction Spun yarn



TH
677.072.3
PRA-I



Dedicated
to
My parents & wife

CERTIFICATE

This is to certify that the thesis entitled “**Influence of Some Parameters on Internal Structure of Open-End and Core-Sheath Friction Spun Yarns**” being submitted by **Mr. Prashant** 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 bonafide research work carried out by him. Mr. Prashant has worked under our guidance and supervision and fulfilled the requirements for submission of the 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.



Prof. S.M. Ishtiaque

Department of Textile Technology
Indian Institute of Technology, Delhi
New Delhi- 110016



Dr. A. Das

Department of Textile Technology
Indian Institute of Technology, Delhi
New Delhi- 110016

ACKNOWLEDGEMENTS

It is great pleasure for me to express my deep sense of gratitude and sincere regards to my learned and most respectable supervisors, Prof. S.M. Ishtiaque and Dr. A. Das, for their invaluable guidance, encouragement, and advice throughout the course work of this research work. Both of them advised me on the structure and framework of the thesis; discussed the major issues involved; deliberated extensively on the methodology. It would not have been possible for me to initiate, conduct and complete this thesis without their counsel and guidance.

I like to express my gratitude to members of Student Research Committee (SRC) Prof. S.N. Singh, Prof. R. Chattopadhyay and Prof. K. R. Salhotra for their valuable inputs at various stages of my doctoral research.

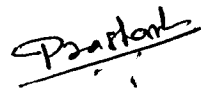
I am also thankful to Prof. V. K. Kothari (Head, department of Textile Technology), Dr. R. Alagirusamy, Dr. R. S. Rengasamy and all other faculty members of the Textile Technology department for their kind co-operation and help during the course of this research work.

I am grateful to Pashupati Acrylon Ltd, M/s Vardhman spinning Mills Ltd, M/s Ginni Internatinal Ltd, M/s Shamkeen Spinners Ltd., M/s Arisht Spinning Mills Ltd, NITRA, Ghaziabad, for providing me necessary facilities for preparation and testing of this research samples.

I express my gratitude to the staff members in various laboratories of the departments especially Mr. Fakir Chand, Mr. B. Biswl, Mr. V.K. Kala, Mr. R. Khattar, Mr. Pratap Singh, Mr. Bhola Mahato, Mr. R. P. Bhogal, Mr. Jugti Ram, Mr. Rameshwar Dayal for their co-operation and assistance during the course of this research work.

I am thankful to my research colleagues Mr. Vijay Yadav, Mr. Asis Patnaik, Mr. H. Arora, Mr. Krishnendu, Mr. Rajesh and all others for their valuable help and suggestions during this research work.

Lastly but importantly, my soul is indebted to for the eternal love and blessings that have been showered by my parents, wife, brothers, sisters, father-in law to accomplish this goal quite comfortably.

A handwritten signature in black ink, appearing to read 'Prashant', with a horizontal line drawn underneath it.

(Prashant)

ABSTRACT

The influence of opening roller speed, difference in drum speed, suction air pressure and sheath sliver feeding position on structural characteristics and properties of friction spun yarns have been investigated in details using Box and Behnken design of experiments. The study was carried out on both open-end and core-sheath types of friction spun yarns.

The air flow at different positions inside the transparent duct of DREF-III friction spinning machine was measured with the help of three-tube yaw probe, multi-tube manometer and traversing mechanism. For this purpose a transparent duct with exactly of same dimensions to that of original duct was fabricated from acrylic sheet. The results show that air flow inside the duct is not uniform both near inlet and outlet of the duct. The instability of air flow is more near the side walls, particularly in the inlet zone. In fact, near the side walls in the inlet zone the air flow is in upward direction. The increase in opening roller speed increases the rate of air flow. However increase in suction air pressure reduces the magnitude of instability in air flow near the side walls.

The internal structure of open-end and core-sheath friction spun yarns were studied with the help of tracer fibre technique. Twist structure of friction spun yarns were studied in leading and trailing half of fibres for different sliver feeding positions. The results show that fibres from 1st feeding position (near to delivery end) have higher helix diameter, helix angle and lower helix twist than fibres from 5th feeding position (away from delivery end). The results also show that there is considerable difference in the level of helix twist, helix diameter and helix angle in trailing and leading half of fibres. Sheath

fibres of core-sheath friction yarns have significantly lower twist than open-end friction yarns under identical spinning conditions. In core-sheath yarns, core fibres have lower level of twist in both 'S' and 'Z' directions, but the intensity of twist is significantly higher near the trailing end in Z direction. The increase in suction air pressure increases twist in sheath fibres for both types of friction spun yarns. The total entrapped false twist in the core also has been found to increase with increase in suction air pressure.

The migration parameters of friction spun yarns were studied in details with 2-dimensional and 3-dimensional images. The results show that 3-dimensional studies gives higher mean fibre position (MFP), root mean square deviation (RMSD) and mean migration intensity (MMI) than 2-dimensional study. It is observed that fibres from 1st sliver feeding position have significantly higher MFP, RMSD and MMI than 5th sliver feeding position. The results show that for open-end friction spun yarns the trailing half of fibres have higher MFP, MMI and RMSD than leading half of fibres for 1st feeding position while reverse trend is observed for fibres from 5th feeding position. The migration parameters are mainly influenced by suction air pressure followed by opening roller speed and difference in drum speed for both open-end and core-sheath friction yarns.

As regard to influence of process parameters on fibre configurations in friction spun yarns, it is observed that the sheath fibres have highest percentage of leading hooks followed by trailing hooks, entangled hooks and straight fibres for both types of yarns. The study also shows that fibres from 5th sliver feeding position have higher percentage of leading and trailing hooks and lower percentage of entangled fibres than fibres from 1st sliver feeding position for both types of yarns. The spinning-in coefficient of sheath

fibres from 1st sliver feeding position is lower than fibres from 5th sliver feeding position. In open-end friction spun yarns the spinning-in-coefficient initially decreases and then increases with the increase in opening roller speed and decreases consistently with increase in suction air pressure. However, the core sheath yarns do not show good correlation with the process variables.

The packing density of both types of yarns is only influenced by suction air pressure and increases with the increase in suction air pressure. The packing density of core-sheath friction spun yarns is higher than open-end friction yarns.

The results show that with the increase in opening roller speed and suction air pressure tenacity, elongation and work of rupture of open-end friction yarns increase but for core-sheath yarns the tenacity, initial modulus and work of rupture only influenced by suction air pressure. With regard to the influence of process parameters on physical properties of friction spun yarns it is observed that increase in opening roller speed and suction air pressure significantly reduces unevenness and imperfections of open-end friction spun yarns but have no significant influence on core-sheath yarns. Hairiness of both types of yarn decreases with the increase in suction air pressure.

Finally, with respect to the influence of transport duct profile on air flow, it has been observed that modified duct profile improves the air flow inside the duct. This improvement in air flow improves the yarn structure and tensile properties for open-end and core-sheath friction spun yarns. However improvement in tensile properties is more significant for open-end friction spun yarns. In core-sheath friction spun yarns the improvement in yarn tenacity is highest for 50:50 core-sheath ratio and for higher linear density.

CONTENT

	Page No.
ACKNOWLEDGEMENTS	
ABSTRACT	i
LIST OF FIGURES	xi
LIST OF TABLES	xvi
CHAPTER 1 INTRODUCTION	1
CHAPTER 2 REVIEW OF LITERATURE	
2.1 DEVELOPMENT AND POTENTIAL OF FRICTION SPINNING	5
2.2 PRINCIPLE OF FRICTION SPINNING MACHINES	6
2.3 YARN FORMATION	9
2.3.1 Sliver Feed	9
2.3.2 Opening of Fibres	10
2.3.3 Fibre Transportation Through Duct	11
2.3.4 Accumulation of Fibres	14
2.3.4.1 <i>Structure of Yarn Tail</i>	15
2.3.4.2 <i>Fibre Transfer</i>	16
2.3.4.3 <i>Fibre Capturing</i>	16
2.3.4.3.1 <i>Fibre capture by other fibres</i>	17
2.3.4.3.2 <i>Fibre capture by self-entrapment</i>	17
2.3.4.4 <i>Loop Formation</i>	19
2.3.5 Twist Insertion	20
2.3.5.1 <i>Twist Insertion in Open-End Friction Spinning</i>	24
2.3.5.2 <i>Twist Insertion in Core-Type Friction Spinning</i>	25
2.4 YARN STRUCTURE	25
2.4.1 Measurement by Tracer Fibre Technique	26
2.4.2 Structure of Open-End Friction Yarns	27
2.4.2.1 <i>Fibre Extent and Orientation</i>	28
2.4.2.2 <i>Fibre Migration</i>	28
2.4.2.3 <i>Twist Structure and its Distribution</i>	29
2.4.3 Structure of Core-Sheath Friction Yarns	30

2.4.3.1	<i>Fibre Extent and Orientation</i>	30
2.4.3.2	<i>Fibre Migration</i>	31
2.4.3.3	<i>Twist Structure and its Distribution</i>	31
2.5	FACTORS AFFECTING QUALITY OF FRICTION SPUN YARNS	32
2.5.1	Machine Parameters	32
2.5.1.1	<i>Opening Roller Assembly</i>	33
2.5.1.1.1	<i>Open-end friction yarns</i>	33
2.5.1.1.2	<i>Core-sheath friction yarns</i>	34
2.5.1.2	<i>Transport Duct</i>	34
2.5.1.3	<i>Friction Drum Assembly</i>	35
2.5.2	Process Parameters	36
2.5.2.1	<i>Friction Drum Speed</i>	36
2.5.2.1.1	<i>Open-end friction yarns</i>	36
2.5.2.1.2	<i>Core-sheath friction yarns</i>	37
2.5.2.2	<i>Yarn Delivery Rate</i>	37
2.5.2.2.1	<i>Open-end friction yarns</i>	37
2.5.2.2.2	<i>Core-sheath friction yarns</i>	38
2.5.2.3	<i>Friction Ratio</i>	38
2.5.2.3.1	<i>Open-end friction yarns</i>	38
2.5.2.3.2	<i>Core-sheath friction yarns</i>	39
2.5.2.4	<i>Suction Air Pressure</i>	39
2.5.2.4.1	<i>Open-end friction yarns</i>	39
2.5.2.4.2	<i>Core-sheath friction yarns</i>	40
2.5.2.5	<i>Core-Sheath Ratio</i>	41
2.5.2.6	<i>Type of Core</i>	41
2.5.2.7	<i>Yarn Linear Density</i>	42
2.5.2.7.1	<i>Open-end friction yarns</i>	42
2.5.2.7.2	<i>Core-sheath friction yarns</i>	43
2.5.3	Fibre Parameters	43
2.5.3.1	<i>Fibre Finish/ Fibre Friction</i>	43
2.5.3.2	<i>Fibre Strength</i>	44

2.5.3.3	<i>Fibre Fineness</i>	44
2.5.3.4	<i>Fibre Length</i>	45
2.6	COMPARISON OF FRICTION SPINNING WITH OTHER SPINNING SYSTEMS	46
2.6.1	Yarn Properties	46
2.6.2	Fabric Properties	47
2.7	ADVANTAGES AND DISADVANTAGES OF FRICTION SPINNING	48
2.7.1	Advantages	48
2.7.2	Disadvantages	48
2.8	CONCLUSIONS	49
CHAPTER 3	DESIGN OF EXPERIMENTS AND SAMPLE PREPARATION	
3.1	INTRODUCTION	50
3.2	DESIGN OF EXPERIMENT	50
3.2.1	Response Surface Designs	51
3.3	SAMPLE PREPARATION PLAN	56
3.3.1	Mixing	56
3.3.2	Sliver Preparation	56
3.3.3	Yarn Preparation	56
CHAPTER 4	AIR FLOW IN FIBRE TRANSPORT DUCT OF DREF-III MACHINE	
4.1	INTRODUCTION	58
4.2	EXPERIMENTAL WORK	59
4.2.1	Measurement of Air Flow inside the Duct	59
4.3	RESULTS AND DISCUSSION	61
4.3.1	Air Flow near Inlet of the Duct	61
4.3.2	Air Flow near Outlet of the Duct	70
4.3.3	Influence of Process Parameters on Air Flow	71
4.4	CONCLUSIONS	76

CHAPTER 5	TWIST STRUCTURE OF FRICTION SPUN YARNS	
5.1	INTRODUCTION	77
5.2	MATERIALS AND METHODS	78
5.2.1	Preparation of Yarn Samples	78
5.2.2	Test Method	79
5.2.2.1	<i>Twist Measurement</i>	79
5.3	RESULTS AND DISCUSSION	83
5.3.1	Twist Structure of Open-End Friction Yarns	83
5.3.1.1	<i>Helix Twist</i>	83
5.3.1.2	<i>Helix Diameter</i>	85
5.3.1.3	<i>Helix Angle</i>	87
5.3.2	Twist Structure of Core-Sheath Friction Yarn	88
5.3.2.1	<i>Sheath Twist Structure</i>	88
5.3.2.1.1	<i>Helix twist</i>	91
5.3.2.1.2	<i>Helix diameter</i>	93
5.3.2.1.3	<i>Helix angle</i>	94
5.3.2.2	<i>Twist Structure of Core Fibre</i>	95
5.3.2.2.1	<i>Helix twist of core fibre</i>	97
5.3.2.2.2	<i>Helix diameter of core fibre</i>	99
5.3.2.2.3	<i>Helix angle of core fibre</i>	99
5.3.3	Comparison of Open-End and Core-Sheath Friction Yarns	99
5.4	CONCLUSIONS	100

CHAPTER 6	MIGRATION CHARACTERISTICS OF FRICTION SPUN YARNS	
6.1	INTRODUCTION	101
6.2	MATERIALS AND METHODS	102
6.3	RESULTS AND DISCUSSION	107
6.3.1	Comparison between 2-D vs. 3-D Migration Parameters	107
6.3.2	Open-End Friction Yarns	108

6.3.2.1	<i>Mean Fibre Position (MFP)</i>	108
6.3.2.2	<i>Amplitude of Migration (RMSD)</i>	110
6.3.2.3	<i>Mean Migration Intensity (MMI)</i>	114
6.3.3	Core-Sheath Friction Yarns	116
6.3.3.1	<i>Mean Fibre Position (MFP)</i>	119
6.3.3.2	<i>Amplitude of Migration (RMSD)</i>	120
6.3.3.3	<i>Mean Migration Intensity (MMI)</i>	122
6.3.4	Comparison of Open-End and Core-Sheath Friction Yarns	124
6.3.4.1	<i>1st Feeding Position</i>	124
6.3.4.2	<i>5th Feeding Position</i>	125
6.4	CONCLUSIONS	126

CHAPTER 7 FIBRE EXTENT AND CONFIGURATION OF HOOKS OF FRICTION SPUN YRNS

7.1	INTRODUCTION	128
7.2	MATERIALS AND METHODS	129
7.3	PROPOSED MECHANISM OF HOOK FORMATION IN FRICTION SPINNING	130
7.3.1	Leading Hooks	130
7.3.2	Trailing Hooks	131
7.3.3	Entangled Fibres	131
7.4	RESULTS AND DISCUSSION	132
7.4.1	Open-End Friction Yarns	132
7.4.1.1	<i>Configuration of Hooks</i>	132
7.4.1.2	<i>Hook Extent</i>	138
7.4.1.3	<i>Spinning-in-Coefficient (K_F)</i>	140
7.4.2	Core-Sheath Friction Yarns	145
7.4.2.1	<i>Sheath Structure</i>	145
7.4.2.1.1	<i>Configuration of hooks</i>	145
7.4.2.1.2	<i>Hook extent</i>	148
7.4.2.1.3	<i>Spinning-in-coefficient (K_F)</i>	151

7.4.2.2	<i>Core Structure</i>	152
7.4.2.2.1	<i>Configuration of hooks</i>	152
7.4.2.2.2	<i>Hook extent</i>	152
7.4.2.2.3	<i>Spinning-in-coefficient (K_F)</i>	153
7.4.3	Comparison of Open-End and Core-Sheath Friction Yarns	153
7.4.3.1	<i>1st Feeding Position</i>	153
7.4.3.2	<i>5th Feeding Position</i>	154
7.5	CONCLUSIONS	154
CHAPTER 8	PACKING DENSITY OF FRICTION SPUN YARNS	
8.2	INTRODUCTION	156
8.2	MATERIALS AND METHODS	157
8.3	RESULTS AND DISCUSSION	158
8.3.1	Open-End Friction Yarns	158
8.3.2	Core-Sheath Friction Yarns	163
8.3.3	Comparison of Open-End and Core-Sheath Friction Yarns	167
8.4	CONCLUSIONS	168
CHAPTER 9	PROPERTIES OF FRICTION SPUN YARNS	
9.1	INTRODUCTION	169
9.2	EXPERIMENTAL	170
9.2.1	Preparation of Yarn Samples	170
9.2.2	Testing	170
9.3	RESULTS AND DISCUSSION	172
9.3.1	Open-End Friction Yarns	172
9.3.1.1	<i>Tensile Properties</i>	172
9.3.1.2	<i>Yarn Unevenness and Imperfections</i>	176
9.3.1.3	<i>Yarn Hairiness</i>	178
9.3.2	Core-Sheath Friction Yarns	179
9.3.2.1	<i>Tensile Properties</i>	180
9.3.2.2	<i>Yarn Unevenness and Imperfections</i>	182

9.3.2.3	<i>Yarn Hairiness</i>	182
9.3.3	Comparison of Open-End and Core-Sheath Friction Yarns	183
9.4	CONCLUSION	185
CHAPTER 10	INFLUENCE OF MODIFIED TRANSPORT DUCT ON AIR FLOW, STRUCTURE AND PROPERTIES OF FRICTION SPUN YARNS	
10.1	INTRODUCTION	186
10.2	MATERIALS AND METHODS	187
10.3	RESULTS AND DISCUSSION	197
10.3.1	Air Flow Pattern near Inlet of Original and Modified Duct	197
10.3.2	Air Flow Pattern near Outlet of Original and Modified Duct	198
10.3.3	Structure and Properties of Open-End Friction Yarns	199
10.3.4	Structure and Properties of Core-Sheath Friction Yarns	202
10.3.5	Influence of Core-Sheath Ratio on Properties of Friction Yarns	204
10.3.6	Influence of Yarn Linear Density on Properties of Core-Sheath Friction Yarns	204
10.4	CONCLUSIONS	205
CHAPTER 11	OVERALL SUMMARY AND CONCLUSIONS	206
	REFERENCES	207
	SCOPE FOR FUTURE WORK	218
	BIO-DATA	