

# **MECHANICS OF 1x1 RIB LOOP FORMATION ON A DIAL AND CYLINDER MACHINE**

*by*

**S. C. RAY**

**Department of Textile Technology**

*Submitted*

*in fulfilment of the requirements of the degree of*

**DOCTOR OF PHILOSOPHY**



**to the**

**INDIAN INSTITUTE OF TECHNOLOGY, DELHI**

**July, 1992**

## CERTIFICATE

This is to certify that the thesis entitled "MECHANICS OF 1x1 RIB LOOP FORMATION ON A DIAL AND CYLINDER MACHINE" being submitted by Mr. Sadhan Chandra Ray, to the Indian Institute of Technology, Delhi, for the award of the degree of DOCTOR OF PHILOSOPHY in Textile Technology, is a record of bonafide research work carried out by him. Mr. Sadhan Chandra Ray has worked under my guidance and supervision and fulfilled the requirements for the submission of the thesis.

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.

Dated: 22.07.1992



(P. K. Banerjee)  
Professor

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

## ACKNOWLEDGEMENT

I wish to express my deep sense of gratitude to Prof. P. K. Banerjee for his valuable guidance, untiring help, encouragement and keen interest throughout the course of this research work.

I express my sincere thanks to the Head, Department of Textile Technology, for his permission to carry out this research work as well as for his co-operation and encouragement.

I am thankful to the Principal and other faculty members of College of Textile Technology, Berhampore for extending their co-operation in order to get the sponsorship from the Govt. of West Bengal for carrying out this research programme.

I gratefully acknowledge the financial support provided for this research programme by the Ministry of Human Resource Development, Govt. of India under the Quality Improvement Programme.

I am also thankful to the Principal and other faculty members of Institute of Jute Technology, Calcutta for offering their moral support in writing the thesis.

I am grateful to Dr. Mantu Sarkar, Dr. Subrata Ghosh and Mr. Kaushik Saha for their assistance in learning computer programming.

I am also grateful to Dr. Bhaskar Bhattacharyya of Electrical Engineering Department and Mr. Niranjana Debnath of Centre for Biomedical Engineering for their assistance in setting-up of the measurement system.

I am thankful to Mr. Kedar N. Saxena of Textile Technology Department for his assistance in carrying out experimental works.

I am also thankful to the staff members of various Laboratories in the Textile Technology Department and Instrument Design Development Centre for their help and co-operation.

Thanks are due to Mr. Siddhartha Banerjee, Dr. Swadesh Sett, Mr. Ashok Karmakar, Mr. Prabal Mazumdar, Mr. Pradip Dey, Mr. Jaydeep Sensharma, Mr. Sanku Bose, Mr. Apurba Das, Dr. Indranil Talukdar, Dr. Arup Rakshit, Dr. Anjan Mukhopadhyay, Dr. Kashinath Bhowmik, Mr. Dhiraj Sinha, Mr. Sanjay Sadhukhan, Mr. Prabir Chatterjee, Mrs. Krishna Ghosh, Mrs. Nibedita Dutta, Mrs Shobha Bhowmik for their help and moral support during the period of my research work.

Finally, I offer my heartfelt thanks to my wife Arati and my daughter Aramita for their constant understanding and co-operation throughout the period of this research.

Dated: 22.7.92

*Sadhan Chandra Ray*  
(Sadhan Chandra Ray)

Dedicated

to

My Mother

## ABSTRACT

An investigation on the mechanics of 1x1 rib loop formation (movement of yarn and knitting elements as well as forces acting on them inside knitting zone) on a dial and cylinder machine is reported in this study.

The work methodology involved the following steps:

- i) observation of yarn movement around knitting elements inside knitting zone (KZ) at ultra low speed under different timings of knitting
- ii) identification of important factors affecting length of loop under different timings of knitting
- iii) development of model (computer programme) on loop formation process under synchronised (SYN) and 2 needle delayed (2 ND) timings
- iv) validation of the model by measuring loop length and needle butt-cam interaction force under actual conditions of knitting
- v) analysis of the behaviour of the modelled system

The important findings of the investigation are:

- i) Rib loop formation process is governed by the phenomenon called robbing back.
- ii) Rib loop is formed in multiple planes and the configuration of the loop arms changes in dynamic KZ.

- iii) The rate of yarn flow across knitting elements is lower in case of 2 ND timing than SYN timing. Moreover, the rate of change in length of loop arm is steadier in case of 2 ND timing as compared to SYN timing. This indicates a delicate treatment of yarn under 2 ND timing.
- iv) The developed model can predict loop length and yarn tension profile inside KZ for various combinations of input variables. However, the model, in general, slightly underestimates loop length (upto 9%). The cam force also tends to be underestimated at the point one needle pitch beyond cylinder knitting point (CKP) (upto 28%) and overestimated at CKP (upto 32%).
- v) Change in only relative position of the dial bed with respect to the cylinder bed (timing of knitting) can result in a wide range of loop length. Loop length varies in the range of 35 to 40% while timing is changed from SYN to 2 ND. Peak cam force also changes with change in timing.
- vi) Increase in input tension causes drop in length of cylinder and dial loops as well as final length of rib loop. However, the extent of drop depends on the combination of cylinder and dial stitch cam settings and timing of knitting. Cam force increases with increase in input tension.

- vii) Cylinder cam setting has direct effect on loop length and cam force irrespective of timing. However, the effect of dial cam setting on loop length and cam force is complex and depends on timing. The loop length may slightly increase, may remain same or even may decrease causing a tremendous rise in cam force as a result of increase in dial cam setting under 2 ND timing.
- viii) Yarn properties and dial height have significant effect on loop length and cam force. However, take down load has only marginal effect on loop length and cam force.
- ix) Under identical conditions of knitting, dial loop is smaller than cylinder loop under SYN timing whereas the reverse holds true under 2 ND timing.
- x) For constant loop length from various combinations of input variables, the relationship between the forces acting on CN and DN is linear under both SYN & 2 ND timings.
- xi) Sensitivity of the loop formation system falls with rising value of peak cam force inside KZ.
- xii) Considering knitting under identical conditions, the sensitivity of the system is lower and cam forces are higher under 2 ND timing as compared to SYN timing.

## CONTENTS

	Page
List of Notations	
List of Tables	
List of Figures	
CHAPTER I : INTRODUCTION	1
CHAPTER II : LITERATURE REVIEW	5
CHAPTER III: PRELIMINARY EXPERIMENTS	
3.1 Introduction	23
3.2 Study of motion of yarn and needles under quasi-static conditions	26
3.2.1 Approach	26
3.2.2 Experimental procedure	27
3.2.2.1 Machine particulars	27
3.2.2.2 Process variables	29
3.2.2.3 Technique of measurement of yarn and needle movement	29
3.2.2.4 Method of onservation of yarn and needle movement under quasi-static condition	30
3.2.2.5 Calculation of yarn displacement	30
3.2.2.6 Calculation of yarn speed	31
3.2.3 Results and discussions	31
3.2.3.1 Yarn displacement	31
3.2.3.2 Yarn speed	34
3.2.3.3 Observations on yarn movement and 1x1 rib loop formation	36
3.2.4 Conclusions	39
3.3 Study on the effect of some input variables on loop length	41
3.3.1 Approach	41
3.3.2 Experimental procedure	42
3.3.2.1 Machine particulars	42

3.3.2.2	Making fabric samples	42
3.3.2.3	Marking on loop arms inside KZ	42
3.3.2.4	Measurement of input tension	43
3.3.2.5	Determination of decrimping load	43
3.3.2.6	Measurement of marked & unroved loop lengths	44
3.3.2.7	Measurement of take down load	44
3.3.3	Results and discussions	46
3.3.4	Conclusions	53
CHAPTER IV : MODELLING OF 1x1 RIB LOOP FORMATION PROCESS		
4.1	Objectives	56
4.2	Geometry of the knitting zone (KZ)	56
4.2.1	The concepts	57
4.2.2	Knitting zone of a rib machine (dial and cylinder)	57
4.2.3	Equations of stitch cam profiles	59
4.2.3.1	Equations of cylinder stitch cam profiles	60
4.2.3.2	Equations of dial stitch cam profiles	61
4.2.4	Initial geometry	61
4.2.4.1	Stages in initial yarn-needle contact geometry	62
4.2.4.2	Initial contact between cylinder needle and yarn	63
4.2.4.3	Initial contact between dial needle and yarn	64
4.3	Wrap angles	64
4.3.1	Expression of wrap angle around cylinder needle	65
4.3.2	Expression of wrap angle around dial needle	65
4.3.3	Expression of wrap angles at cylinder and dial bed verges	66
4.3.4	Wrap at feeding hole	67

4.4	Formulae for expressing the instantaneous length of rib loop on dial and cylinder machine	68
4.4.1	Instantaneous loop arm configuration	69
4.4.1.1	Synchronised (SYN) timing	69
4.4.1.2	2 Needle delayed (ND) timing	71
4.4.2	Derivation of formulae	72
4.4.2.1	Assumptions	72
4.4.2.2	Formulae of instantaneous length of loop under SYN timing	72
4.4.2.2.1	Case I	73
4.4.2.2.2	Case II.A	73
4.4.2.2.3	Case III	74
4.4.2.2.4	Case IV.A	74
4.4.2.2.5	Case IV.B	74
4.4.2.2.6	Case V	75
4.4.2.2.7	Case VI	76
4.4.2.3	Formulae of instantaneous length of loop under 2 ND timing	76
4.4.2.3.1	Case II.C	77
4.4.3	Theoretical length of rib loop	77
4.4.3.1	Generalised co-ordinates of needles at knitting points	78
4.4.3.1.1	SYN timing	78
4.4.3.1.2	2 ND timing	78
4.4.3.2	Theoretical length of rib loop under SYN timing	79
4.4.3.2.1	Theoretical length at CKP	79
4.4.3.2.2	Theoretical length at DKP	79
4.4.3.3	Theoretical length of rib loop under 2 ND timing	80
4.4.3.3.1	Theoretical length at CKP	80

4.4.3.3.2	Theoretical length at DKP	80
4.5	Effect of cast off loop on loop formation	80
4.5.1	Nature of interaction between cast off loop and new loops	80
4.5.2	Components of force in cast off loop	82
4.5.2.1	Assumptions	82
4.5.2.2	Derivation of expressions of force components	82
4.5.3	Contribution of forces ( $q_A$ & $q_N$ ) towards tension building in new loop arms	84
4.6	Yarn tension and knitting force	85
4.6.1	Needle movement and needle force	85
4.6.2	Derivation of needle forces	87
4.6.2.1	Force on cylinder needle ( $CN_1$ ) hook	87
4.6.2.1.1	CN situated above CBV (Case I & II)	87
4.6.2.1.1.1	Neighbouring DN hooks are yet to catch yarn (Case I)	87
4.6.2.1.1.2	One of the neighbouring DN has caught yarn	87
4.6.2.1.2	CN hook situated below CBV	88
4.6.2.2	Forces on dial needle ( $DN_1$ )	88
4.6.2.2.1	DN hook is yet to catch yarn (Case I)	88
4.6.2.2.2	DN hook has caught yarn but is yet to reach DBV	88
4.6.2.2.2.1	One of the neighbouring CN ( $CN_1$ ) is situated above CBV (Case II)	88
4.6.2.2.2.2	Both the neighbouring CNs are situated below CBV	89
4.6.2.2.3	DN hook is situated below DBV	89
4.6.3	Needle butt-cam force	89
4.7	Formulation of the model	91
4.7.1	Introduction	91
4.7.1.1	Assumptions	92

4.7.2	Determination of yarn tension and yarn length due to change in co-ordinates of the needles	93
4.7.2.1	Co-ordinates of the needles inside KZ	93
4.7.2.2	New geometrical length	94
4.7.2.3	Change in yarn tension due to change in geometric length	95
4.7.2.4	Final length of yarn segment	96
4.7.3	Method of determination of final length of loop and tension profile inside KZ	96
4.7.3.1	Generalised formulae	96
4.7.3.1.1	For forward flow	97
4.7.3.1.2	For backward flow	97
4.7.3.2	The approach	98
4.7.3.2.1	The first approximation	98
4.7.3.2.2	Iteration for final loop length	107
CHAPTER V :	VALIDATION OF THE MODEL	
5.1	Approach	109
5.2	Coding	110
5.3	Measurement techniques	122
5.3.1	Measurement of resistance to needle movement inside trick	122
5.3.2	Measurement of yarn tensile properties	123
5.3.3	Measurement of yarn thickness	123
5.3.4	Measurement of yarn bending rigidity	124
5.3.5	Measurement of yarn unevenness	124
5.3.6	Measurement of coefficient of yarn to needle friction	124
5.3.7	Measurement of coefficient of yarn to yarn friction	125
5.4	Experiments on loop length	126
5.4.1	Experimental procedure	126

5.4.2	Results and discussions	127
5.4.2.1	Loop length under SYN timing	131
5.4.2.2	Loop length under 2 ND timing	136
5.4.3	Summary	143
5.5	Experiments on yarn tension inside KZ	146
5.5.1	Experimental set-up	146
5.5.1.1	The outline	146
5.5.1.2	Quartz Force Link	148
5.5.1.2.1	Description of the Quartz Force Link	148
5.5.1.2.2	Operating principle	148
5.5.1.3	Description of the Charge Amplifier	148
5.5.1.4	Modifications on knitting machine	150
5.5.1.5	Installation of the experimental set-up	151
5.5.1.5.1	Transducer	151
5.5.1.5.2	Recording system	151
5.5.1.5.3	Charge Amplifier adjustments	154
5.5.1.5.4	Testing	154
5.5.1.5.4.1	A D C	154
5.5.1.5.4.2	Transducer and Charge Amplifier	154
5.5.2	Force measuring experiments	156
5.5.3	Results and discussions	158
5.5.4	Summary	170
5.6	General conclusions	172
CHAPTER VI :	ANALYSIS OF THE MODELLED SYSTEM	
6.1	Introduction	175
6.2	Approach	175
6.3	Discussion of the theoretical results	177
6.3.1	Effect of input variables on output variables	177
6.3.1.1	SYN timing	177

6.3.1.1.1	Effect of input tension	178
6.3.1.1.2	Effect of cam settings	182
6.3.1.1.3	Effect of yarn relative rigidity and coefficient of yarn-needle friction	184
6.3.1.1.4	Effect of stitch cam angles	185
6.3.1.1.5	Effect of dial height	185
6.3.1.1.6	Effect of machine gauge	185
6.3.1.1.7	Effect of resistance to needle movement inside trick	185
6.3.1.1.8	Effect of take down load	186
6.3.1.2	2 ND timing	186
6.3.1.2.1	Effect of input tension	186
6.3.1.2.2	Effect of cam settings	190
6.3.1.2.3	Effect of input tension and cam settings on peak needle forces	192
6.3.1.2.4	Effect of yarn relative rigidity and coefficient of yarn-needle friction	194
6.3.1.2.5	Effect of stitch cam angles	194
6.3.1.2.6	Effect of dial height	195
6.3.1.2.7	Effect of machine gauge	195
6.3.1.2.8	Effect of resistance to needle movement inside trick	196
6.3.1.2.9	Effect of take down load	196
6.3.1.3	Theoretical length of loop	196
6.3.1.4	Peak yarn forces on needles inside KZ	198
6.3.1.5	Summary	199
6.3.2	Composition and formation of 1x1 rib loop	204
6.3.2.1	Theoretical length of cylinder and dial loops	204
6.3.2.2	Build up of loop arms	205
6.3.2.3	Yarn tension profile inside knitting zone	216
6.3.2.4	Summary	219

CHAPTER VII :	FURTHER EXPERIMENTS UNDER DELAYED TIMINGS	
7.1	Purpose	223
7.2	Approach	223
7.3	Discussion on the results of loop length	224
7.3.1	1 ND timing	224
7.3.2	3 ND timing	224
7.3.3	5 ND timing	226
7.4	Discussion on the results of cam force	226
7.5	Summary	230
7.5.1	Findings under 1 ND, 3 ND and 5 ND timings	230
7.5.2	Comparision of the results obtained under 1 ND, 3 ND and 5 ND timings with those under SYN and 2 ND timings	232
CHAPTER VIII :	SUMMARY AND CONCLUSIONS	237
CHAPTER IX :	SUGGESTATION FOR FURTHER WORK	246
	BIBLIOGRAPHY	248
	APPENDICES :	
	Appendix 1	253
	Appendix 2	254
	Appendix 3	255
	Appendix 4	255
	Appendix 5	256
	Appendix 6	257
	Appendix 7	258
	Appendix 8	260
	Appendix 9	261
	Appendix 10	262
	Appendix 11	264
	Appendix 12	275
	BIO-DATA OF THE AUTHOR	288