

STUDIES ON FALSE-TWIST TEXTURING OF DIFFERENT TYPES OF POLYESTER YARNS

By

SOUMYEN KUMAR PAL

Department of Textile Technology

Thesis submitted

in fulfilment of the requirements

of the degree of

DOCTOR OF PHILOSOPHY



to the

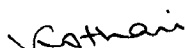
INDIAN INSTITUTE OF TECHNOLOGY, DELHI

DECEMBER, 1995

CERTIFICATE

This is to certify that the thesis entitled "**Studies on False-Twist Texturing of Different types of Polyester Yarns**" being submitted by Mr. Soumyen Kumar Pal to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him. Mr. Soumyen Kumar Pal has worked under our joint 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 full to any other University or Institute for the award of any degree or diploma.



(V. K. Kothari)

Professor

Department of Textile Technology
Indian Institute of Technology,
New Delhi - 110 016, India.



(R. S. Gandhi)

Hon. Director
Man-Made Textiles
Research Association
Surat - 395 002, India.

Dedicated to
My Grandmother

ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Prof. V.K. Kothari, Department of Textile Technology, Indian Institute of Technology, New Delhi, for his immense interest, co-operation and professional guidance throughout the entire course of work that has helped me to complete this work in time.

I express my sincere gratitude to Dr. R.S. Gandhi, Honary Director, Man-Made Textiles Research Association (MANTRA), Surat for his encouragement and guidance during the course of the work. I also take this opportunity to express my sincere thanks to the Management of MANTRA for kind co-operation during this work.

I wish to thank Dr. N.D. Sharma and Dr. B.V. Rao, SPRC, Kota for supplying the polymer chips for this work. I am also thankful to Dr. A. Venkatraman, BTRA, Bombay for tests on X-ray diffractometer and M/s Petrofils Co-operative Ltd., Baroda for testing work on Texturmat-M. I wish to thank Mr. D.B. Chauhan for help in sample preparation. I am also thankful to Mr. N.H. Saraiya and Late Mr. Y.C. Mehta for their co-operation. My thanks are also due to all my colleagues at MANTRA for their encouragement. Mr. J.K. Sensarma, Dr. A.L.N. Rao, Dr. A.B. Talele, Dr. M.V.S. Rao, Mr. A.K. Gandhi, Dr. R.K. Datta, Dr. D.H. Joshi, Mr. M.G. Patel, Mr. K. Saha, Mr. R.J. Sharma,

Mr. H.G. Purohit, Mr. D.L. Gavade, Mr. A.K. Chakraborty, Mr. P. Kar deserve my special thanks. I am thankful to Mr. J.R. Nagoria for typing the thesis.

Finally, I appreciate the understanding and patience of my wife Mrs. Rachita Pal. She was a constant source of inspiration during this work. Mention must be made to my parents and uncles, who have always been source of encouragement to me.



(SOUMYEN KUMAR PAL)

ABSTRACT

Production of polyester fibre has rapidly increased since its introduction in the world market in 1950s. Continuous research work to improve performance and versatility has led to the development of many new polyester fibres amongst which microfibre and cationic dyeable poly(ethylene terephthate) fibre are noteworthy commercial exploited examples. The texturing behaviour of these new fibres has been studied. Draw ratio, D/Y ratio, first heater temperature and heater contact time have been varied during texturing of POY polyester yarns on SDS 600C draw-texturing machine. Box and Hunter statistical experimental design has been adopted to prepare samples. The textured yarn properties examined include tensile, crimp and dyeing properties. In addition to these, yarn quality in terms of broken filaments and tight spots has also been studied. X-ray diffractometer, Polarising microscope, Sonic modulus tester, Differential scanning calorimetry have been used for analysing the structural properties of fibres. Observed changes in properties of textured yarns have been explained on the basis of structural studies.

Study on the effect of texturing variables on the properties of microfibre polyester reveals that the crystalline content in microfibre yarns after texturing is lower than that of normal polyester, while orientation is higher. Tenacity and crimp contraction are poorer in

textured microfibre polyester yarns as compared to textured normal polyester yarns. Dye uptake of microfibre polyester is found to be lower. Broken filaments are more in microfibre polyester than in case of normal polyester. To reduce incidence of broken filaments in microfibre polyester, draw ratio should be reduced.

Study on the effect of texturing variables on cationic dyeable polyester (CDPET) yarn reveals that the crystallinity as well as orientation is less in CDPET yarn due to presence of bulky $-\text{SO}_3\text{Na}$ group in the polyester fibre. The tensile properties are poorer in CDPET as compared to normal polyester. It is found that the tenacity of CDPET increases upto 190°C followed by decrease with further increase in heater temperature. The crimp stability is less in CDPET than that of normal polyester. Dye uptake is more in CDPET as compared to normal polyester. Broken filaments are higher in case of CDPET.

With increasing DMS salt content in CDPET, the crystalline fraction, orientation and crystal size decreases, which, in turn, results in lower mechanical properties. Tenacity, crimp contraction and crimp stability reduces with increase in DMS salt content in CDPET. The dyeability of CDPET with both disperse dyes and cationic dyes improves with increase in DMS salt content. The DMS salt content should be less than 1.5 mol percent in CDPET to get a fibre with good dyeability as well as satisfactory mechanical properties.

CONTENTS

ABSTRACT	i
CONTENTS	iii
GLOSSARY	ix
LIST OF FIGURES	xi
 Chapter 1 INTRODUCTION	
1.1 Introduction	1
1.2 Microfibres	2
1.3 Cationic Dyeable Polyester	2
1.4 Texturing	4
1.5 Objective of Study	5
 Chapter 2 REVIEW OF LITERATURE	
2.1 Poly(ethylene terephthalate) Fibre	6
2.2 Production of Polyester Yarns	8
2.2.1 Production of microfibre	10
2.2.1.1 Quality of the chips for microfibre polyester	11
2.2.1.2 Manufacturing methods for microfibre	12
2.2.2 Production of cationic dyeable polyester	14
2.3 Structure and Properties	18
2.3.1 Structure and properties of microfibres	18
2.3.2 Structure and properties of cationic dyeable polyester	22
2.4 False-twist Texturing	30
2.4.1 Twisting system	31

2.4.2	Feeder yarn quality	32
2.4.3	Geometrical structure of false-twist textured yarns	34
2.4.4	Molecular structure of properties of false-twist textured yarns	38
2.4.5	Texturing of microfibre yarns	42
2.5	Applications of Microfibre and Cationic Dyeable Polyester Yarns	43
2.5.1	Applications of microfibre polyester yarns	43
2.5.2	Applications of cationic dyeable polyester yarn	46

Chapter 3 EXPERIMENTAL METHODS

3.1	Materials	48
3.1.1	Feed yarns	48
3.1.2	Preparation of draw-textured yarns	51
3.2	Methods of Characterisation of Structure and Properties	51
3.2.1	X-ray diffraction	53
3.2.2	Density crystallinity	57
3.2.3	Birefringence	59
3.2.4	Amorphous orientation	61
3.2.5	Sonic modulus	62
3.2.6	Thermal properties	64
3.2.7	Intrinsic viscosity	66
3.2.8	Draw force	68
3.2.9	Tensile properties	68
3.2.10	Crimp properties	69

3.2.11	Dyeing	71
3.2.12	Broken filaments	72
3.2.13	Tight spots	72
3.3	Design of Experiment	72
3.3.1	Box and Hunter design	73
3.3.2	Response surface equation	74
3.3.3	Analysis of variance	76
3.3.4	The test of significance of the fitted regression equation	77
3.3.5	Effectiveness of variables on properties	78

Chapter 4 DRAW-TEXTURING MICROFIBRE POLYESTER YARN

4.1	Introduction	79
4.2	Experimental	80
4.2.1	Materials	80
4.2.2	Texturing	80
4.3	Results and Discussion	81
4.3.1	Properties of POY polyester yarns	81
4.3.2	Structural characteristics of textured yarns	83
4.3.2.1	Crystalline content	87
4.3.2.2	Molecular orientation	92
4.3.2.3	Crystalline orientation	100
4.3.2.4	Amorphous orientation	105
4.3.2.5	Crystal size	108
4.3.3	Properties of textured yarns	112
4.3.3.1	Tensile properties	117
4.3.3.2	Crimp properties	127

4.3.3.3	Dyeing property	141
4.3.3.4	Yarn quality	146
4.4	Summary	152
 Chapter 5 DRAW-TEXTURING OF CATIONIC DYEABLE POLYESTER YARN		
5.1	Introduction	154
5.2	Experimental	155
5.2.1	Materials	155
5.2.2	Texturing	155
5.3	Results and Discussion	156
5.3.1	Properties of POY polyester yarns	156
5.3.2	Structural properties	154
5.3.2.1	Crystalline content	158
5.3.2.2	Birefringence	169
5.3.2.3	Crystalline orientation	174
5.3.2.4	Amorphous orientation	177
5.3.2.5	Crystal size	180
5.3.3	Properties of texture yarns	182
5.3.3.1	Tensile properties	186
5.3.3.2	Crimp properties	191
5.3.3.3	Dyeing property	201
5.3.3.4	Yarn quality	205
5.4	Summary	207
 Chapter 6 EFFECT OF THE AMOUNT OF COMONOMER ON THE PROPERTIES OF DRAW-TEXTURED CATIONIC DYEABLE POLYESTER YARN		
6.1	Introduction	210

6.2	Experimental	210
6.2.1	Materials	210
6.2.2	Texturing	211
6.3	Results and Discussion	213
6.3.1	Properties of POY polyester yarns	213
6.3.2	Structural characteristics of textured yarns	213
6.3.2.1	Crystalline content	214
6.3.2.2	Birefringence	222
6.3.2.3	Crystalline orientation	224
6.3.2.4	Amorphous orientation	224
6.3.2.5	Crystal size	228
6.3.3	Properties of textured yarns	228
6.3.3.1	Tensile properties	234
6.3.3.2	Crimp properties	238
6.3.3.3	Dyeing property	251
6.3.3.4	Yarn quality	258
6.4	Summary	264

Chapter 7 CONCLUSIONS

7.1	Conclusions	265
7.2	Suggestion for future work	268

REFERENCES	270
-------------------	-----

APPENDIX I	281
-------------------	-----

APPENDIX II	285
--------------------	-----

APPENDIX III	286
---------------------	-----

APPENDIX IV	289
APPENDIX V	290
APPENDIX VI	292
LIST OF PUBLICATIONS	295
BIO-DATA	296