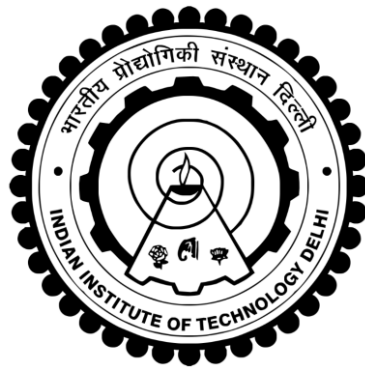


STUDIES ON BENDING AND SHEAR BEHAVIOURS OF WOVEN FABRICS

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**DEPARTMENT OF TEXTILE & FIBRE ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI**

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STUDIES ON BENDING AND SHEAR BEHAVIOURS OF WOVEN FABRICS

by

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Submitted

in fulfilment of the requirements of the degree of

Doctor of Philosophy

to the



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Dedicated to
My Parents & Wife

CERTIFICATE

This is to certify that the thesis titled '**Studies on Bending and Shear Behaviours of Woven Fabrics**', being submitted by **Md Samsu Alam** 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. He has worked under our guidance and supervision and fulfilled the requirements for submission of the thesis which has attained the standard required for a Ph.D. degree of this Institute.

The results contained in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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ABSTRACT

The formation of fabric structures by means of weaving, knitting, braiding, etc. involves the bending of fibres and yarns. Bending plays an important role during the end use of textiles, because fabrics and their constituent fibres and yarns undergo flexing to different extent. On the other hand, shear is a property which distinguishes textile fabrics from other sheet like materials, namely paper and plastic. Though many researches have been conducted to understand and model the bending and shear behaviours of woven fabrics, still there are some unsolved issues like generalised model of shear behaviour of woven fabrics and engineering design of woven fabrics with targeted bending and rigidities.

In the first part of this research, influence of fibre blend, yarn count and fabric sett (ends per inch $\times$ picks per inch) on bending and shear rigidities of plain woven fabric was studied. Square plain fabrics were woven using 20 Ne, 30 Ne and 40 Ne yarns of three different blends (100% cotton, 100% polyester and 50:50 polyester-cotton). Different levels of fabric sett were considered as 50 inch⁻¹, 60 inch⁻¹ and 70 inch⁻¹. Fabric bending and shear rigidities were measured by using Kawabata Evaluation System (KES) at low stress region. An increasing trend of fabric bending and shear rigidities was observed with lower proportion of polyester, coarser yarn count and higher fabric sett. Yarn count was found to be the most important parameter influencing fabric bending and shear rigidities followed by fabric sett and proportion of polyester. A strong degree of association was found between bending and shear rigidities of fabric.

In second part of this research, influence of weave on bending and shear rigidities of woven fabric was studied. Twelve fabrics were woven (6 each of 100% cotton and 100% polyester) by using yarns of 30 Ne. Six different weaves (plain, 2/1 twill, 3/1 twill, 2/2 twill, 2 $\times$ 2 matt and 5-end satin) were considered. Plain woven fabric showed the highest bending and shear rigidities, followed by twill and matt, in that order, whereas

satin showed the minimum values. The effect of weave was more dominant on shear rigidity than that on bending rigidity. Fabric weave factor was represented by two parameters, namely fabric crossover firmness factor and floating yarn factor. It was found that both the factors had a strong degree of association with bending and shear rigidities.

In the third part of this research, a generalised mathematical model of shear rigidity of woven fabric, having different weaves, was proposed. The shear rigidity of fabric was expressed as functions of yarn bending rigidity, fabric geometrical parameters and crossover firmness factor. Very good agreement was found between theoretically calculated and practically measured values of shear rigidity.

When fabrics are woven by varying fibre blend, yarn count and fabric sett independently, bending and shear rigidity show excellent agreement. However, this inference may not be valid if the fabric areal density is kept constant. Using the aforesaid logic, if fabrics of same areal density are woven by judiciously adjusting the yarn count and fabric sett, it may be possible to counter the concomitant relationship between fabric bending and shear rigidities. Thus, it may be possible to design a set of woven fabrics having similar bending rigidity but different shear rigidity or vice versa. In the fourth part of this research, 18 fabrics were woven (9 each of 100% cotton and 100% polyester) keeping the areal density same. All the fabrics were woven using yarns of 20 Ne, 30 Ne and 40 Ne in various combinations in warp and weft directions by adjusting yarn count and fabric sett. As the warp yarns became finer keeping the weft yarn same, fabric bending rigidity in warp direction remained unchanged but fabric shear rigidity in warp direction increased. On the other hand, as the weft yarns were made finer keeping the warp yarn same, warp wise fabric bending as well as shear rigidities increased. Similar results were obtained in transpose direction.

In the last part of this research, an attempt was made to design woven fabrics having low bending rigidity and high shear rigidity using multi-objective optimisation. Two approaches were used for multi-objective optimisation. The first approach was based on desirability function which combined individual desirability of objectives into overall desirability varying from 0 to 1. The overall desirability was maximised against the target values of bending and shear rigidities. It was possible to attain the overall desirability of 0.684 resulting from individual desirability of 0.662 and 0.707 for bending and shear rigidities, respectively. Experimental validation confirmed that the applied method can be effectively used to optimise the woven fabric mechanical properties at low stress region. The second approach was based on an evolutionary algorithm called Non-dominated Sorting Genetic Algorithm II (NSGA-II) which offered multiple optimal solutions which were non-dominating in nature. Pareto-optimal solutions were obtained. The experimental validation confirmed that the actual values of bending and shear rigidities of woven fabrics are very close to the respective Pareto optimal values.

सार

बुनाई, बुनना, ब्रेडिंग आदि के माध्यम से कपड़े संरचनाओं के गठन में रेशा और धागा के झुकने शामिल हैं। झुकने वस्त्र के अंत उपयोग के दौरान एक महत्वपूर्ण भूमिका निभाता है, क्योंकि कपड़े और उनके घटक रेशा और धागा अलग हद तक फ़्लेक्सिंग। दूसरी ओर, शियर एक गुण है, जो कपड़े को कागज और प्लास्टिक की तरह अन्य शीट से अलग करता है। हालांकि कई शोध को समझने और बुना कपड़े के शियर और बेन्डिंग व्यवहार मॉडल आयोजित किया गया है, अभी भी बुना कपड़े के शियर व्यवहार के सामान्य मॉडल और बुना कपड़े के इंजीनियरिंग डिजाइन की तरह कुछ अनसुलझे मुद्दों के साथ कर रहे हैं लक्षित बेन्डिंग और शियर ।

इस शोध के पहले भाग में , रेशा मिश्रण के प्रभाव, धागा गिनती और कपड़े सेट (प्रति इंच × प्रति इंच उठाता है) बेन्डिंग और शियर पर और सादे बुने हुए कपड़े की का अध्ययन किया गया। वर्ग सादे कपड़े का उपयोग कर बुना गया 20 ने, 30 ने तथा 40 ने तीन अलग मिश्रणों के धागा (100% कपास, 100% पॉलिएस्टर और 50:50 पॉलिएस्टर-कपास। कपड़े सेट के विभिन्न स्तरों को 50 इंच⁻¹, 60 इंच⁻¹ और 70 इंच⁻¹ माना जाता। कम तनाव क्षेत्र में कावाबाटा मूल्यांकन प्रणाली का उपयोग करके कपड़े बेन्डिंग और शियर को मापा गया। कपड़े बेन्डिंग और शियर की बढ़ती प्रवृत्ति पॉलिएस्टर के कम अनुपात के साथ मनाया गया, मोटे धागा गिनती और उच्च कपड़े सेट साथ मनाया गया। धागा गिनती, कपड़े सेट और पॉलिएस्टर के अनुपात के बाद कपड़े बेन्डिंग और शियर को प्रभावित करने के लिए सबसे महत्वपूर्ण पैरामीटर होना पाया गया। कपड़े के बेन्डिंग और शियर के बीच एक मजबूत डिग्री संघ पाया गया।

इस शोध के दूसरे भाग में, बुने हुए कपड़े के बेन्डिंग और शियर पर बुनाई के प्रभाव का अध्ययन किया गया। 12 कपड़े बुना गया (6-100% कपास और 6-100% पॉलिएस्टर)। प्रत्येक कपड़े बुना गया 30 ने धागा से। छह विभिन्न बुनाई के उपयोग करके (प्लेन, 2/1 ट्विल, 3/1 ट्विल, 2/2 ट्विल, 2×2 मैट और 5-एन्ड साटन) गया। सादा बुना हुआ कपड़ा, ट्वील और मैट से ज्यादा बेन्डिंग और शियर दिखता है। उच्चतम बेन्डिंग और शियर उस क्रम में, जबकि साटन न्यूनतम दिखता है। बुनाई का प्रभाव बेन्डिंग और शियर पर उस से शियर पर अधिक प्रभावी था। कपड़ा बुनाई कारक दो मापदंडों, अर्थात् कपड़े विदेशी दृढ़ता कारक और चल धागा कारक द्वारा प्रतिनिधित्व किया गया था। यह पाया गया कि दोनों कारकों बेन्डिंग और शियर के साथ सहयोग की एक मजबूत डिग्री है।

इस शोध के तीसरे भाग में, बुना कपड़े की शियर का एक सामान्यतः गणितीय मॉडल, अलग बुनाई वाले, प्रस्तावित किया गया है। कपड़े की शियर धागा का बेन्डिंग कपड़े ज्यामितीय मापदंडों और विदेशी दृढ़ता कारक के कार्यों के रूप में व्यक्त किया गया है। बहुत अच्छा समझौता सैद्धांतिक रूप से गणना की और व्यावहारिक रूप से शियर के मूल्यों मापा के बीच पाया गया।

जब कपड़े अलग फाइबर मिश्रण, धागा गिनती और कपड़े सेट से बुना जाता है, बेन्डिंग और शियर उत्कृष्ट समझौते दिखता है। हालांकि, यह अनुमान मान्य नहीं हो सकता है अगर कपड़े वास्तविक घनत्व स्थिर रखा जाता है। उपर्युक्त तर्क का उपयोग करना, यदि एक ही क्षेत्रीय घनत्व के कपड़े विवेकपूर्ण रूप से धागा गिनती और कपड़े सेट का समायोजन करके बुना जाता है, तो कपड़े बेन्डिंग और शियर के बीच सहवर्ती संबंध का मुकाबला करना संभव हो सकता है। इस प्रकार, यह इसी तरह सामान बेन्डिंग लेकिन विविध शियर का बुना कपड़े का एक सेट डिजाइन करने के लिए संभव हो सकता है।

इस शोध के चौथे भाग में, 18 कपड़े बुना गया (9 100% कपास और 100% पॉलिएस्टर) क्षेत्रीय घनत्व ही रखते हुए। सभी कपड़े धागा गिनती और कपड़े सेट का समायोजन करके ताना और बाने दिशाओं में विभिन्न संयोजनों में 20 ने, 30 ने और 40 ने के धागा का उपयोग कर बुना गया था। जैसे-जैसे बाने के धागा को एक ही रखने में ताना दिशा में महीन वृद्धि हुई, ताना दिशा में झुकने वाले कपड़े का बेन्डिंग अपरिवर्तित रहे। विपरीत परस्थिति में कपड़े का बेन्डिंग और शियर ताना दिशा में वृद्धि हुई। इसी प्रकार के परिणाम स्थानांतरित दिशा में प्राप्त किए गए थे।

इस शोध के अंतिम भाग में, बहु-वस्तुपरक अनुकूलन का उपयोग करके कम बेन्डिंग और उच्च शियर वाले बुने हुए कपड़ों को डिजाइन करने का प्रयास किया गया । बहु-ऑब्जेक्टिव ऑप्टिमाइज़ेशन के लिए दो तरीकों का उपयोग किया गया। पहला दृष्टिकोण वांछनीयता समारोह पर आधारित था जो उद्देश्यों की व्यक्तिगत वांछनीयता को 0 से 1 तक अलग-अलग समग्र वांछनीयता में संयुक्त करता था। बेन्डिंग और शियर के लक्ष्य मूल्यों के खिलाफ समग्र वांछनीयता अधिकतम किया गया था। यह क्रमशः बेन्डिंग और शियर के लिए 0.662 और 0.707 की व्यक्तिगत वांछनीयता के परिणामस्वरूप 0.684 की समग्र वांछनीयता प्राप्त करने के लिए संभव है। प्रायोगिक सत्यापन की पुष्टि की है कि लागू विधि प्रभावी ढंग से कम तनाव क्षेत्र में बुना कपड़े यांत्रिक गुणों को अनुकूलित करने के लिए इस्तेमाल किया जा सकता है। दूसरा दृष्टिकोण गैर-प्रमुख छंटनी आनुवंशिक एल्गोरिथ्म द्वितीय - II (न. स. ग. ऐ. - II) कहा जाता है जो कई इष्टतम समाधान है जो प्रकृति में गैर प्रभुत्व थे की पेशकश की एक विकासवादी एल्गोरिथ्म पर आधारित था. परेटो-अनुकूल समाधान प्राप्त किए गए थे। प्रयोगात्मक सत्यापन की पुष्टि की है कि बुना कपड़े के बेन्डिंग और शियर के वास्तविक मूल्यों बहुत संबंधित परेटो अनुकूल मूल्यों के करीब हैं।

TABLE OF CONTENTS

Certificate		i
Acknowledgements		ii
Abstract		iv
Table of contents		vii
List of figures		xiv
List of tables		xviii
Chapter 1	Introduction	
1.1	Motivation for the work	1
1.2	Objectives	4
1.3	Organization of thesis	4
Chapter 2	Literature review	
2.1	Introduction	7
2.2	Woven fabric	7
2.3	Bending rigidity	8
2.3.1	Yarn bending rigidity	9
2.3.2	Fabric bending rigidity	11
2.3.3	Mathematical model of fabric bending rigidity	14
2.4	Shear rigidity	19
2.4.1	Mathematical model of fabric shear rigidity	22
2.5	Evaluation of bending rigidity	25
2.5.1	Cantilever bending test	25
2.5.2	Hanging loop bending test	26

2.5.3	Kawabata evaluation system (KES FB2)	27
2.6	Evaluation of shear rigidity	28
2.6.1	Kawabata evaluation system (KES FB1)	28
2.6.2	Bias extension test	29
2.7	Weave factor of fabric	29
2.8	Factors affecting fabric bending and shear rigidities	35
2.8.1	Influence of fibre properties	35
2.8.1.1	Type of fibre	35
2.8.1.2	Fibre linear density	35
2.8.1.3	Fibre cross-sectional shape	38
2.8.1.4	Fibre diameter	39
2.8.2	Influence of yarn properties	39
2.8.2.1	Type of yarns	40
2.8.2.2	Yarn twist	40
2.8.2.3	Yarn count, diameter and porosity	42
2.8.3	Influence of fabric properties	43
2.8.3.1	Fabric sett	43
2.8.3.2	Weave	44
2.9	Optimisation process	47
2.9.1	Linear programming	47
2.9.1.1	Application of linear programming	47
2.9.2	Quadratic programming	48
2.9.2.1	Application of quadratic programming	48
2.9.3	Multi-objective optimisation	49
2.9.3.1	Goal programming	49

2.9.3.2	Desirability function	50
2.9.3.3	Non-dominating sorting genetic algorithm –II (NSGA-II)	50
2.9.3.4	Application of multi-objective optimisation in textiles	51
2.10	Research Gaps	53
Chapter 3	Materials and methods	
3.1	Introduction	54
3.2	Materials	54
3.3	Preparation of fabric samples	55
3.3.1	Sizing	55
3.3.2	Warping	55
3.3.3	Drawing-in and denting	56
3.3.4	Weaving	56
3.4	Preparatory wet treatments of fabric samples	57
3.4.1	Desizing	57
3.4.2	Scouring	57
3.5	Testing methods	58
3.5.1	Yarn diameter	58
3.5.2	Yarn twist	58
3.5.3	Fabric sett	58
3.5.4	Fabric fractional cover	59
3.5.5	Fabric areal density	59
3.5.6	Yarn crimp in fabric	60
3.5.7	Bending rigidity of fabric	60
3.5.8	Shear rigidity of fabric	61

3.5.9	Tensile modulus of fabric	62
Chapter 4	Bending and shear rigidities of plain woven fabrics: Roles of fibre, yarn and fabric parameters	
4.1	Introduction	64
4.2	Materials and methods	65
4.2.1	Materials	65
4.2.2	Preparation of fabric samples	66
4.2.3	Testing	67
4.3	Response surface equations	68
4.4	Results and discussions	69
4.4.1	Bending and shear rigidities of fabrics	69
4.4.2	Effect of fabric cover and areal density on bending and shear rigidities	73
4.4.3	Response surface models	74
4.5	Conclusions	82
Chapter 5	Bending and shear rigidities of woven fabrics: Role of weave	
5.1	Introduction	83
5.2	Fabric weave factor	84
5.2.1	Crossover firmness factor	84
5.2.2	Floating yarn factor	85
5.3	Materials and methods	85
5.3.1	Materials	85

5.3.2	Sample preparation	86
5.3.3	Testing	86
5.4	Results and discussions	87
5.4.1	Fabric weave factor	87
5.4.2	Fabric constructional parameters	88
5.4.3	The effect of weave on bending and shear rigidities of fabric	89
5.4.4	Association of bending and shear rigidities of fabric with crossover firmness factor and floating yarn factor	93
5.5	Conclusions	98
Chapter 6	A generalised mathematical model for predicting shear rigidity of woven fabrics	
6.1	Introduction	99
6.2	Woven fabric structure	100
6.3	Theoretical analysis	101
6.3.1	Leaf's model of fabric shear rigidity	101
6.3.2	Generalised mathematical model of fabric shear rigidity	103
6.3.2.1	Assumptions	103
6.3.2.2	Nomenclatures	103
6.3.2.3	Analysis of plain woven structure	104
6.3.2.4	Analysis of 2/1 twill woven structure	106
6.3.2.5	Generalised model of fabric shear	107
6.4	Materials and methods	109
6.5	Results and discussions	110
6.6	Experimental validation	111

6.7	Conclusions	115
Chapter 7	Bending and shear rigidities of plain woven fabrics having similar areal density	
7.1	Introduction	116
7.2	Materials and methods	117
7.2.1	Materials	117
7.2.2	Sample preparation	117
7.2.3	Testing	119
7.3	Results and discussions	119
7.3.1	Areal density of fabrics	119
7.3.2	Bending rigidity of fabrics	121
7.3.3	Shear rigidity of fabrics	125
7.3.4	Fabric shear rigidity and number of interlacements	129
7.4	Conclusions	132
Chapter 8	Multi-objective optimisation of bending and shear rigidities of woven fabrics	
8.1	Introduction	133
8.2	Materials and methods	135
8.3	Multi-objective optimisation using desirability function	136
8.3.1	Desirability function	136
8.3.2	Results and discussions	138
8.3.3	Experimental validation of results of desirability function approach	143
8.4	Multi-objective optimisation using non-dominated sorting	144

	genetic algorithm – II (NSGA-II)	
8.4.1	Genetic algorithm	146
8.4.2	Multi-objective optimisation using NSGA – II	148
8.4.2.1	Step 1: Initialisation of random binary population	148
8.4.2.2	Step 2: Fast non-dominated sorting	149
8.4.2.3	Step 3: Crowding distance	150
8.4.2.4	Step 4: Crowded tournament selection	151
8.4.2.5	Step 5: Crossover and mutation	152
8.4.2.6	Step 6: Recombination and selection	152
8.4.3	Formulation of optimisation problem	152
8.4.4	Optimisation results of NSGA-II	153
8.4.5	Experimental validation of results of NSGA-II	157
8.5	Conclusions	158
Chapter 9	Overall conclusions	159
Chapter 10	Suggestions for future research	161
References		162
List of publications		177
Bio-data		178

LIST OF FIGURES

Figure no.	Figure caption	Page no.
2.1	A plain woven fabric	8
2.2	Typical bending curve of woven fabric	12
2.3	Representation of shear deformation	20
2.4	(a) Force in bias direction in fabric, (b) Resistance to shear	21
2.5	Typical shear curve of fabric	21
2.6	Cantilever bending	26
2.7	Different shapes of hanging loops	26
2.8	Pure bending principle of KES FB 2 tester	27
2.9	Shear test (a) before deformation and (b) during deformation	28
2.10	Fabric fields	31
2.11	A repeat of plain weave	33
2.12	Nine types and weights of floating yarns	33
2.13	Relationship between fibre flexural rigidity and fabric bending rigidity (a) warp way and (b) weft way	37
2.14	Influence of polyester fibre fineness on shear rigidity of their fabrics	38
2.15	Flexural rigidity of fabrics in warp direction	41
2.16	Flexural rigidity of fabrics in weft direction	41
2.17	Relationship between fabric shear rigidity and inter yarn porosity	42
2.18	Dependence of bending rigidity (B) and bending hysteresis (2HB) on warp sett	43
2.19	Dependence of bending rigidity (B) and bending hysteresis (2HB) on weft sett	44
2.20	Relationship between shear rigidity and crossover firmness factor	45

2.21	Relationship between shear rigidity and floating yarn factor	45
2.22	Effect of weave on fabric bending rigidity	46
3.1	CCI Tech single end sizing machine (Model: SS 565)	55
3.2	CCI Tech single end warping machine (Model: SW 550)	56
3.3	CCI Tech single rigid rapier loom (Model: SL 8900S)	57
3.4	A repeat unit of plain woven fabric	59
3.5	KES FB 2 bending tester	61
3.6	KES FB 1 shear tester	62
3.7	Tensile testing of fabric in (a) warp direction, (b) weft direction and (c) bias direction	62
3.8	Instron tensile tester	63
4.1	Bending behaviour of fabrics having the highest and the lowest bending rigidity	71
4.2	Shear behaviour of fabrics having the highest and the lowest shear rigidity	71
4.3	Fabric bending rigidity and areal density	74
4.4	Fabric shear rigidity and areal density	74
4.5	Effect of yarn count and fabric sett on bending rigidity of fabrics	78
4.6	Effect of yarn count and fabric sett on shear rigidity of fabrics	79
4.7	Effect of proportion of polyester and fabric sett on bending rigidity of fabrics	80
4.8	Effect of proportion of polyester and fabric sett on shear rigidity of fabrics	80
4.9	Bending rigidity of yarns for different proportion (wt. %) of polyester	81
4.10	Association between bending and shear rigidities of fabrics	82
5.1	Repeat unit of a plain weave	84
5.2	Types of float in woven fabrics	85

5.3	Schematic representation of different weaves	86
5.4	Bending rigidity of 100% cotton fabrics	91
5.5	Bending rigidity of 100% polyester fabrics	91
5.6	Shear rigidity of 100% cotton fabrics	92
5.7	Shear rigidity of 100% polyester fabrics	92
5.8	Bending rigidity and crossover firmness factor of 100% cotton fabrics	93
5.9	Shear rigidity and crossover firmness factor of 100% cotton fabrics	94
5.10	Bending rigidity and crossover firmness factor of 100% polyester fabrics	94
5.11	Shear rigidity and crossover firmness factor of 100% polyester fabrics	95
5.12	Bending rigidity and floating yarn factor of 100% cotton fabrics	96
5.13	Shear rigidity and floating yarn factor of 100% cotton fabrics	96
5.14	Bending rigidity and floating yarn factor of 100% polyester fabrics	97
5.15	Shear rigidity and floating yarn factor of 100% polyester fabrics	97
6.1	Plain woven fabric	100
6.2	Cross-sectional view of plain woven fabric	102
6.3	Repeat unit of plain woven	104
6.4	Repeat unit of 2/1 twill woven	106
6.5	Weave repeat with m number of interlacements and float over n number of threads	107
6.6	Deformation in a woven fabric during tensile testing	112
6.7	Calculated and experimental shear rigidities of woven fabrics	115
7.1	Scheme of manufacturing of woven fabrics having same areal density	118
7.2	Bending behaviour of fabrics having similar bending rigidity	122
7.3	Cross-section of a plain woven fabric	123

7.4	Shear behaviour of fabrics having similar bending rigidity	127
7.5	Shear rigidity in warp wise direction and number of interlacements (cotton fabrics)	130
7.6	Shear rigidity in warp wise direction and number of interlacements (polyester fabrics)	130
7.7	Shear rigidity in weft wise direction and number of interlacements (cotton fabrics)	131
7.8	Shear rigidity in weft wise direction and number of interlacements (polyester fabrics)	131
8.1	Desirability functions to (a) maximise; (b) minimise; (c) reach a target response	137
8.2	Individual desirability function diagram of (a) bending rigidity and (b) shear rigidity of woven fabric	140
8.3	Overall desirability as a function of (a) yarn count and fabric sett, (b) polyester proportion and fabric sett	142
8.4	Variable space of initial solutions	155
8.5	Pareto optimal front for bending rigidity and shear rigidity	155
8.6	Variable space for Pareto optimal solutions	156

LIST OF TABLES

Table no.	Table caption	Page no.
2.1	Calculated values of CFF and FYF	34
3.1	Details of yarn samples	54
3.2	Scouring parameters	58
4.1	Yarn and fabric parameters for square fabrics	66
4.2	Box and Behnken design plan	67
4.3	Fabric bending rigidity, shear rigidity, areal density and fractional cover	70
4.4	Regression coefficients of various terms of response surface equations	75
4.5	Response surface equations of bending and shear rigidities	77
5.1	Crossover firmness factor for different weaves	87
5.2	Floating yarn factor for different weaves	88
5.3	Constructional parameters of 100% cotton woven fabrics	89
5.4	Constructional parameters of 100% polyester woven fabrics	89
6.1	Crossover firmness factor of different weaves	109
6.2	Fabric constructional parameters and calculated value of shear rigidity	111
6.3	Experimental values of tensile modulus and shear rigidity of fabrics	114
6.4	Calculated and experimental values of fabric shear rigidities	114
7.1	Construction parameters (nominal) of fabrics	118
7.2	Actual thread density and areal density of cotton fabrics	120
7.3	Actual thread density and areal density of polyester fabrics	120
7.4	Bending rigidity (gf.cm ² /cm) of cotton fabrics in warp wise direction	121
7.5	Bending rigidity (gf.cm ² /cm) of polyester fabrics in warp wise direction	122
7.6	Bending rigidity (gf.cm ² /cm) of cotton fabrics in weft wise direction	125
7.7	Bending rigidity (gf.cm ² /cm) of polyester fabrics in weft wise direction	125

7.8	Shear rigidity (gf/cm.deg) of cotton fabrics in warp wise direction	127
7.9	Shear rigidity (gf/cm.deg) of polyester fabrics in warp wise direction	127
7.10	Shear rigidity (gf/cm.deg) of cotton fabrics in weft wise direction	129
7.11	Shear rigidity (gf/cm.deg) of polyester fabrics in weft wise direction	129
8.1	Response surface equations for bending and shear rigidities of woven fabric	135
8.2	Expressions of desirability functions for different goals	138
8.3	Boundaries and target values of different responses	139
8.4	Solutions of optimisation problem	141
8.5	Optimised and achieved values of objectives	143
8.6	Some selected Pareto optimal solutions	156
8.7	Pareto optimal and achieved values of objectives	157