CHAPTER III

EXPERIMENTAL WORK

3.0 Introduction

The properties of mechanical textured yarns in relation to structure and methods of characterizing the structure of mechanical-bulk yarn have been reported by Sen and Wray[1]. However, no details or analysis has been yet reported on the method of production, structural geometry of mechanical crimp textured yarns and its bearing on structure related properties like bulk, degree of crimpiness, stability of the crimp, mechanical properties etc. So the major focus of the present study has been centered not only on the development of innovative system of texturising but also identifying the structure of newly engineered yarn. Based on its structural geometry correct methods and standards for the evaluation of product yarn quality-parameters are realised.

3.1 Methodology:

Methodology of experimentation adopted in the present work has been divided into three phases, viz;

Phase: I – Fabrication of the prototype model machine (lab apparatus) by identifying suitable machine components for the production of desired innovative textured yarn.

Phase: II - Carrying out the pilot trials for finalized setting of the machine to get the desired product-yarn. The structural geometry of this newly designed product has been studied. Based on its structural characteristics suitable methods and standards of evaluation have been derived.

<u>Phase: III</u> - The impact of various process-parameters and material-parameters on the structure and quality of newly engineered yarn has been diagnosed.

<u>Phase: IV</u> - Stability of newly acquired structure against the stresses imposed during weaving and finishing is of prime importance for any textured yarn. Even latent property like bulk also decisive for the comfort becomes prominent only after wet treatment. So the performance of innovative yarn has been evaluated in terms of its major texturising properties, and mechanical properties.

<u>Phase: V</u> - Cost effectiveness of newly designed product facilitates in locating the position of new process in the world of texturising. In the absence of shop floor production record, actual status is difficult to derive. Thereby comparative study of cost effectiveness of lab model machine of new system with shop floor machineries of commercially successful systems has been done.

<u>PHASE: I</u>

3.1.1 Development/ Fabrication of the Model Machine for Innovative Texturising.

The design concept adopted for mechanical texturising is as follows:

Design Concept:

"Pre twisted Fully Drawn flat multifilament yarn has been subjected to the higher false twisting (depending on yarn fineness) action under the condition of underfeed. The torque caused due to high level of false twisting, forces the filaments to follow helical path at a certain angle (depends on magnitude of twist and denier per filament) to the filament yarn longitudinal axis. Internal stresses arising in single filaments tend to bent the filament and take the shape of spatial helical spring. After the yarn has passed through the false twisting unit, the initial twist would reassert itself and lock the already formed crimpy convolutions in position".

Based on this design concept an apparatus working on the concept of mechanical bulking was modified for the present experimentation. Keeping in mind difference in working of newly derived concept and mechanical bulking apparatus various important machine components were identified. These components as per the ease of availability were either procured or else fabricated. Experimentally their success or failure in producing the targeted product has been checked. A schematic diagram of final lab set up used for the production of mechanical crimp textured yarn is shown in figure 3.1. It consists of four basic sections, viz; i) Pre twisting zone, ii) Feeding zone, iii) False-twisting zone or Bulking-zone and iv) Delivery and Winding zone.

3.1.1.1 Pre-twisting zone:

This section is designed to impart desired level of real-twist to the parent yarn. This twist is used for locking newly attained crimpy configuration on texturising. So this section is composed of twister along-with suitable guide. Twister speed must be regulated to deal with different pre-twist level required for constant delivery speed of the machine. In order to ensure uniform twist distribution at pre-twisting zone, positive take-up device is required for constant yarn delivery from the pre-twisting zone without causing any undue slippage.

Based on these needs defined for pre-twisting zone, various options of machine components of this zone, viz; twister, guide, take up device (as per described in section-II) were checked for their feasibility. Brief mention about these experimental-trials conducted has been given. Based on their out-come machine components for the lab apparatus has been then finalized.

Pre-twister

'Higher rate of twist insertion at half the speed of the twisting media can economies the product.'- was the basic thought kept in mind while selecting two for one twister as a pre-twisting media for lab apparatus. North and the south poles of the magnet on the selected two for one twister pot have been set facing opposite poles of the stationary permanent magnet (figure 3.2) thereby prevent undue rotation of pot along with the driving disk.

First trial was made with two for one twister used for the twisting of cotton yarn having aluminum protection pot of 197 mm diameter [figure 3.3 (a)].

Figure 3.1 (a) Mechanical-Crimp Texturising Apparatus.

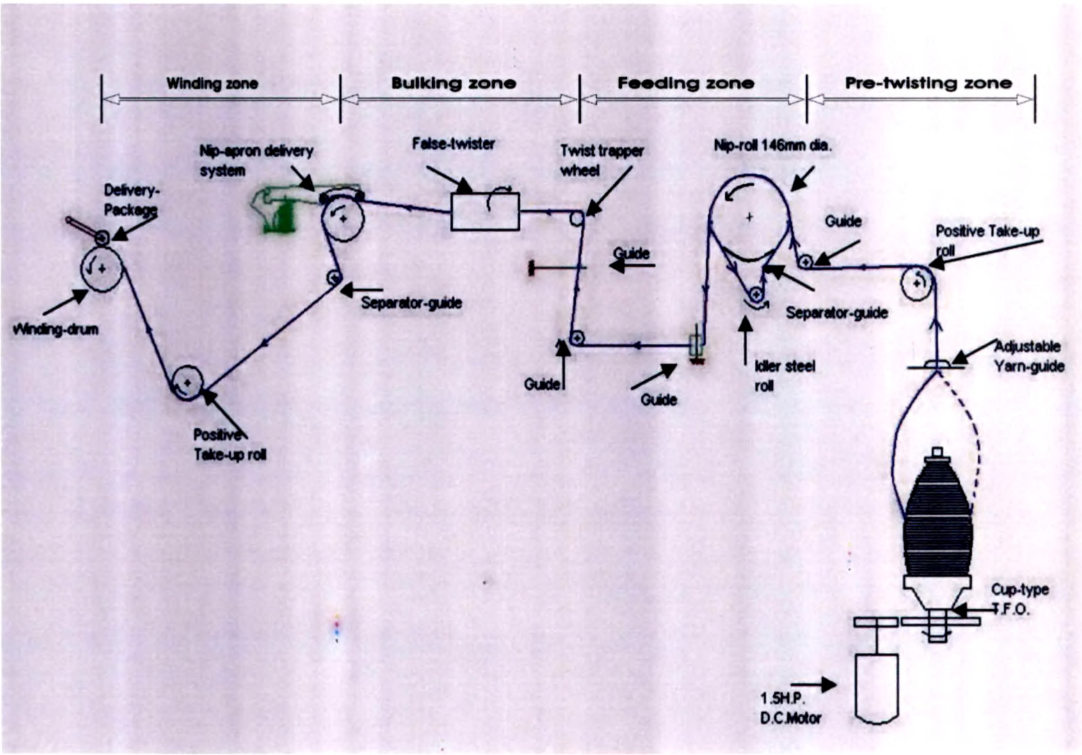


Figure 3.2 Magnetic control on protection pot of T.F.O.

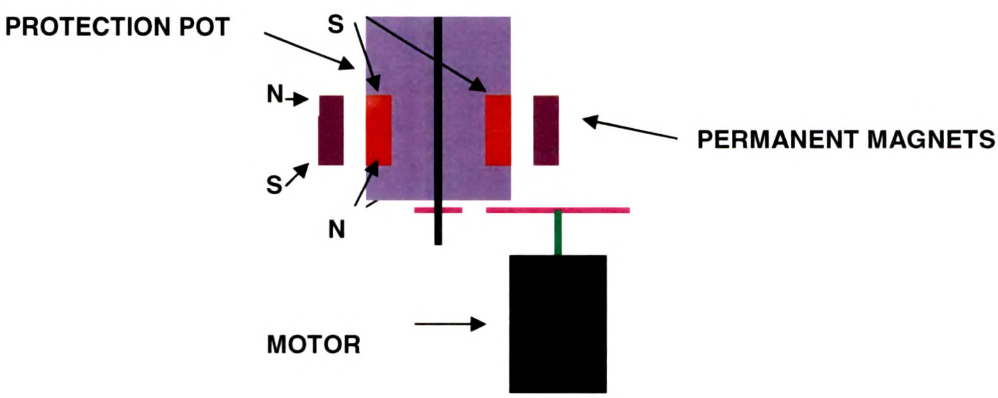
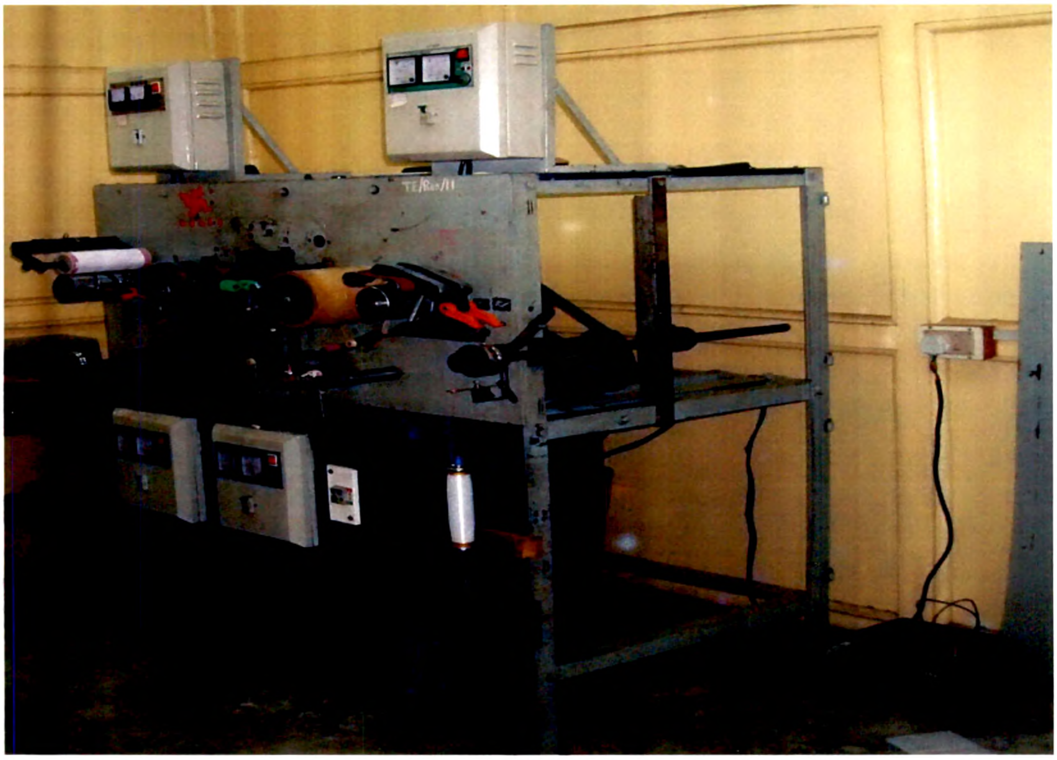
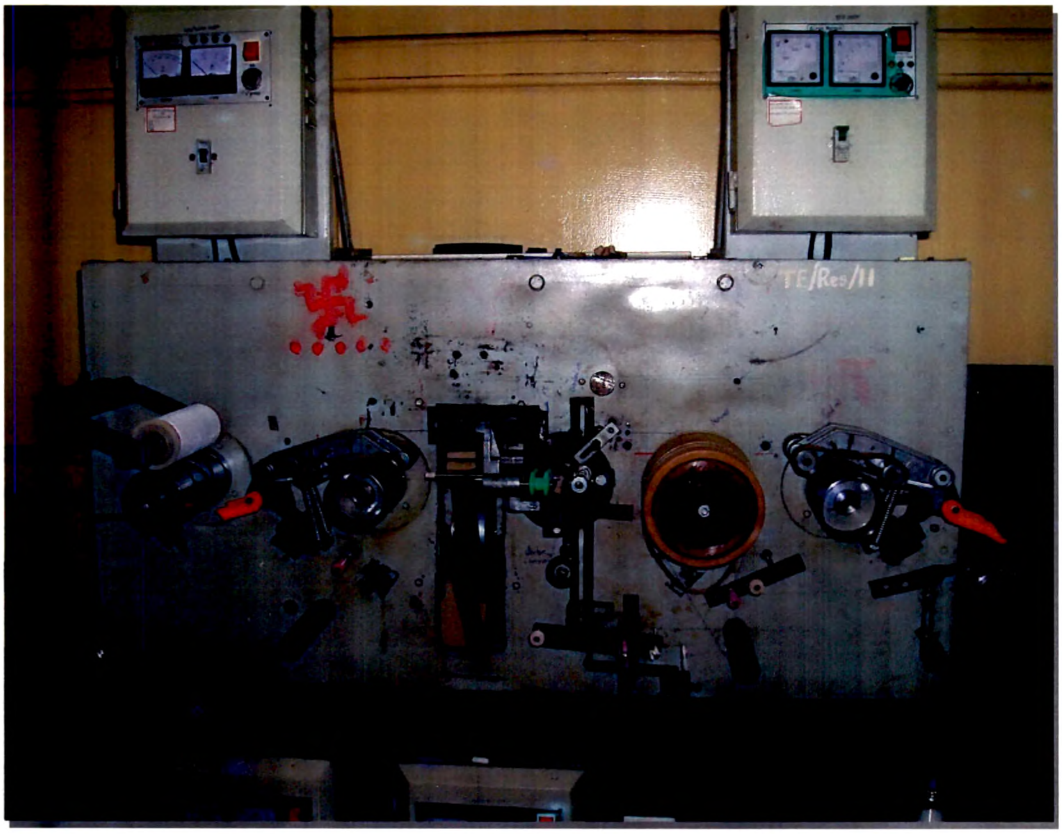


Figure 3.1 (b) Photographs of Mechanical Crimp Texturising Machine.

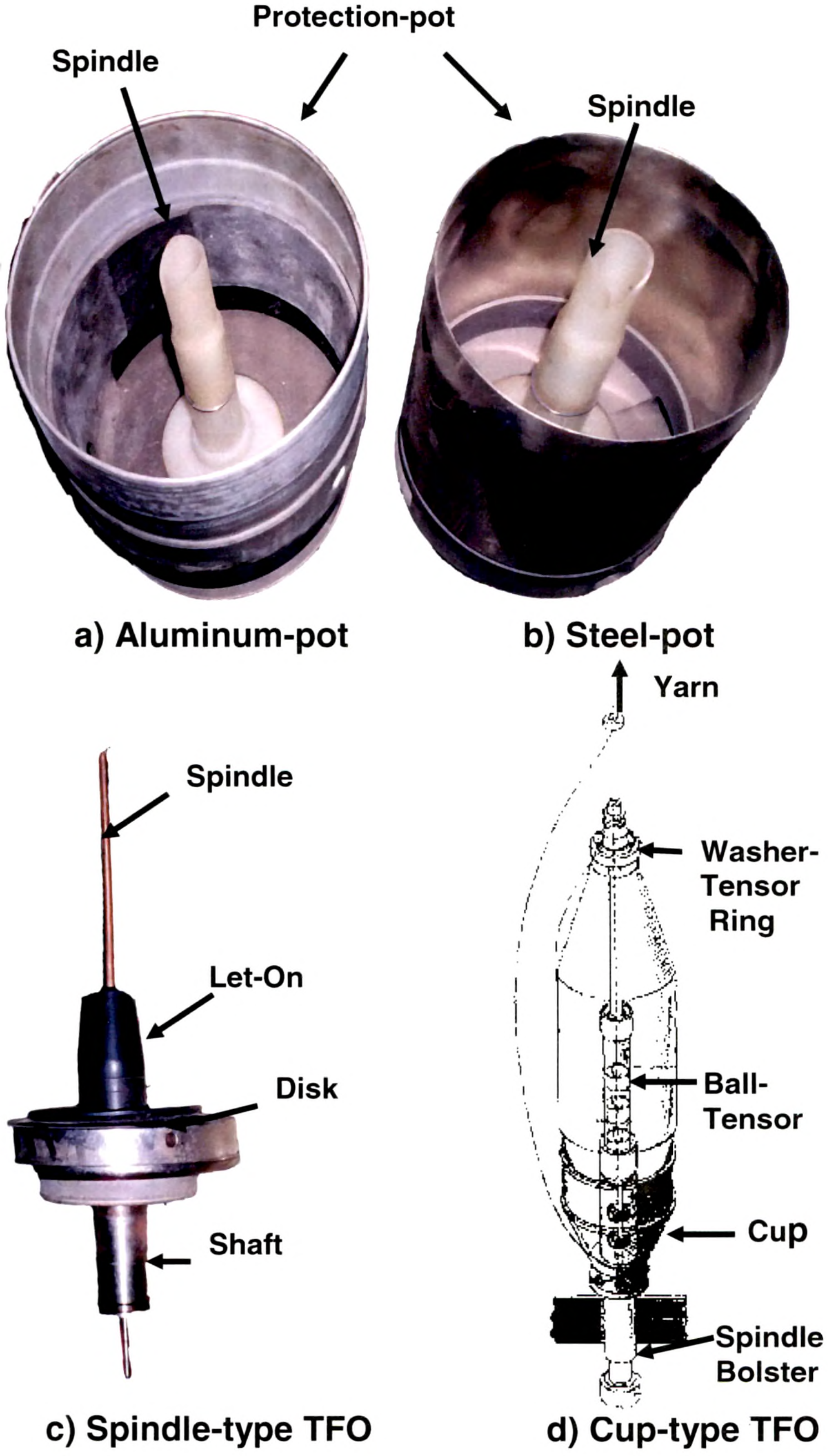




Twisting of fully drawn multifilament polyester yarn with this set-up had ended up with the fusing or fraying-off the filament and excessive end-breaks, resulted in poor yarn quality. Suspecting rough surface of the pot responsible for yarn damage, it was smoothen out by rubbing well with waterproof emery paper (E4 150) along with little water for eliminating tight spots and then scrubbed well with the chalk powder. This had made its surface smooth, but still filaments get frayed off at the top edge of the protection pot.

So to overcome this problem it was decided to go for the fabrication of the stainlesteel protection pot [figure 3.3 (b)]. This had allowed in overcoming the problem of fraying off of filaments caused due to rubbing with outer rough surface as in the previous case. Still higher end-breaks were encountered due to bigger balloon formation owing to big protection-pot, led the search towards smaller size pot or else elimination of pot. Spindle-type twister [figure 3.3 (c)] was employed next in sequence. But it required use of heavy large package, thereby ended the trial in failure due to uncontrolled vibrations. Cup type two for one twister of 65mm diameter [figure 3.3 (d)], extensively used for twisting/doubling filament yarns at faster rate in synthetic industries was the next search in sequence. It had given successful twisting of multifilament without causing any undue damage to yarn. Provision of ball-tensor of different weight had facilitated in controlling balloon size for supply yarn with different fineness, thereby better yarn tension control during twisting. While washer tension ring had given control on unwinding tension. Thus it was found suitable pre-twisting media for ensured twist transfer at high speed with minute settings to deal with different type and fineness of yarns.

Figure 3.3 Types of Two for One twisters used



Aluminum cheese tube of 32mm diameter and 220mm length, suitable for finalized cup-type two for one twister was used as supply package. Assemble-wind package of 55 mm diameter has been built up on winder (figure 3.4) from the parent yarn chosen for texturising. Provision of adjustable spring loaded tensioner at assembly winder had allowed uniform building of package under constant tension.

Adjustable Guide

Higher rotational speed of two for one twister had resulted in the formation of balloon. This was adding to yarn tension. In order to control balloon tension initially balloon control ring was used between aluminum protection pot and adjustable self threading guide [figure 3.5 (a)]. However cup type two for one twister has been provided with ball-tensor, an inbuilt balloon control system. Perfect alignment with spindle has been achieved with an adjustable porcelain guide [figure 3.5 (b)], capable of making widthwise and height wise movements. Thus consistency of balloon tension was achieved with cup type twister.

Drive to Two for One Twister

Separate D.C.Motor (0.5 H.P., 3000 rpm, 2.6 Amp.) along with the speed regulator system was used to drive two for one twister (figure 3.6) in the original set-up. Twister's speed can be well regulated to get desired pre-twist level at established delivery rate. System was found sufficient enough to drive two for one twister without slippage at desired speed with new set up also, thereby kept unaltered.

Figure 3.4 Assembly Winder for Filament Yarns.

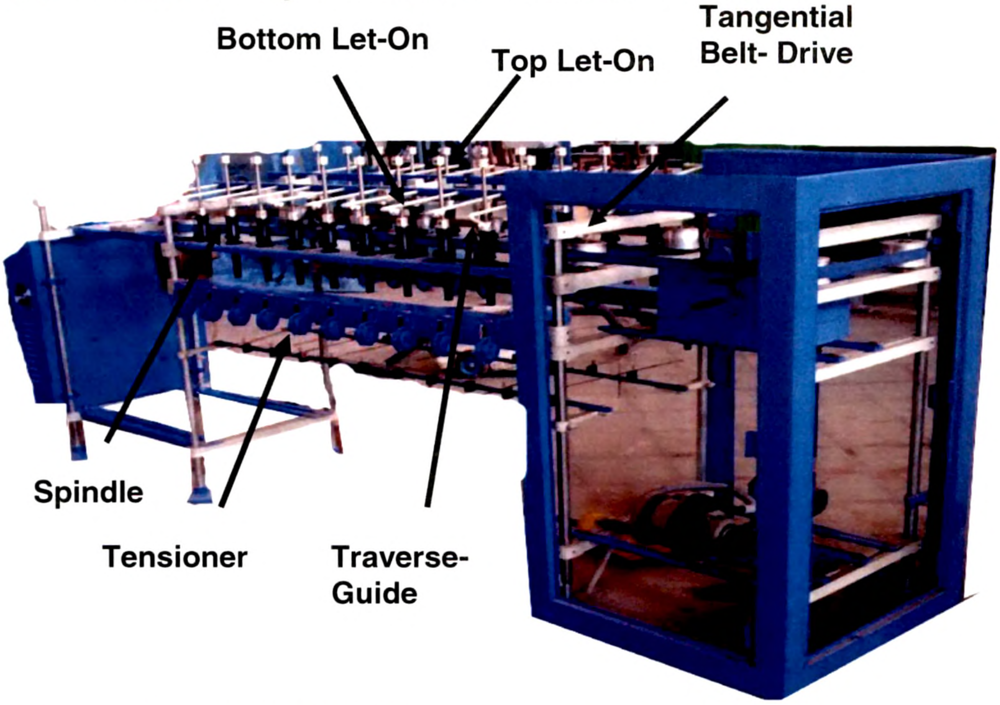
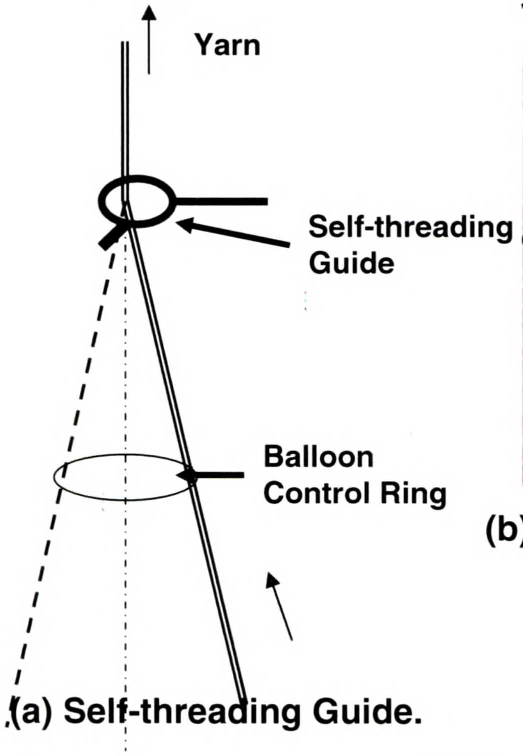
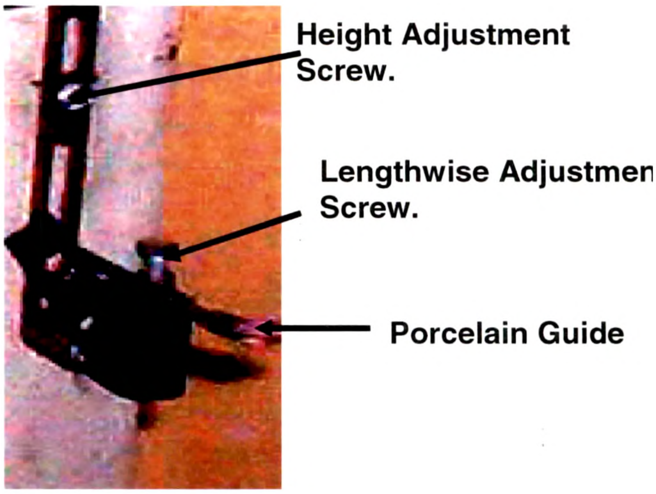


Figure 3.5 Yarn Guides.

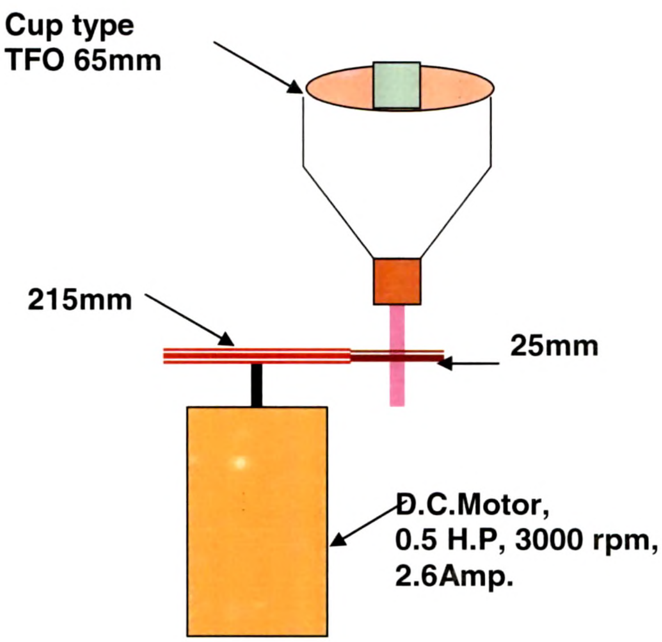


(a) Self-threading Guide.



(b) Adjustable Porcelain-guide.

Figure 3.6 Drive System for Two for one Twister.



3.1.1.2 Feeding Zone

This section is designed to feed the twisted parent yarn at constant rate under a constant tension to the bulking zone. Speed of the feed roll has also an influence on amount of pre-twist inserted to the parent yarn by two for one twister.

Original set up was using idler roll feeding system along with stainlesteel positively driven take-up roll system [figure 3.7 (a)]. Steel take-up roll was used before feed rolls to withdraw yarn from pre-twisting zone at constant rate to ensure uniform distribution of twist and bring the yarn from vertical to horizontal plane of bulking zone. Highly polished surface of steel roller was unable it to control constant rate of withdrawal however capable of preventing yarn damage under high tension and speed. So it was replaced by positive take up roll [figure 3.7 (b)] in new system.

Figure 3.7 (a): Feed System on Mechanical-Bulking.

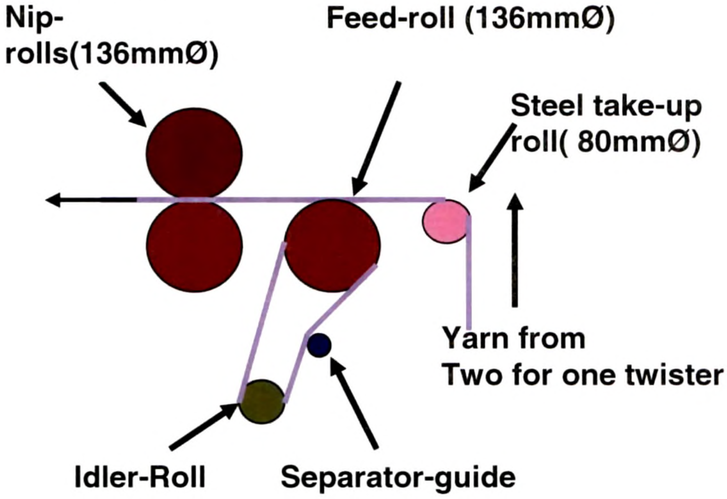
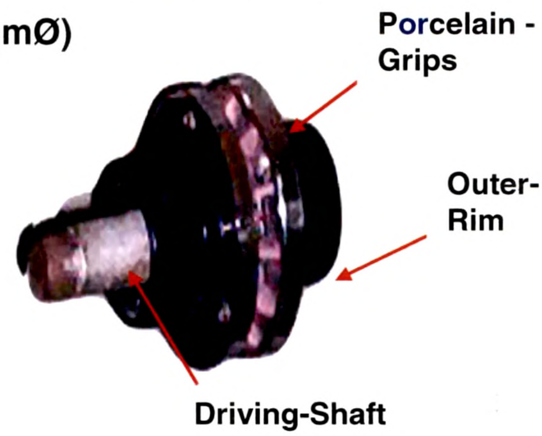


Figure 3.7 (b) Positive Take-up roll

(80mmØ)



It has two outer rims separated by number of closely spaced porcelain-grips arranged in zigzag fashion, thereby ensures positive grip on the yarn at the point of withdrawal. This was driven positively from feed roll via chain and sprocket system [figure 3.8 (b)] with same speed to avoid undue stretch or slackness of the feed material, likely to introduce variations in the product. As a consequence of these it became possible to withdraw yarn at constant rate without causing undue slippage from supply package and feed it to the nip roll feed system under constant tension.

Three to four wraps had been taken around feed roll, idler-roll and separator guide to regulate feed under the condition of over feed for mechanical-bulking on the original model machine. Even this feeding system was incorporated with additional nip roll feeding device [figure 3.7 (a)] to control balloon geometry during bulking. Since for the innovative concept yarn has been under fed, additional nip-roll feed control became unnecessary. So it was eliminated from the set-up. Idler roll feed system alone was found efficient enough to regulate feed for new concept. Only number of wraps had been varied for yarns with different fineness and strength. Thus end breaks were controlled caused due to undue rise in yarn tension.

Mechanical-bulking is dealing with the over-feed of the yarn. So, feed section and delivery section were driven from the separate motors and provided with independent speed regulators to set up different levels of over-feed [figure 3.8 (a)]. While mechanical crimp texturising is working with under feed of the yarn and constant extension principle has been adopted to set up and maintain consistency of under feed. So, separate drive of the feed roll and delivery roll were merged together [figure 3.8 (b)]. Thus from one single D.C. motor (0.5 H.P.) three parts, viz; take-up roll, feed roll and delivery roll are driven in new drive set up [figure 3.8 (b)]. By varying change pulley diameter in the drive, percent under feed of the supply yarn was set. Amount of under feed was set up to reduce ductility of the product yarn and mainly dependent on the percent breaking extension value of the parent yarn. Speed regulator was provided to vary feed rate as well as delivery rate as per pre-twist/ false-twist level required. Tangential belt drive has replaced original v-belt drive to deal with the longer span of drive transmission without slippage.

Figure 3.8 (a) Drive set up of Mechanical-Bulking Apparatus.

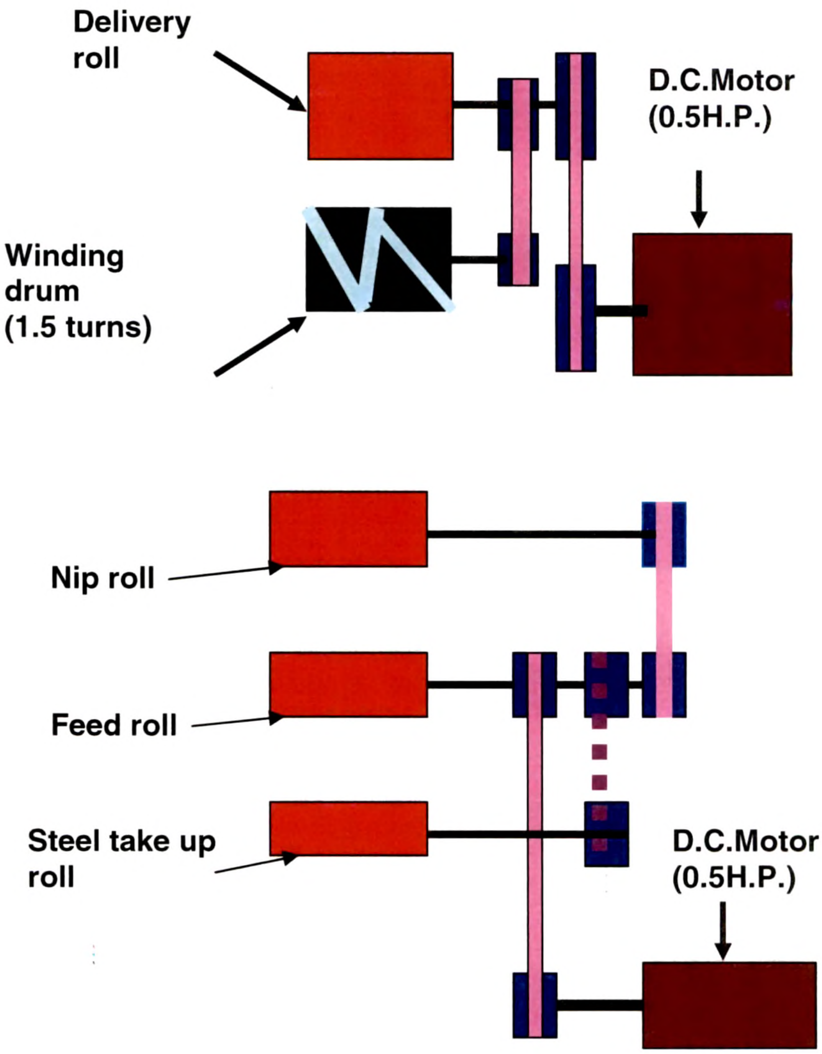
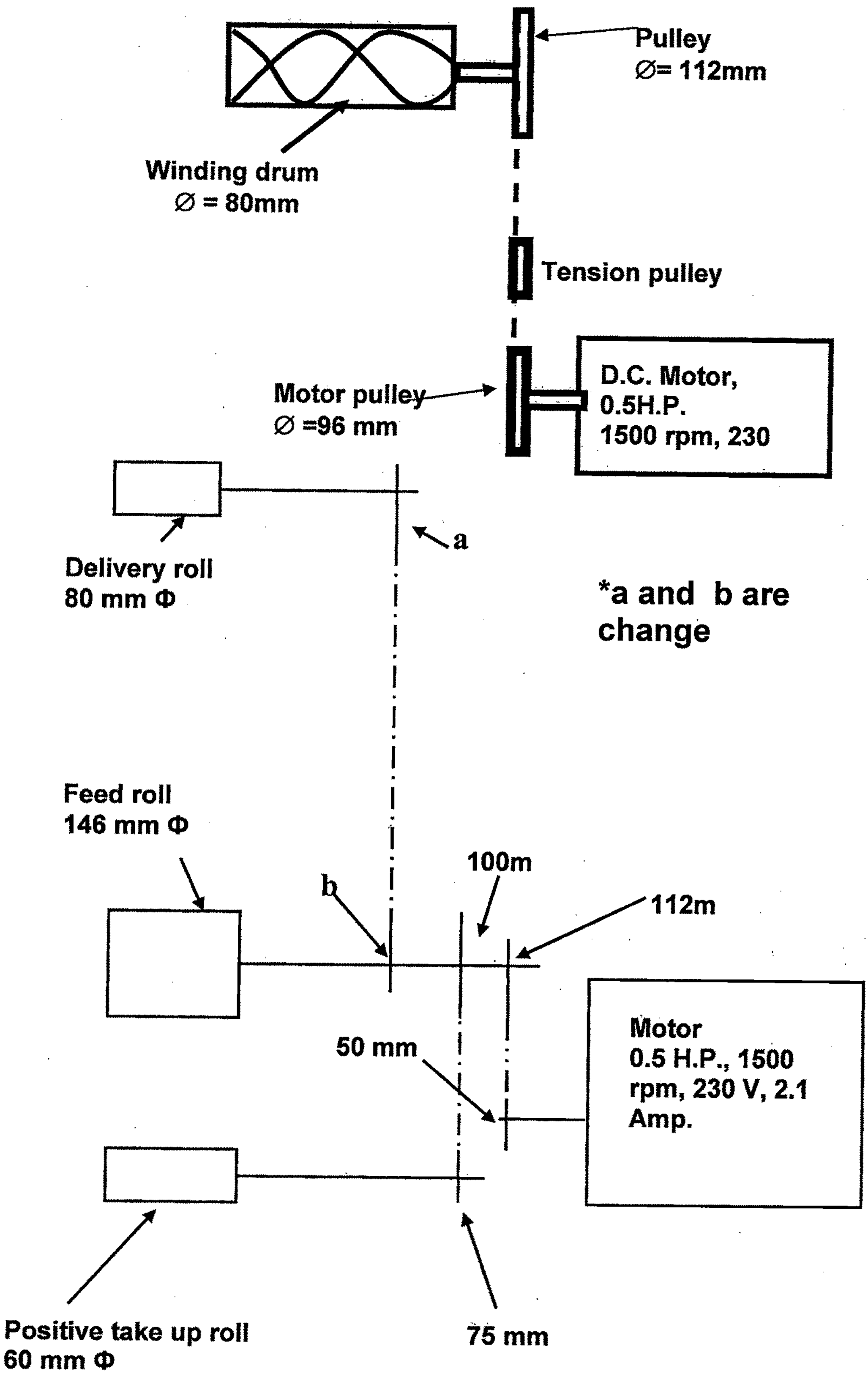


Figure 3.8 (b) Drive set up of Mechanical Crimp-Texturising Apparatus.

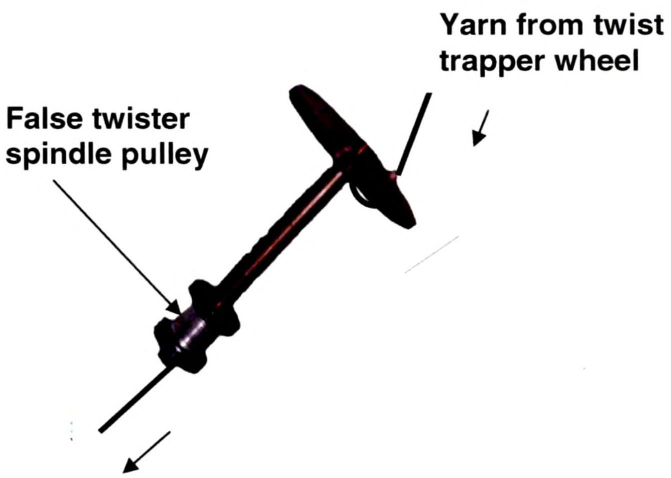


3.1.1.3 False-Twisting Zone

This zone is also known as mechanical bulking zone. Bulking has been imparted to the flat feeder yarn by false-twisting media only in both the system. So, false-twister was remained as an integral part of the apparatus, only its type has been changed as per the demand of the process.

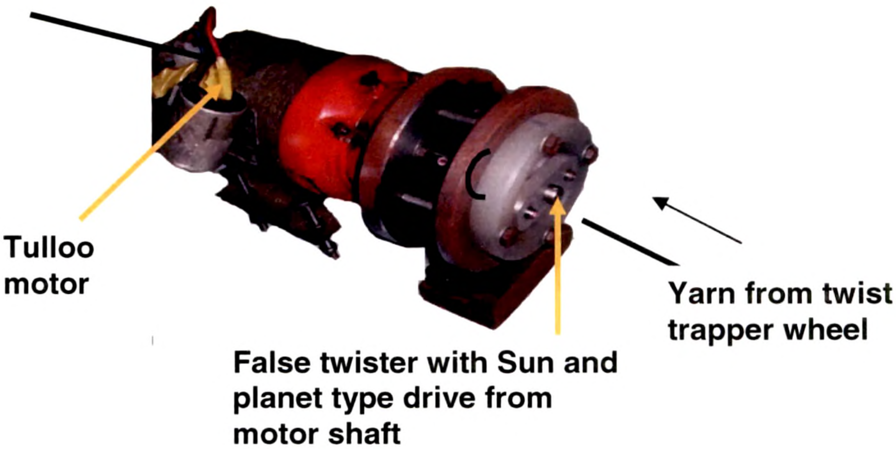
Fabricated bush type friction twister was used on the mechanical bulking apparatus [figure 3.9 (a)]. However yarn was underfed for mechanical crimp texturising, but still precision of twist value was not maintained due to slippage. This was resulted in the increased bulk variation for the product yarn. Increased abrasion between yarn and twisting surface at higher tension had also adversely affected yarn appearance due to increased hairiness.

Figure 3.9 (a) Fabricated Bush type False-twister.



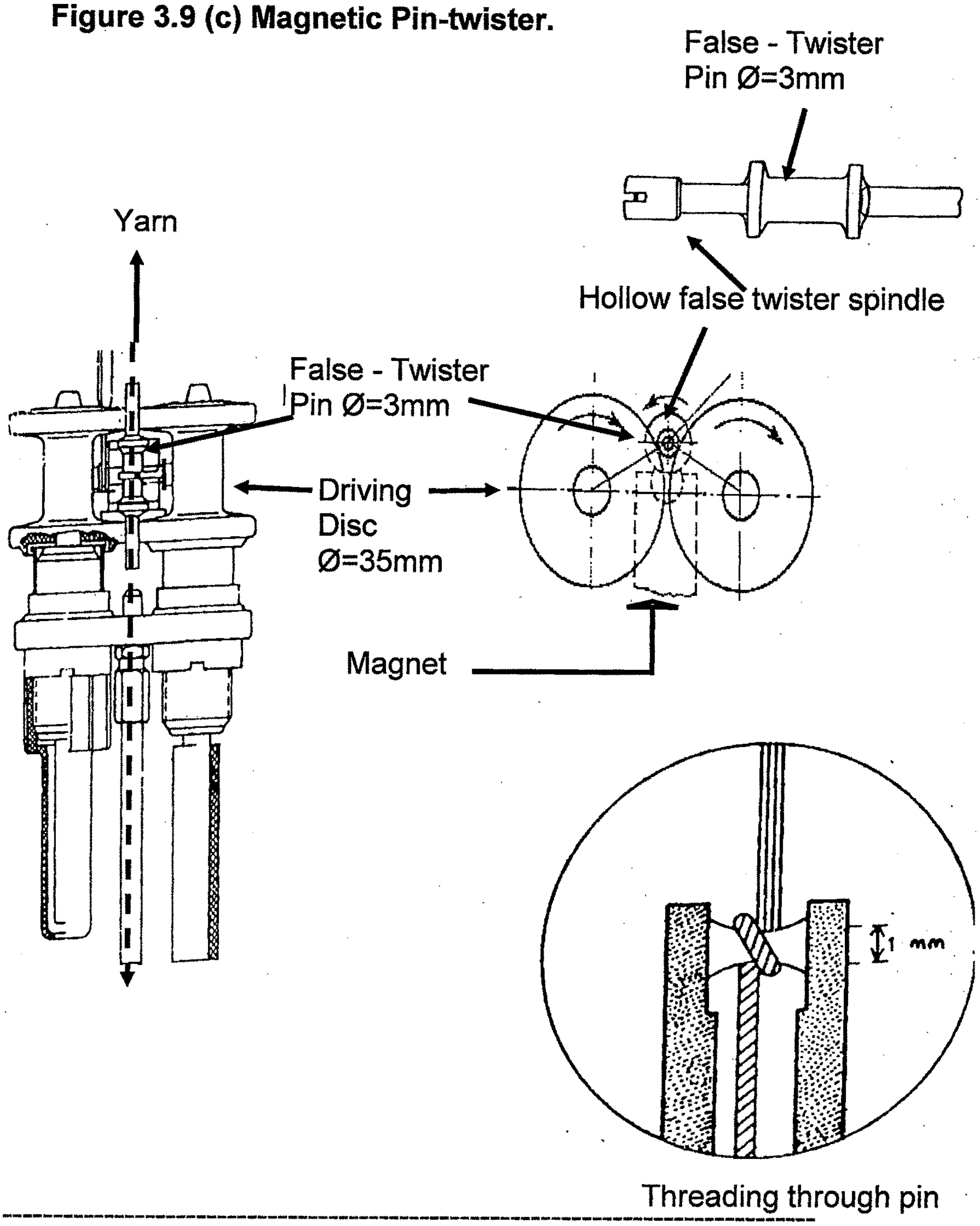
Gaining higher level of twist for slow speed of twister had prompted to fabricate one more bush type twister for experimentation. In this twister yarn tube was driven positively like a sun and planet gearing directly from the motor shaft [figure 3.9 (a)]. Lightweight small "Tulloo" motor was used for this purpose and solid motor shaft was made hollow so as to perform dual role of driver as well as yarn transfer tube. The system was expected to attain higher false-twister speed at reduced friction. But this trial was also not met to success due to complication in threading through hollow motor shaft. However enough precision had taken in finishing inner surface of hollow shaft, yarn during its passage through hollow tube met with increased hairiness. Still exact input twist calculation from the drive was difficult due to slippage.

Figure 3.9 (b) Fabricated Bush type False- twister with Sun and Planet type drive from motor shaft



Finally negative mode of friction-twisting was replaced by positive mode of magnetic pin twister for newly designed apparatus [figure 3.9(c)]. This change has ensured correct input of twist as per calculated and set value from drive. Thereby outcome product was found more uniform in its crimpiness. However noise level has been increased.

Figure 3.9 (c) Magnetic Pin-twister.



Surface drive was used on mechanical bulking apparatus for bush type false-twister [figure 3.10 (a)]. But for magnetic pin twister it was adding slippage and wear at high speed. So, surface drive was replaced by belt and pulley drive [figure 3.10 (b)].

Figure 3.10 (a) Drive to Bush type false-twister on Mechanical-Bulking Apparatus.

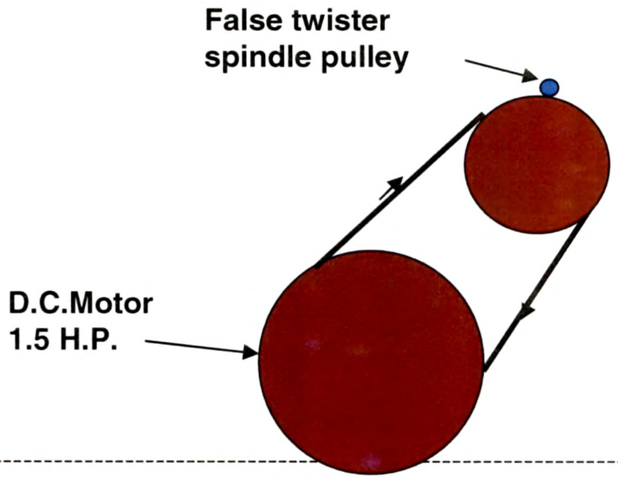
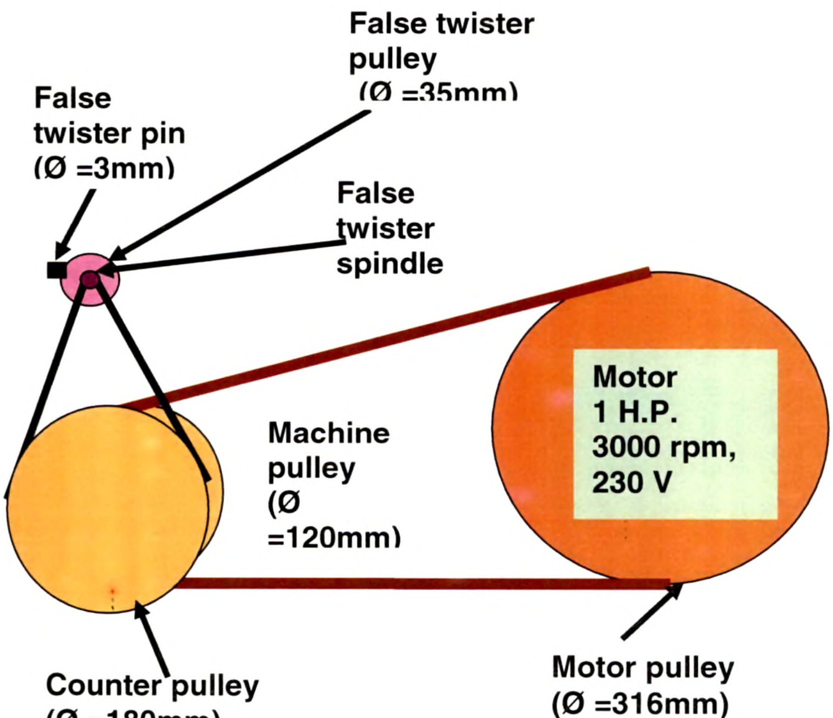


Figure 3.10(b) Drive for Magnetic pin type False-twister on Mechanical Crimp Texturising Apparatus



Yarn guides and twist trapper wheel were the other additional constituents defined for this section on new apparatus. Porcelain guides were used to guide yarn between feed roll to the twist trapper wheel (figure 3.11). Twist trapper wheel was a stainless steel wheel of 18mm diameter rotating freely around its own axis due to yarn pull. Its top outer edge is aligned with the centre of false twister pin. Its function is to prevent twist inserted by false-twister, from passing beyond this point. One turn of yarn is wrapped around to assure complete twist trapping. Thus false-twist magnitude during crimp texturising have been defined as ratio of number of turns inserted by the false-twister to that of bulking zone length. Bulking zone length refers to the centre to centre distance between twist trapper wheel and twist trapper pin of magnetic pin twister [figure 3.11 (b)].

Figure 3.11 (a) Twist Trapper Wheel

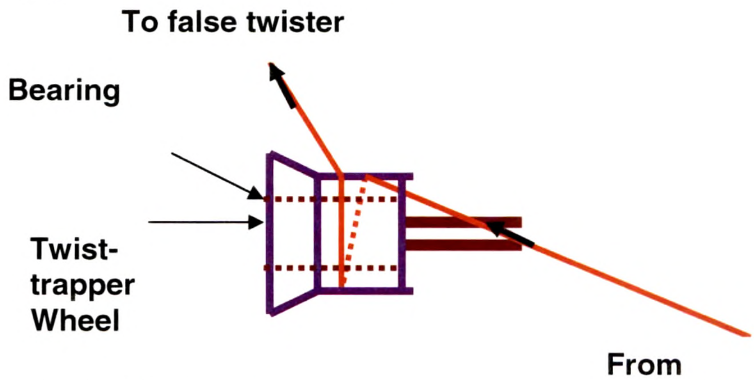
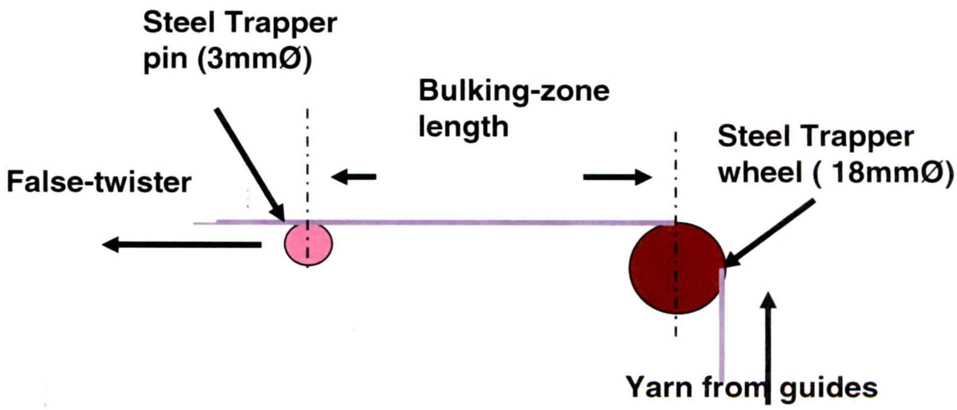


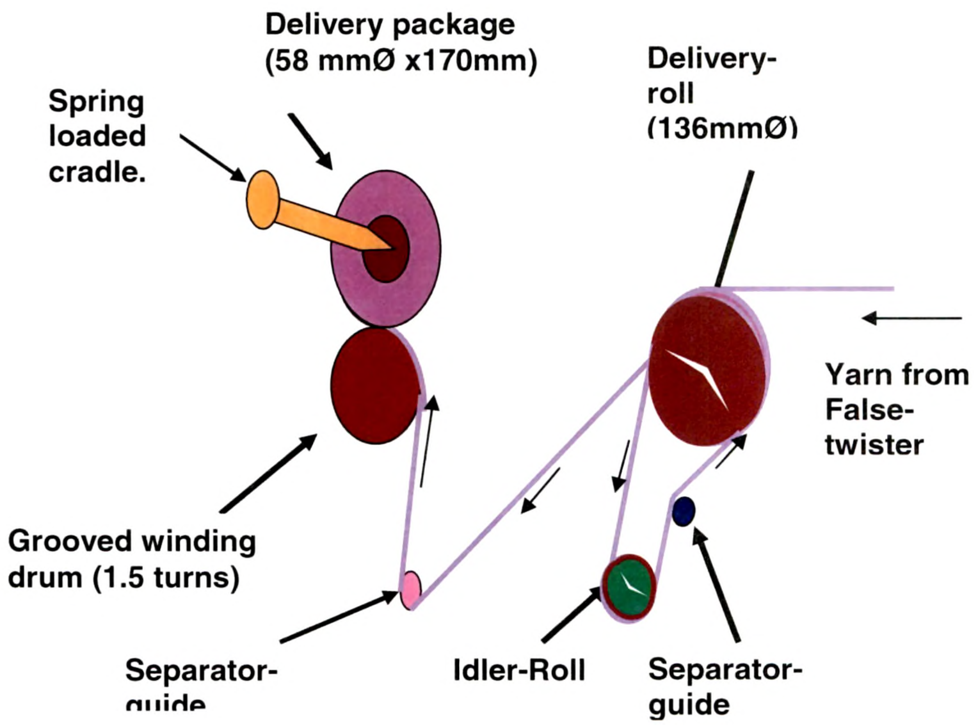
Figure 3.11 (b) Bulking-zone.



3.1.1.4 Delivery and Winding Zone

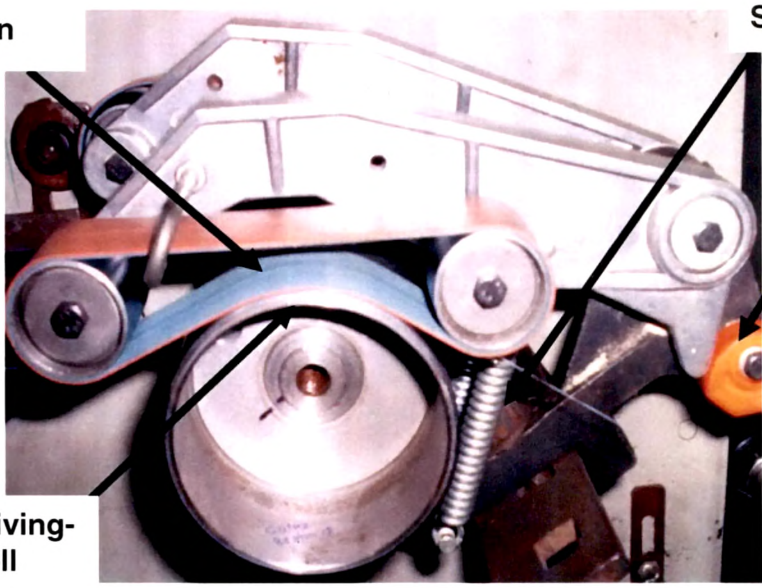
Components of take-up system of mechanical bulking apparatus were positively driven synthetic rubber coated roll, steel idler roll and separator guide [figure 3.12 (a)]. Under the state of over feed for bulking, delivered yarn was given 2-3 wrappings around delivery roll, steel idler roll and porcelain separator guide to ensure enough nipping force at the take-up point.

Figure 3.12 (a) Take-up and Winding Systems of Mechanical Bulking Apparatus.



However for mechanical crimp texturising over feeding was replaced by underfeeding this additional nipping force was resulted in undue rise in tension and thereby increased hairiness as well as end breaks. So trials were conducted with less number of wraps but not able to serve the purpose. So, number of wraps made zero in subsequent trial but it had reduced nip pressure considerably thereby take up rate was adversely affected, executed in the form of non-uniform crimp. Finally idler roll system was replaced with nip apron roll system [figure 3.12 (b)]. This change has allowed in securing constant delivery rate without causing yarn damage.

Figure 3.12 (b) Nip Apron take-up on Mechanical Crimp Texturising Apparatus

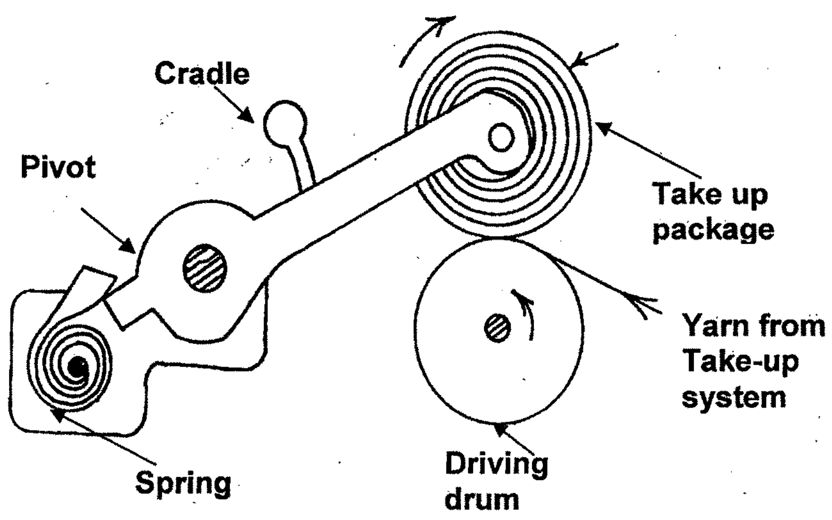


Earlier delivery roller and winding drum were driven from separate motor [figure 3.8 (a)] and provided with common speed regulator for the ease in setting of over feed amount. Product yarn tension could be well regulated by setting up pulley diameter ratio in drive originated and controlled from common motor and regulator respectively. Under feed mode of mechanical crimp texturising had demanded fixed setting for under feeding of selected yarn type throughout the study. It was found easy to set and maintain consistency of under feed with change pulleys in drive [figure 3.8 (b)] rather than by varying speed with regulator. Even calculation and setting of desired constant pre-twist and false-twist level for the given delivery rate for experimentation became more accurate with this change. Thus also minimize variations in the product due to machine variables.

Positively driven steel 2.5 turns grooved winding drum was used for driving the delivery package by surface contact as well as for traversing the yarn during winding.

The same system has been continued on the new apparatus only its drive has been separated from delivery roll [figure 3.8 (b)] as per mentioned in section 3.1.1.2. Thus in new set up winding speed can be regulated independent of delivery rate with separate regulator. Throughout the experimentation it has been driven at 2 percent lower speed than delivery rate to facilitate yarn relaxation after bulking. Separator guide was provided to guide yarn correctly through winding drum grooves on original set up [figure 3.12 (a)].

Figure 3.13. Spring loaded Winding-Cradles.



Reduced speed of winding drum as compared to take up roll was making the yarn to come out of separator guide groove, adversely affecting package build up. So freely rotating positive take up roll has replaced separator guide in new set up to assure a uniform build up of yarn on plastic spool.

Spring loaded winding cradle was used for compact winding of the product yarn (figure 3.13). Plastic spool of 58 mm diameter and 170 mm length was used for winding textured yarn in both the systems.

3.1.2. Experimental:

Experimental work has been divided into five sets. As per mentioned in section 3.1. Pilot-trial was conducted in phase: II. Set-1 describes the aim set up for pilot trial. Effect of various process and material variables on the innovative yarn performance had been studied in the third phase. Set-(2 to 5) describes aim set up for respective experimentation.

Set-1: Identifying the structural properties of a new product yarn experimentally. Based on the structure of the product yarn locate its resemblance between the two commercial products as well as identify respective methods to be adopted for the measure of various quality parameters. Interpreting the measured values of newly engineered yarn with the reported properties of classical air-jet textured yarn and false-twist textured yarn in related domain. Thus confirm the potential of new system for texturising

Set-2: Studying the effect of important process parameters on the performance of new type of textured yarn.

Set-3: Studying the effect of important material parameters on the performance of new type of textured yarn.

Set-4: Identifying the performance of knitted and woven fabric produced by using this newly engineered textured yarn to locate its feasibility in the commercial market.

Set-5: Studying the cost effectiveness of the mechanical textured yarn with respect to commercial texturising systems.

Phase: II

3.1.2.1 Evaluation of Structure and Properties of Innovative Textured Yarn.

There is no precedence available for this innovative method of texturising as well as its product quality parameters and their methods of measures. So this set of experiment has been designed to examine the structure of the new product using microscope. This evaluation can facilitate in locating resemblance of structural characteristics of new product with air-jet textured yarn as well as false-twist textured yarn structures, as it is an outcome of good combination of both the concepts. Resemblance of structure facilitates in adopting suitable methods for measuring important texturising properties of the product yarn. Mechanical properties and physical properties can be measured by adopting standard methods defined for textured yarn.

Materials: To study the structure and properties of the new product Fully Drawn polyester 100 denier multifilament flat yarn, supplied by one of the reputed industry was used. Specifications and properties of parent yarn were given in table 3.1.

Table 3.1 Specifications/ Properties of Parent Yarn (Set: I)

1. Type of material	**Fully Drawn Polyester multifilament yarn.**
2. Denier	**100**
3. Number of filaments	**48**
4. Appearance of yarn	**Semi dull**
5. Cross sectional shape	**Circular**
6. Colour	**White**
7.Tenacity (gpd)	**3.56**
8. Extension (%)	**35**
9. Boiling water shrinkage(%)	**2.0**
10.Uster (%)	**1.02**
11.Spin finish (%)	**0.85**
12.-Nips/m	**15**
13. TiO_2 content (%)	**0.30**

Texturising was carried out on the model machine at 25 percent underfeed to reduce its ductility. Percentage underfeed has been decided based on the results of trials conducted. Trials were conducted at 10%, 15%, 20%, 25% and 30% underfeed for the parent yarn. The underfeed level, where the crimping effect not gets subsidized due to higher ductility of the basic material as well as not causes occurrences of higher broken filaments, has been chosen as the suitable value for the experimentation. Thus 25% has been found as the suitable underfeed level for the parent yarn of 100/48 denier.

Pre- twist of 315 twist per meter, false- twist of 2557 twist per meter and delivery speed of 100m/min were used for this experimentation. Product so obtained had been tested for its structure as well as various properties as per the methods described in section 3.2. It has also sent to an ISO 9001: 2000 certified laboratory nearby, for the confirmation of texturising and verification of evaluation done. Certification of the same is attached in Appendix-I.

Phase: III

3.1.2.2 Effect of Process Variables on Structure and Properties of Mechanical Textured Yarn.

This set was aimed at finding the influence of important process parameters on the product yarn performance. Pre-twist level, false-twist level, bulking zone length and delivery speed was identified as major process variables in the pilot trials. These parameters need to be either optimized or their impact on the performance of new type of textured yarn must be well defined. So for future trials they can be set up to get favorable effect as per end user criteria. The experimental work therefore had been further divided into four groups.viz;

A) Studying the effect of false twist level at different Pre-twist level.

B) Studying the effect of delivery speed on product quality.

C) Studying the effect of bulking zone length and optimized the value.

D) Developing the empirical formula for defining optimum false-twist level to obtain best possible texturising effects for yarns with different fineness.

Based on the outcomes of the above experiments, optimum process parameters for lab apparatus had been defined.

Finally confirmation trial had been conducted at optimum process parameter values, only pre-twist level had been varied. This had facilitated in identifying impact of pre-twist on major texturising properties of newly engineered yarn.

Materials

All the experiments in this set were carried out with same material, viz; fully drawn multifilament polyester yarn of 100denier/48 filaments, used in previous set.

Derivation of empirical formula for optimum twist level with respect to different yarn fineness had demanded in exception use of other materials.

Confirmation trial was also conducted with dope dyed fully drawn polyester 150denier/72filaments yarn. This had made easy visualization in relative changes in appearance of product yarn at different pre-twist levels used during study. In addition to that study of the behaviour of pre-dyed yarn became possible.

Specifications of 100/48 fully drawn polyester yarn are given in table 3.1. While specifications of other fully drawn polyester yarns used for fourth group and the confirmation trial are given in table 3.2.

Percentage underfeed levels had been identified based on the pilot trials conducted at 5%, 10%, 15%, 20%, 25% and 30% for all the parent yarns under consideration. Underfeed level identified for the parent yarns of 100/48, 75/36 and 30/14 was 25% and for 150/72, 60/6 and 50/36 yarns was 15%. Delivery speed had been kept constant 50 m/min for first group. For rest of the trials 100m/min speed had been adopted invariably on the model machine. It was based on the results of the second group, where effect of delivery speed had been studied. Length of the bulking zone had been kept one inch as constant, except for the third group.

The experimental designs used for first three groups in set-II have been given in table 3.3, 3.4, and 3.5 respectively. Table 3.6 represents experimental design for confirmation trial. Products so obtained had been checked for quality parameters as per the methods described in the section 3.2.

Table-3.2 Properties of the Parent yarns Selected for the Development of an Empirical Formula.(Group: D)

Description of Parent Yarn	Dpf	Colour	C.S.	Extension (%)	Tenacity (gpd)	Boiling Water Shrinkage (%)
30 /14	2.14	White	T	34	4.75	5.50
50 /36	1.39	Black	C	24	3.50	5.00
60/6	10	White	C	28	4.40	7.00
75 /36	2.08	Peach	T	35	4.00	7.18
100 /48	2.08	White	C	35	3.56	2.00
150/72	2.08	Green	T	24	3.50	3.00
200 /96, (2 x 100/48)	2.08	White	C	35	3.56	2.00
250/120, (100/48 + 150/72)	2.08	White + Green	C + T	31	3.12	2.40
300 /144, (3 x 100/48)	2.08	White	C	35	3.56	2.00

- *Dpf = Denier per filament, C.S = cross section, T = Trilobal*
- *C = Circular, gpd = gram per denier.*

Table 3.3 Experimental Design for the Effect of False Twist Level at Different Pre-twist level (Group: A).

(Parent yarn=100d/48fils. Underfeed=25%, delivery speed= 50m/min, bulking zone length = 1inch.)

Group	Sample code	Pre-twist level tpm	False twist level tpm
I	A1	80	1970
	A2		2364
	A3		2560
	A4		2757
II	A5	154	1970
	A6		2363
	A7		2560
	A8		2757
III	A9	238	1970
	A10		2363
	A11		2560
	A12		2757
IV	A13	315	1970
	A14		2363
	A15		2560
	A16		2757

- ***tpm = twist per meter.***

Table 3.4 Experimental Design for the Effect of Delivery speed (Group: B)

(Pre-twister tpm= 154, False twister tpm = 1970)

Sample code	Delivery speed m / min.
A17	50
A18	100
A19	150
A20	200

tpm = twist per meter.

Table 3.5 Experimental Design for the Effect of Bulking zone length (Group: C)

(Pre-twister tpm = 315, False-twister tpm = 1970)

Sample code	Bulking zone length Inches
A21	4
A22	3
A23	2
A24	1

tpm = twist per meter.

Table 3.6 Experimental Design for the Effect of Pre twist Level at Optimum Process-Parameters. (Confirmation-Trial, group D).

(False-twister tpm = 2942)

Sample code	Pre-twist tpm
G1	118
G2	197
G3	275
G4	354
G5	472
G6	590
HG6*	590

tpm = twist per meter.

*** Additional trial has been conducted to study the effect of post heat setting treatment in the package form at 110°C for 30 minutes on the performance of the product yarn.**

Group*: D DEVELOPMENT OF EMPIRICAL FORMULA*

It was found from the results of group: A that texturising effects became better on increasing the false-twist level. Thus it becomes imperative to develop relationship for determining optimum twist level for Mechanical crimp texturising yarn. Heberlain[51] had put forward an advanced empirical formula (equation 2.11), registered under U.S.Patent 2,904,952, in September 1959 for determining the optimum twist **K** (twist per meter) in texturising for yarns of different linear density.

$$K = 800 + \frac{2,75,000}{D + 60} \quad \text{..........equ.2.11}$$

This equation has been kept as a base for the development of an empirical formula for the new process of texturising. Experiment has been designed with Fully Drawn polyester yarns of different fineness, viz; 100d / 48fils., 150d /72fils., 200d / 96fils., 250d/120fils. and 300d /144fils. keeping pre-twist level constant (twist factors 24 $tex^{1/2}$.turns/cm). Minimum false twist level employed was calculated as per Heberlain[51] advanced formula (equation 2.11) for each respective yarn and then increased gradually with the uniform increment of 200 twist per meter until results in the breakage of constituent filaments. In order to study the structural changes all the product yarns were observed under microscope with the magnification of 100X.

The false-twist values where filament rupture begins instead of improving crimpiness were recorded as highest false-twist (H) for all the yarns under the considerations. Based on these results, Heberlain[51]advanced formula (equation 2.11) has been restructured. This modified formula has been further crosschecked only for Polyester yarns with different denier per filament, viz; 10 (60d /6fils.), 2.14 (30d /14fils.), 2.08 (75d /36fils.), and 1.39 (50d /36fils.) by keeping rest of the parameters constant. Even experiments were also conducted with 100d/ 48 fully drawn polyester yarns at four different basic twist levels, viz; twist factor (tex1/2.turns/cm) of 2.4, 6, 12 and 24 respectively.

Mathematical programming (MATLAB) was used for establishing new empirical formula for innovative texturising process. The same practically derived optimum false-twist results (for different polyester yarn fineness) were utilised for verification of the formula.

3.1.2.3 Effect of Raw Material Characteristics on Structure and Properties of Mechanical Textured Yarn.

This set was aimed at finding the influence of raw material parameters on the performance of new type of textured yarn. The work was further divided into two groups, viz;

A) Studying the effect of type of material, filament fineness (denier per filament), filament cross-section / type of finish (bright, dull, semi dull).

B) Studying the effect of fineness of multifilament yarn for other identical raw-material characteristics.

Materials: The characteristics of raw materials chosen for the group: A are given in table 3.7. All the materials selected for the study were processed at the constant speed of 100 m/min on the Mechanical crimp Texturising lab model machine with the constant pre-twist of 197 twist per meter and false-twist of 2953 twist per meter.
Selection of under feed level was done as per mentioned in the earlier section 3.1.2.2. Under feed of the order of 15 percent was taken for 150denier/72filaments denier polyester yarn and 25 percent for rest of the samples based on the percentage extension of the parent yarn.

Products so obtained have been checked for quality parameters like yarn appearance, mechanical properties, percentage boiling water shrinkage, percent instability, bulk, percentage change in the linear density and tube knitting and dyeing test as per the methods described in the section 3.2.

For the group: B fully drawn polyester 100denier/48filaments yarn (table 3.1) was used in single end (100d/48fils.), double end (200d/96fils.) and triple end (300d/144fils.) form to study the effect of yarn fineness. Texturising was carried out at constant delivery speed of 100 m/min, at 25 percent under feed and with constant pre twist factor of $24tex^{1/2}$.turns/c.m.

The optimum false twist level K (twist per meter) has been calculated for all the samples using the empirical formula developed for optimum twist level (equation 4.1)* for mechanical crimp textured yarn in group D of Set-II.

The experimental set up used for the study is given in table 3.8.

$$K = 800 + \frac{4,50,000}{D+60} \quad \text{..........equ.4.1*}$$

Where, D is the denier of the feeder yarn.

Table-3.7 Properties of the Parent yarns selected for studying Effect of Raw- Material Parameters. (Group: A)

(Delivery speed =100m/min, Pre-twist =197 tpm, False-twist = 2953 tpm)

Sample Code	Description of Parent Yarn	Df	dpf	Elongation (%) Ep	Ef	Tenacity (gpd) Tp	Tf	% B.W.S.	U %	% Spin finish
A) Nylon Fully Oriented Multi-Filament yarn										
N1	160/48,W, B(T)	126	3.3	42	28.5	4.6	4.69	8.5	1.8	0.9
N2	70/24,W, B(T)	54	2.9	42	29.3	4.8	4.92	8.5	1.8	0.9
N3	44/24, W, S.D. (C)	35	1.8	42	30.2	4.7	4.88	8.5	1.8	0.9
B) Polyester Fully Oriented Multi-Filament yarn										
P1	150/72,G, B(T)	130	2.0	24	17.3	3.5	3.98	3	1.1	1.1
P2	100/48, G, S.D. (C)	79	2.0	35	24.8	3.6	4.20	2.0	1.02	0.9
P3	75/36, W, S.D. (C)	54	1.9	38	28.1	4.5	4.62	5.6	3.2	0.95

- ***C = Circular, T = Trilobal, W= White, G= Green, B = Bright, S.D. = Semi Dull***
- ***Df =Denier of feeder yarn (Drawn yarn after under feed), Ef = Extension of feeder yarn, Tf = Tenacity of feeder yarn, FOY = Fully Oriented Yarn.***
- ***B.W.S.= Boiling water shrinkage, dpf =denier per filament***
- ***Ep = Elongation of parent yarn, Tp = Tenacity of parent yarn.***
- ***tpm = twist per meter, gpd =gram per denier.***

Table-3.8 Experimental Design for the Effect of Yarn Fineness of Study. (Group: B)

(Pre twist factor of 24tex $^{1/2}$.turns/c.m.)

Sample Code	Yarn Denier	Amount of Pre-twist (tpm)	Amount of False-twist (tpm)
C1	100	720	3612
C2	200	509	2531
C3	300	416	2050

tpm = twist per meter.

PHASE IV

3.1.2.4 Identifying the performance of knitted and woven fabric produced by using newly engineered textured yarn.

A circular single feeder-knitting machine of Harry Lucas Textile machine, Germany was used for knitting. Machine was having positive feeder device, tension control arrangement and auto-change over from package to package. Knitted hoses (or sleeves) were prepared from parent yarns and textured yarns. Hundred courses were knitted for all the yarns. The samples were checked for their Dye-ability, courses/cm, wales/cm and thickness as per the methods explained in sec.3.2

Woven fabric samples were prepared using parent yarns and textured yarns (table 3.9) as weft, using plain weave. Selected textured yarn samples, viz; F2, F4, F5 and F6 were also post heat set in package form (heat-set at 110°C for 30 minutes) and designated as HF2, HF4, HF5 and HF6 respectively. These yarns were also used as weft for weaving. This trial has helped in identifying the effect of post heat setting on the performance of newly engineered yarn as compared to equivalent non heat set yarn against the stresses induced during forthcoming weaving and wet-processing.

Table 3.9 Specifications of the Parent and textured yarns Used as weft in weaving (set-IV).

Delivery speed = 100 m /min,

Percent Under feed = 25% for F1- F5 and 15% for F6- F7.

Sample code	Parent yarn Denier	fil/ c.s.	Colour	C.S.	Pre-twist factor ($tex^{1/2}$.tpcm)	False-twist tpm
F1	100	48	White	C	0.6	3619
F2	100	48	White	C	24	3619
F3	200	96	White	C	0.6	2558
F4	200	96	White	C	24	2558
F5	300	144	White	C	24	2041
F6	150	72	Green	T	24	2942
F7	100 + 50	48 + 36	White + Black	C C	24	2942

- ***C =Circular =Trilobal, tpcm = twist per centimeter, tpm= twist per meter, fils. =filaments, C.S.= cross-section.***

Weaving details

Weaving details for all the samples under consideration are given below.

Warp: 50 denier /24 filaments, highly twisted yarn with 3000 twist per meter and heat set at 90-95°C for 50 minutes.

Weft: Fp = Parent yarn, Ft = Textured yarn.

Ends: 100 per inch (40 per cm) on the loom.

Picks: 80 per inch (32 per cm) for 100 denier yarn.

70 per inch (28 per cm) for 150 denier yarn.

60 per inch (24 per cm) for 200 denier yarn.

40 per inch (15 per cm) for 300 denier yarn, on the loom.

Fabric width: 52 inches (1.32 meters) on the loom.

Reed count: 100s with 2 ends per dent.

Loom speed: 130rpm with shuttle size of 15.5 inches.

Selvedge: Plain-woven selvedge with 27 ends per edge.

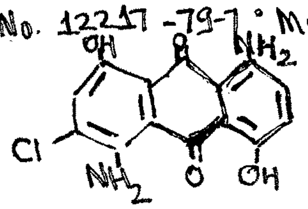
Woven with 6 ends /dent and 3 ends /heald eye.

These fabrics were then finished /dyed at nearby dyeing mill using their normal sequence followed for false twist textured polyester yarn fabrics. Details of the dyeing process used are given below.

Details of the dyeing process:

Disperse Dye* along with acetic acid and dispersing agent was used for dyeing of fabric samples by HTHP (high temperature high pressure) method. Starting temperature was kept 40°C, increased steadily and reached to highest temperature of 132°C in 10 minutes. Diffuse dyeing was carried out for next 145 minutes at higher pressure of 4-5 kg/cm^2. It was followed by cooling at 80°C for next 30 minutes. Washing, drum drying and setting were the processes followed in the sequence.

* • Disperse Blue 56, • CAS Registry No. 12217-79-7, • Molecular wt = 304.69
• Molecular Formula $C_{14}H_9ClN_2O_4$
• Commercial Name : Terenix Blue FBL



Different colour shades were used for the different samples for the ease of identity. All the woven fabric samples were checked for their structural properties, mechanical properties, comfort properties, aesthetical properties and low stress mechanical properties as per the methods explained in sec.3.2.

PHASE: V

3.1.2.5 Studying the Cost Effectiveness of the Mechanical Textured yarn with respect to Commercial Texturising systems.

For any newly developed product along with its quality, cost effectiveness is equally important to identify its stand in the commercial market. However theme of new concept of texturising was worked out on the laboratory module only, it is no more be possible to quote absolute figures for the shop floor production rate, respective labour allocation utilized in the process and accordingly their wage cost. Full flanged production machine due to optimized machine parameters and use of improved metallurgy is giving higher production rates at less power consumption. Consequence of these resulted in considerable reduction in power cost per kilogram as well as labour cost per kilogram for the system.
Thereby only a relative comparison has been done (sec.4.9) with respect to commercial system/s. This has helped in visualizing economical advantages of newly developed system if launched as full-flanged commercial shop-floor machine.

3.2 Testing Methods

Major Quality Parameters for parent and Mechanical-Crimp Textured Yarn were identified as follows:

I <u>Quality Parameters for Evaluation of Parent as well as Mechanical-Crimp Textured Yarn:</u>

- Denier
- Uniformity
- Twist
- Percentage boiling water shrinkage
- Tenacity and Percentage breaking extension.

II <u>Specific Quality Parameters for Evaluation of Mechanical-Crimp Textured Yarn only:</u>

- Yarn appearance/ structure
- Increase in denier
- Reduction in tenacity
- Crimp properties: Crimp stability, Percentage bulk
- Dyeability and Strippiness.

The following quality parameters were identified for the evaluation of fabric under the study:

III <u>Fabric Parameters:</u>

A. Constructional Properties

- Fabric Width shrinkage
- Linear Density and Count of constituent yarns
- Weight per Unit area (GSM- Grams per Square Meter)
- Fabric sett: ends/cm x picks/cm
- Fabric Thickness (mm)

B. Mechanical Properties

- Tensile properties
- Tear-strength
- Abrasion resistance

C. Comfort related Properties

- Air permeability

D. Aesthetical Properties and Low stress Mechanical Properties.

- Drape
- Crease Recovery
- Stiffness (Bending Rigidity)

Yarn testing was carried out as per ISO-9002 (1994) standards followed by one of the reputed and nearby industry in the field of false-twist texturising. Various methods adopted for the study are described below. All the samples were conditioned at standard atmospheric conditions at 27°C ± 2 °C, temperature and 68% ± 2%, relative humidity for 24 hours before testing.

3.2.1 Denier and Increase in Denier

Zweigle L232 (Germany) Automatic Wrap reel with 1meter circumference rotating at 2000rpm along with Afcoset ER-200A balance with 0.001gm.accuracy were used for the testing carried out at nearby industry. Whereas Kamal Metal Industry's manually operated 1 meter circumference wrap reel (figure 3.14) along with Anamed Electronic balance with 0.01 gm accuracy were used at lab. Lea of 90 meter was prepared by using pretension of 0.5gms.± 0.005gm/tex for parent yarn and 2.0 gms± 0.25gm/ tex (as per

BISFA) for textured yarn[32]. Then leas were weighted on the balance mentioned above. Yarn denier was calculated by using following relationship.

Denier = Lea weight (g) x 100 ....equ.3.2

Average of ten readings was reported. Deviation from measured denier was calculated by the following relationship.

$$\textbf{Deviation in Denier} = \frac{[\mathbf{D_t} - \mathbf{D_f}] \times 100}{\mathbf{D_f}}$$ equ.3.3

Where D_t is the denier of the textured yarn and D_f is the denier of the feeder yarn[3].

3.2.2 Uniformity Measure:

Zwellger Uster Evenness Tester for filament was used for measuring uniformity of parent as well as textured yarn. Testing was carried out at 100m/min speed and at 4-bar pressure.
Average of five readings per package was taken in consideration.

3.2.3 Twist Measurement

Surbhi Electronics Twist Tester (figure 3.15) was used for twist measurement. Test was conducted at 1.5meter gauge length at 0.2gm/denier pretension[64]. Amount of twist (twist per inch / twist per meter) and twist direction were measured. Average of 10 readings per package was recorded for each sample.

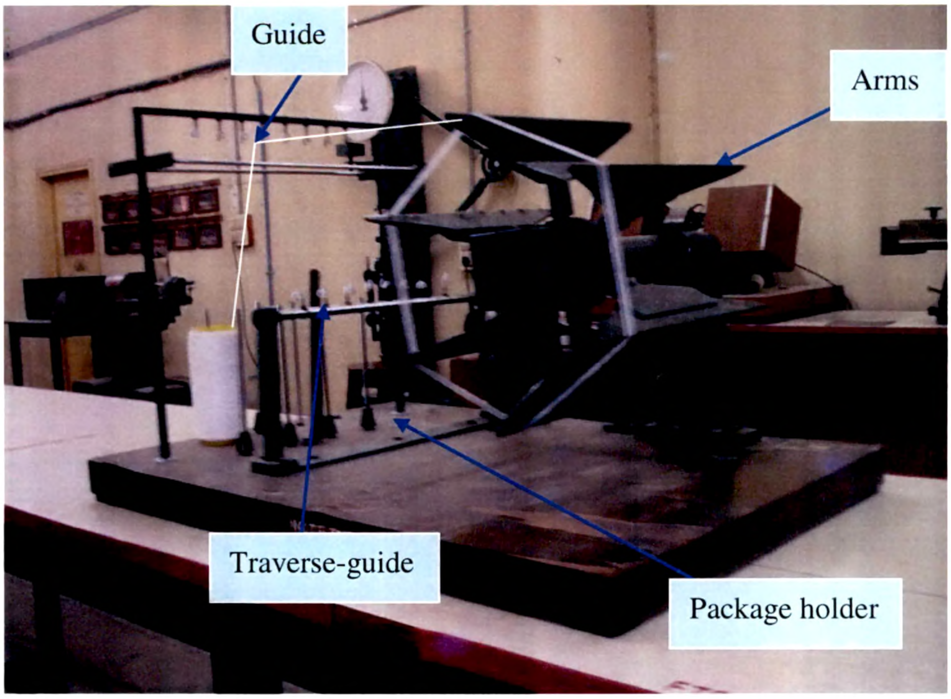


Figure 3.14 One Meter Wrap-reel.

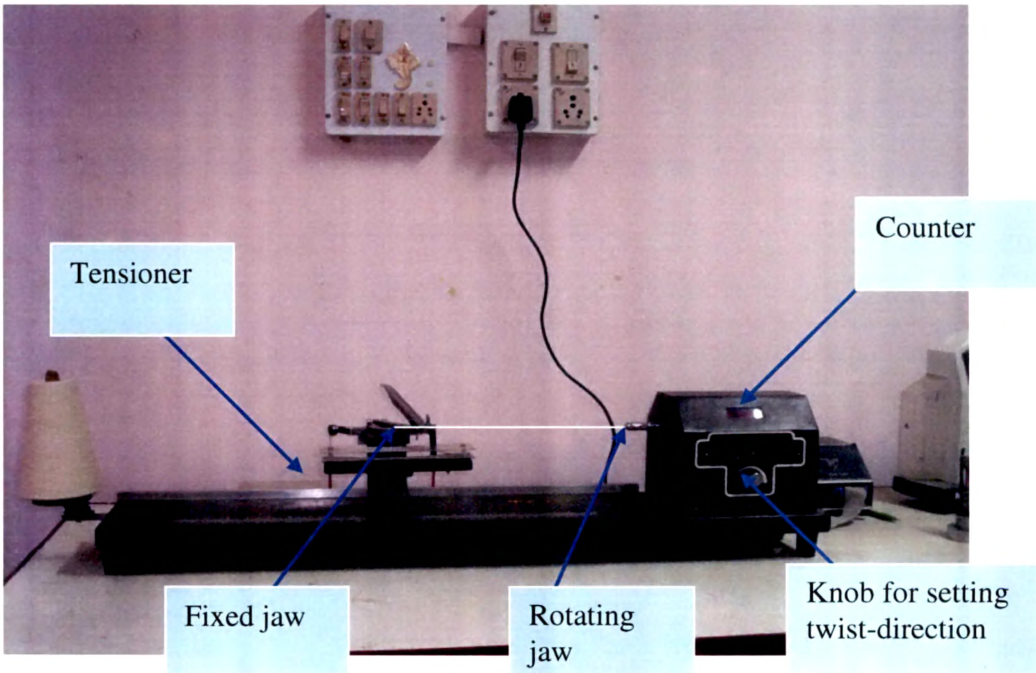
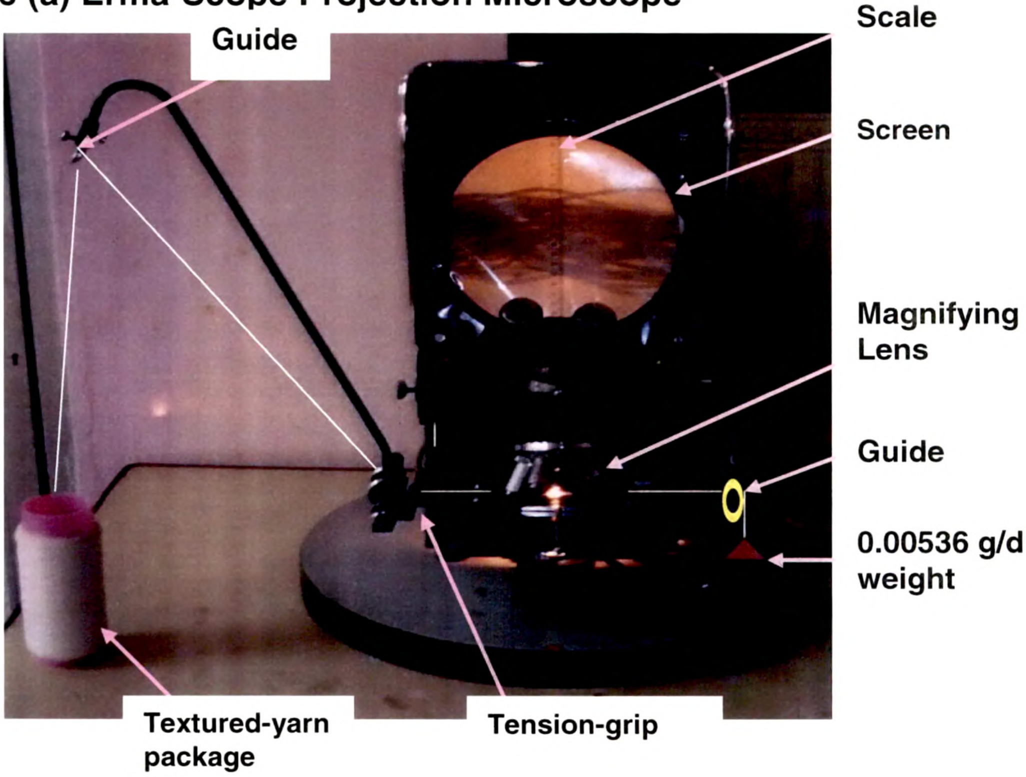


Figure 3.15 Semi-Automatic Twist-tester

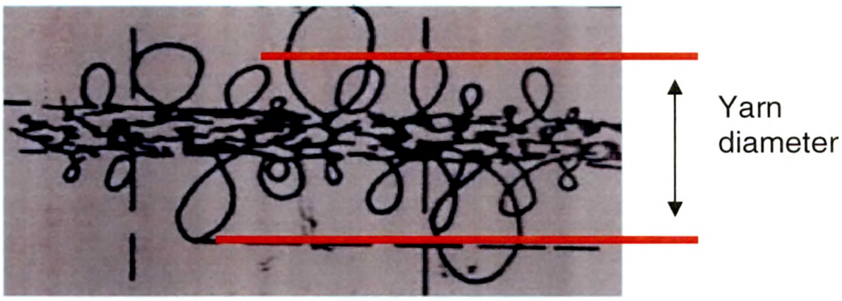
3.2.4 Yarn- structure and Yarn- appearance test

The first confirmation for the occurrence of texturing without performing any of the physical tests comes from the study of yarn structure at high degree of magnification. The yarn samples were viewed by using ERMA SCOPE Projection microscope [figure 3.16(a)] at 100X magnification. Video photography over the longer sections of length as well as snap shots of the magnified views of textured yarn under study was prepared from 200mm screen of projection microscope. They provide the record of the structural changes with different process and material variables in textured yarn as compared to flat configuration of parent yarn.

Fig.3.16 (a) Erma-Scope Projection Microscope

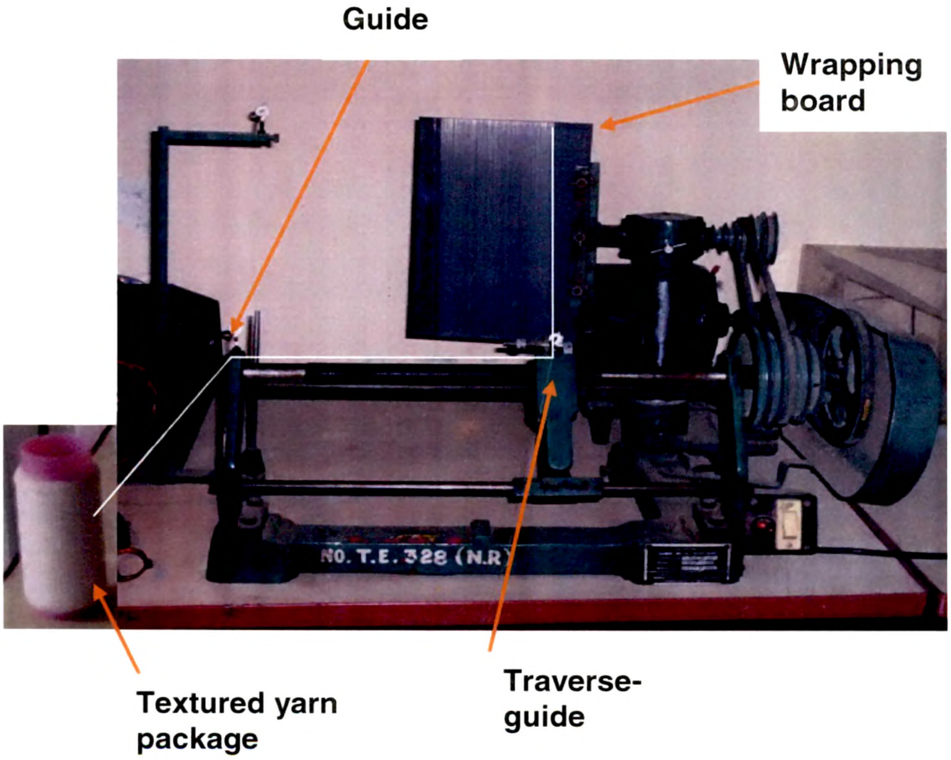


(b) Measure of Yarn diameter from the screen of projection-microscope



Pilot trial prototype textured yarn was studied for its regularity in appearance from 100m wrapping boards. Three wrapping boards were prepared from randomly selected top, middle and bottom layer of the package under constant tex/2 gram tension on board-winder (figure 3.17) at constant speed of 20m/min. These boards were then checked for the presence of irregularities like tight spot, variation in yarn diameter, broken filament etc. under light.

Figure 3.17 Wrapping-Board Winder

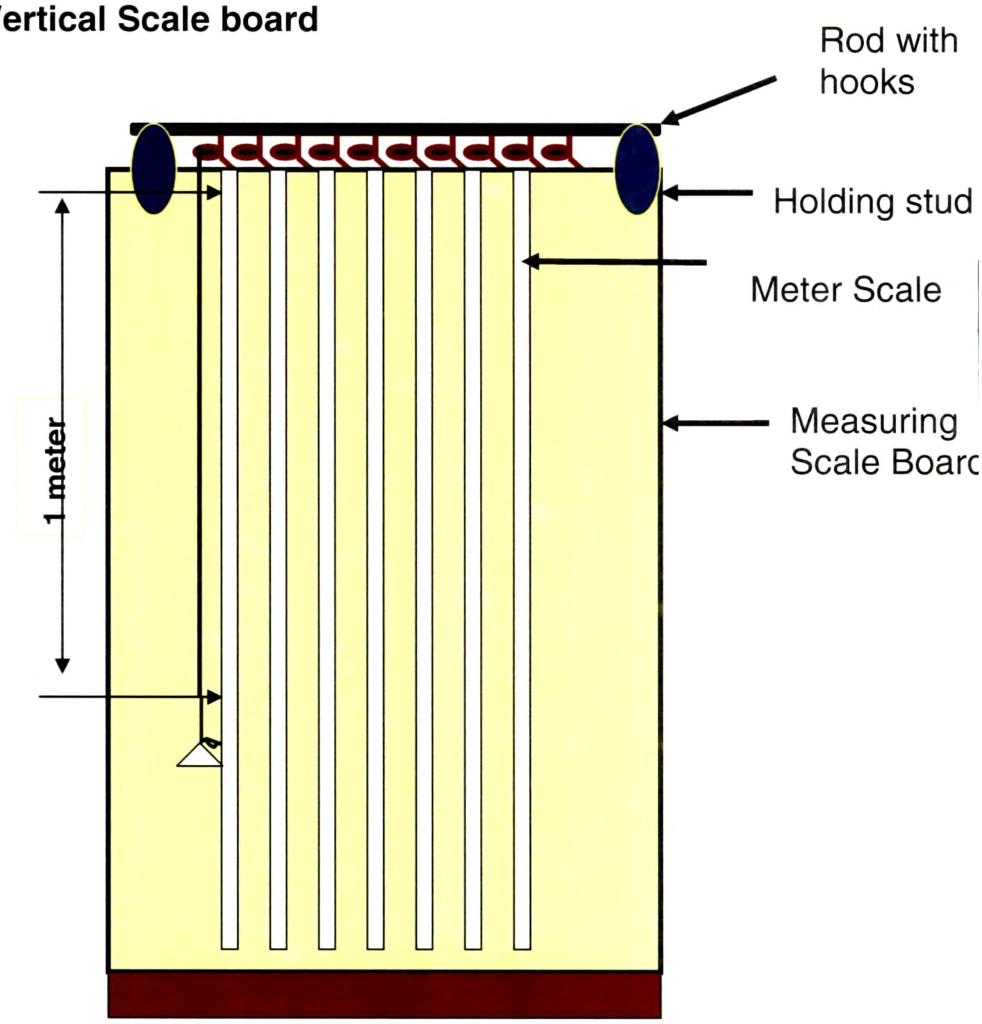


3.2.5 Measure of Crimp properties:

3.2.5.1 Crimp stability:

The method suggested by Du Pont[5] (described in section 2.6.1.2) was used to evaluate the structural stability of the mechanical crimp textured yarn.

Figure3.18 Vertical Scale board



Du Pont method:

Vertical scale board (figure 3.18), with the arrangement of suspending top clamp for holding top end of the yarn such that clamp line always facing zero on the scale board was fabricated and installed in the laboratory. A weight hanger was provided for hanging the weights on the specimen. A fixed weight of 0.01gf/den (0.088cN/ tex) was hung at the end of the yarn and left on the specimen throughout the test. A one meter length on this tensioned specimen was marked. The specimen was then subjected to a higher load of 0.33gf/den (2.97cN/tex) for 30 seconds. The permanent elongation in the length of the specimen was measured 30 seconds after the higher load has been removed by using the one-meter mark as the reference. This permanent elongation percentage was taken as the direct measure of the instability. Average of ten readings per sample was taken.

3.2.5.2 Textured Yarn Bulk

Parents as well as textured yarns were tested for diameter on Erma scope projection microscope [figure 3.16(a-b)] using magnification of 100X. The sample yarn of 100 mm was mounted horizontally in the jaws of a small clamp fixed on the platform of the micro scope, the free ends of the sample being affixed to the piece of the spun yarn with a piece of self-adhesive tape. The spun yarn was the part of simple pulley weighting system. When thirty seconds had been elapsed after jointing the two yarns, a standard tension of 0.00536 g/denier as per defined by Burnip et al[46]. was applied to the yarn in test for diameter measure. The method of joining the two yarns by simple pressure adhesion ensured any sudden stretching of the yarn during the application of tension was eliminated.

The length of the yarn '*l*' was measured in millimeters using scale under the standard tension conditions mentioned above. The sample was then released by cutting with a razor blade at the clamped end and by removing self adhesion tape at the free end, and weighted on a milligram torsional balance for measuring mass "m".

The assumption that the textured yarn is of circular cross-section although textured yarn contains real twist in the present case, found insufficient to cause a flattening of the yarn. The specific volume v was therefore given by

$$v = \pi d^2 l / 4m \quad \text{.......equ.3.4}$$

Where **d = mean yarn diameter in millimeter**

l = length of sample in millimeter

m = mass in milligram.

In order to assess the amount by which the specific volume of a filament yarn had increased on texturising, the term "Bulking factor (Θ)" was defined as the ratio of the specific volume of the textured yarn to the specific volume of the parent filament yarn before texturising. Fifty readings were averaged for each yarn sample. Since the applied tension affects the diameter considerably, a standard loading of 0.00536 g/denier was used throughout for all samples.

3.2.6 Measure of Percent Boiling water shrinkage

Parent yarns as well as textured yarns were tested for boiling water shrinkage. Skein of 2250 denier was prepared on 1meter wrap reel.

Number of wrap reel turns was calculated for different denier yarns by using the formula 3.5.

No. of wraps =1125/ denier of yarn. equ.3.5

Prepared hanks were hung freely under corresponding weight and the initial length "**L_o**" was noted by using the scale board (figure 3.18). Then the load was removed and immersed hank completely in boiling water bath (figure 3.19). Bath was heated electrically from the false-bottom and provided with thermostat to maintain desired constant temperature, "100°C". After 10 minutes the hank was taken out of the bath and allowed to dry and condition for 24 hrs in free-state at room temperature, viz; 27°C± 2 °C. Final length (**L_f**) was then measured by applying the same constant load of 500 gm by using the scale board (figure 3.18). Percentage boiling water shrinkage was calculated using following relationship[15, 32].

$$\textbf{Percentage Boiling water shrinkage} = \frac{[L_0 - L_f] \times 100}{L_0}$$

......equ.3.6

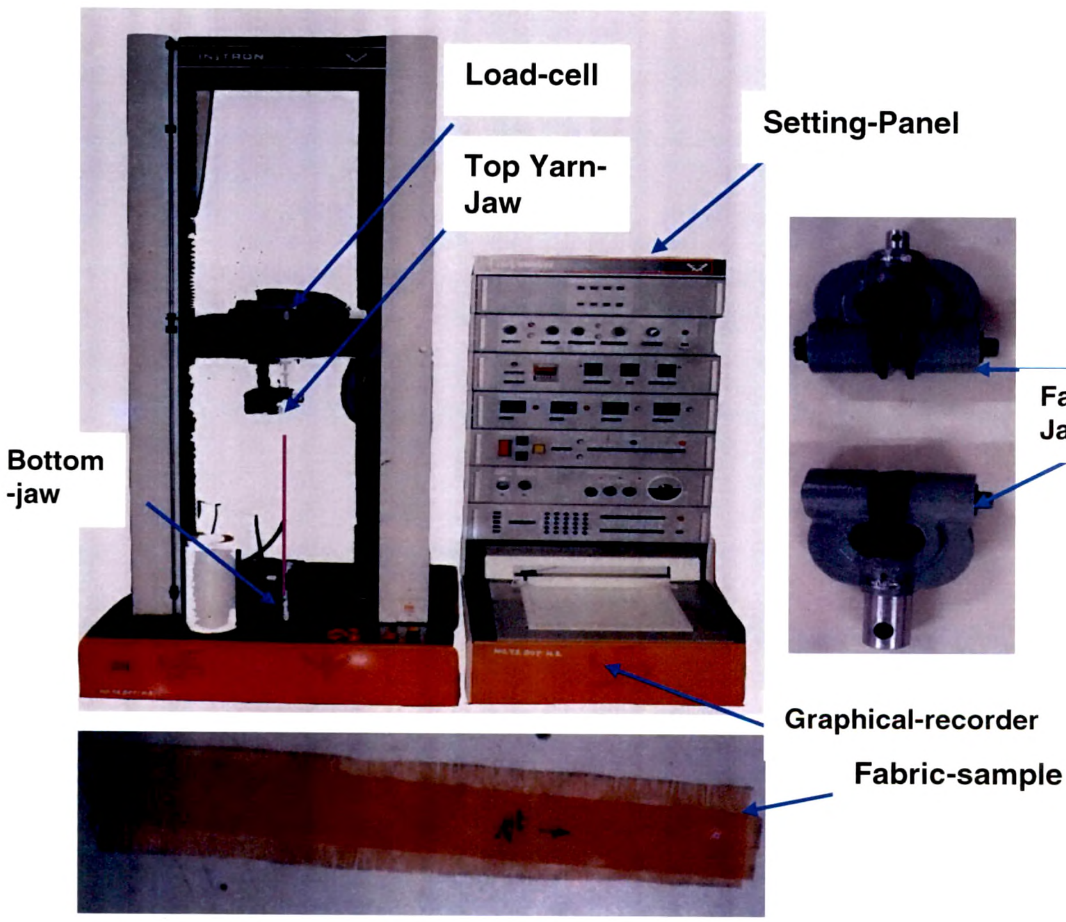
Figure 3.19 Boiling Water Bath

3.2.7 Measure of Mechanical Properties

Instron tensile tester 1121 model (figure 3.20), C.R.E method was used for the measure of mechanical properties. Average of ten readings was used per bobbin. Test specifications [32,52] used were as follows:

- Gauge length: 500mm,
- Cross head speed: 300mm/min
- Full scale load: 1000 gm
- Chart speed: 1:1
- Pre tension = denier x 0.5cN/tex

Figure 3.20 Instron Tensile- tester



Reduction in tenacity for textured yarn was measured as follows:

$$\textbf{Percentage Drop in Tenacity} = \frac{[T_p - T_t] \times 100}{T_p} \quad \text{......equ.3.7}$$

Where; T_t = Tenacity of textured yarn

T_p = Tenacity of parent yarn.

3.2.8. Dyeability and Strippiness

Purpose of conducting this test was confirming texturising. Increased amorphous region in textured yarn facilitates in increased dye up take[4]. It had also facilitated in gradation of grey yarn through tube knitting and Dyeing (TKD) by checking shade variations. Tube Knitting of Grey yarn was done as explained in Set-IV of sec.3.1.2. Minimum 100 courses were knitted from the parent as well as textured yarns and then dyed with disperse dye for polyester and acid dye for nylon samples [15, 32].

Preparation of 15% Dye solution:

15gms disperse dye and 2-3 drops of Acetic acid were added in100 ml water.

Dyeing of Knitted hose

Approximately 8 liters water was taken in Vessel. 200ml of dye solution was added to it and then kept on hot plate for heating. All the hose were washed to remove the oil and then dipped in vessel (in boiling water), kept for 20 minutes for proper dyeing. After 20 minutes all the hoses were taken out from vessel and washed in clean water to remove extra dye on the surface. All hoses were kept in spin dryer for drying and then in oven for proper drying.Strippiness was performed by Formaldehyde at 80° -90°C for 30 minutes to remove dye.

Checking and Gradation of hose:

Dyed hose were taken on wooden template laminated with sunmika (1m x 9inch), one by one and checked for following defects.

- Darker shade.
- Lighter shade.
- Untextured portion.
- Tight spot portion.

The number and type of defects were recorded and samples to be graded accordingly.

- **Darker/Lighter shade** – PQ-grade, green marking on bull nose of paper tube.
- **High darker/Untextured/Tight spot** - SS grade, black marking on bull nose of paper tube.
- **Rest samples** - graded as 1st.

3.3 Testing Methods used for Fabric

All the samples were conditioned at standard atmospheric conditions, viz; Temperature of 27°C ± 2 °C and Relative Humidity 68% ± 2% for 24 hours before testing.

3.3.1 Measure of Fabric Width Shrinkage

The width of the fabric on the loom and after undergoing finishing processes not remains same due to shrinkage. So the grey fabric width (**W_g**) and finished fabric width (**W_f**) were measured with the help of measuring tape. Fabrics were conditioned to a standard atmospheric condition for 24 hours before taking measurements. Ten measurements per piece were taken at equal distance to the nearest accuracy of 0.1inches.Fabric width shrinkage was calculated using following relationship[61].

$$\textbf{Fabric width shrinkage} = \frac{W_g - W_f}{W_g} \times 100 \qquad \text{....equ.3.8}$$

3.3.2 Density and Count of Constituent Yarns

The fabric density, viz; ends per inch x picks per inch; for woven fabrics and courses per inch x wales per inch; for knitted fabrics were measured with the help of "One-inch counting glass (Pick-glass)". Fabrics (woven/ knitted) were conditioned to the standard atmospheric condition for 24 hours before the test. Fabrics were then laid on the glass plate without causing undue stretch for the observation under pick-glass [figure 3.21]. Average of ten readings, taken randomly for each direction, excluding selvedge was considered[61].

Figure 3.21 Fabric-Density Measurements

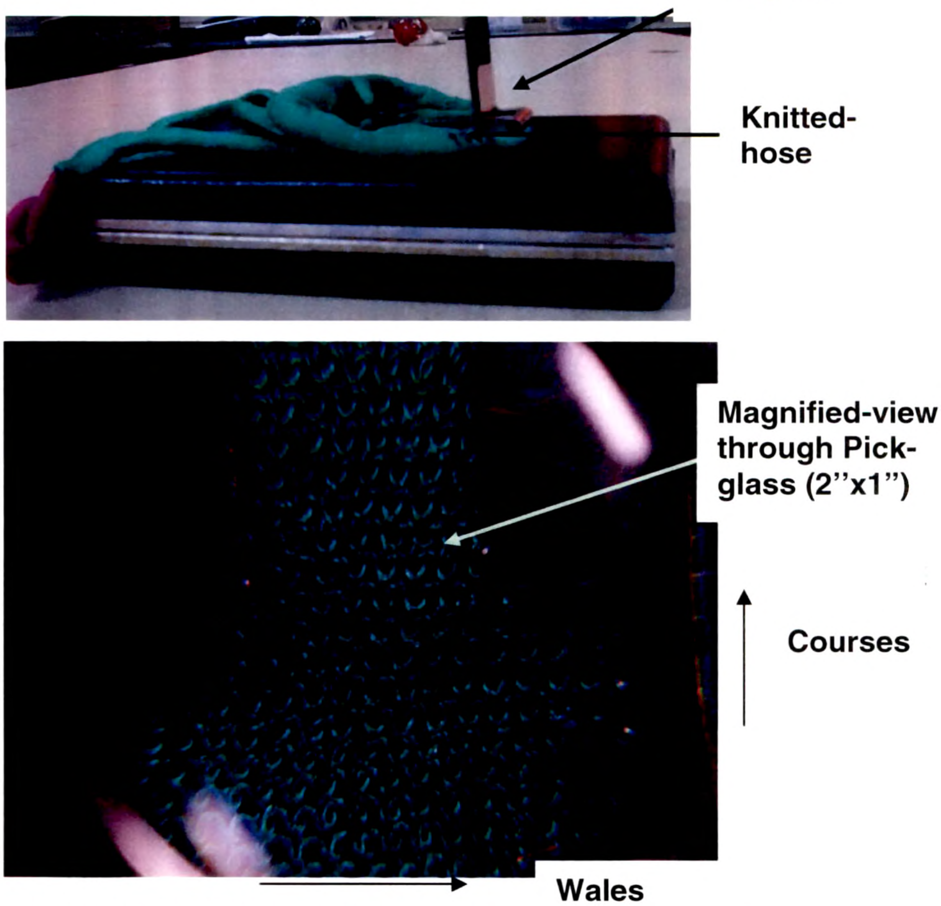
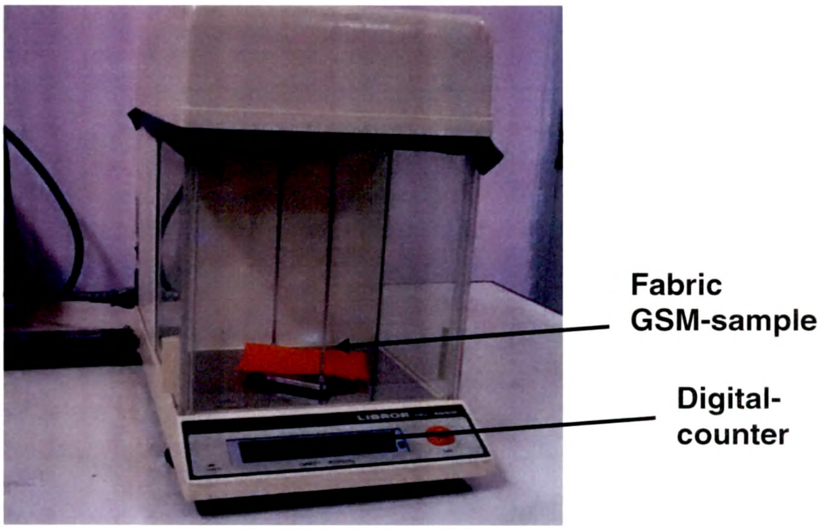


Figure 3.22 Libror AEL- 40SM, Shimadzu electronic balance



One-meter length of each constituent yarn unraveled from the fabric was measured under the sufficient pre tension of about 0.5 gm/tex, just to remove the crimp, but not to stretch the yarn[61, 64]. This length was then weighted in grams on Libror AEL- 40SM, Shimadzu electronic balance [figure 3.22] with the accuracy of 0.01mgm. Average of ten readings was multiplied with 9000 to get denier of the respective constituent yarn. These values of yarn fineness were corrected by the percentage crimp in the respective direction by using following relationship[61,64].

$$\textbf{Actual yarn denier} = \textbf{Measured denier} \times \left[\frac{\textbf{100} - \textbf{Crimp (\%)}}{\textbf{100}}\right] \quad \text{....... equ.3.9}$$

3.3.3 Percent Crimp

Warp and weft crimp in the finished fabric were measured on Instron tensile tester 1121 model (figure 3.20). Elongation (ΔL) for each constituent yarn at tex/2 gram load was measured for the original length (L) of 200mm. Percent Crimp in the respective direction is measured by using following relationship[64].

Percent Crimp C = [ΔL / L] x 100 ....equ. 3.10

This method was adopted instead of using crimp tester to avoid error caused due to slippage. As available crimp tester is basically designed for cotton yarns.

Test specifications used for test were as follow:

- **Gauge length: 200mm,**
- **Cross head speed: 20mm/min**
- **Full-scale load: 500 grams.**

3.3.4 Weight per Unit area (GSM):

Fabric was conditioned at standard atmosphere for 24 hours and then 10 cm x 10 cm sample had been marked with the help of template and cut with one percent accuracy. This cut piece of the fabric was then weighted on Anamed Electronic balance with an accuracy of 0.01 gram. Average of three readings was calculated to get "w" , viz; weight per 100 cm^2. Weight in gram per square meter (gsm) was then calculated by using following relationship[61, 64].

GSM = w x 100 ......equ.3.11

3.3.5 Air Permeability:

METEFEM Air permeability tester (figure 3.23) was used for measuring the volume of air in cubic meter passed per hour through one square meter of the fabric at a constant pressure of 5mm of water for the one inch diameter circle of the fabric, clamped in the holder[64]. The average rate of airflow from five random locations per piece had been considered. Standard pressure of 10 mm of water was not adopted for measure, as air permeability of majority of samples then goes beyond the capacity of the tester. As main intension of this study was only the comparison of air permeability of samples under consideration. Thereby all the measures were taken at 5mm water pressure rather than 10mm standard water pressure.

Figure 3.23 METEFEM Air permeability tester

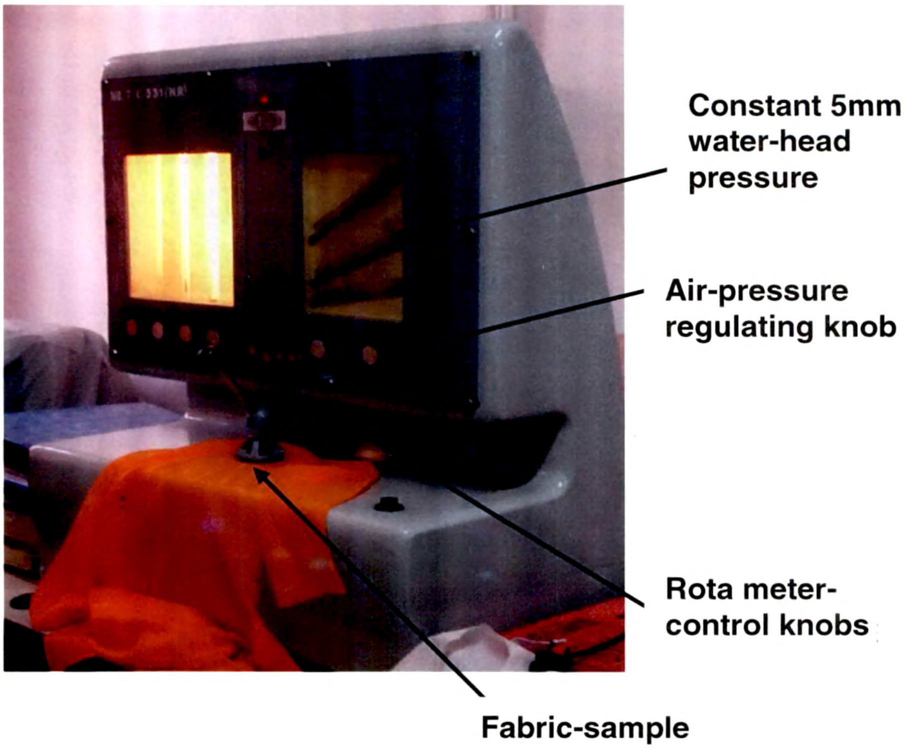
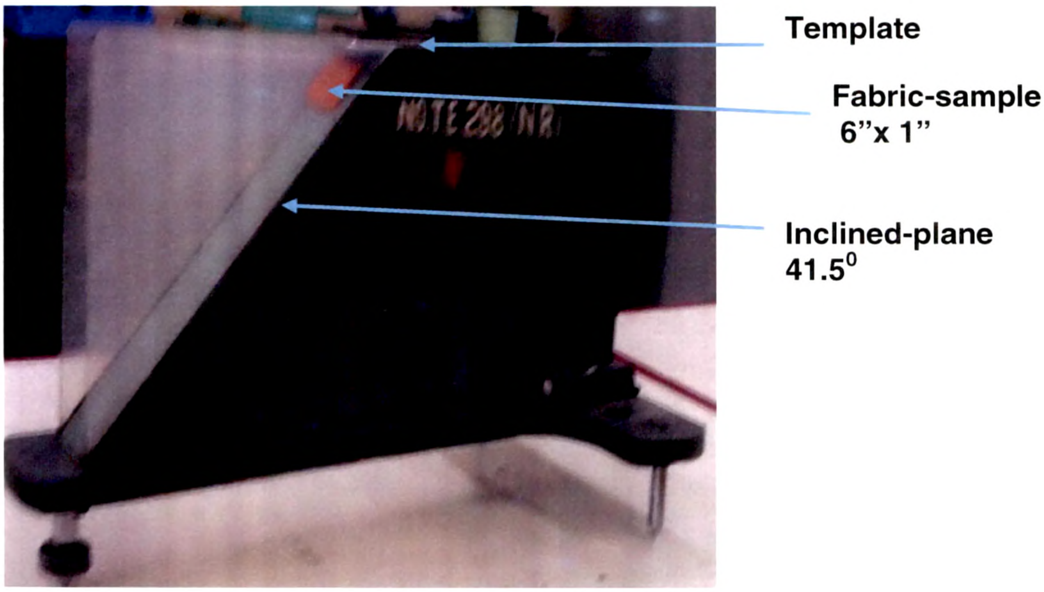


Figure 3.24 Universal Stiffness Tester



3.3.6 Stiffness:

National Industrial Designers' Universal type stiffness tester, working on the same "Cantilever principle" that of Shirley Stiffness Tester (figure 3.24), was used. Bending length(c) from a rectangular fabric strip of 6 inch x 1 inch was measured. Average of three was considered.

Bending length (c) was calculated by using following relationship[61,64].

Bending length (c) = $l\,f_1(\Theta)$ equ.3.12

Where,

l is the straight length of strip forming cantilever due to its own weight.

Θ is the angle of deflection of the strip = 41.5° in the present case and $f_1(\Theta)$ was evaluated by equ.3.13.

$$f_1(\theta) = \sqrt{\cos_2^1\theta/8\tan\theta}$$ equ.3.13

*for Θ= 41.5°, $f_1(\Theta) = 0.5$

Three specimens warp way and three weft way were tested from face as well as back side. Since the relative humidity can affect the results the tests were made in a standard atmosphere. Bending modulus **q** (Intrinsic stiffness) and Flexural rigidity **G** were calculated as follows[61, 64]:

$$\textbf{Flexural rigidity G (mg/cm)} = wc^3 \times 10^3$$ equ.3.14

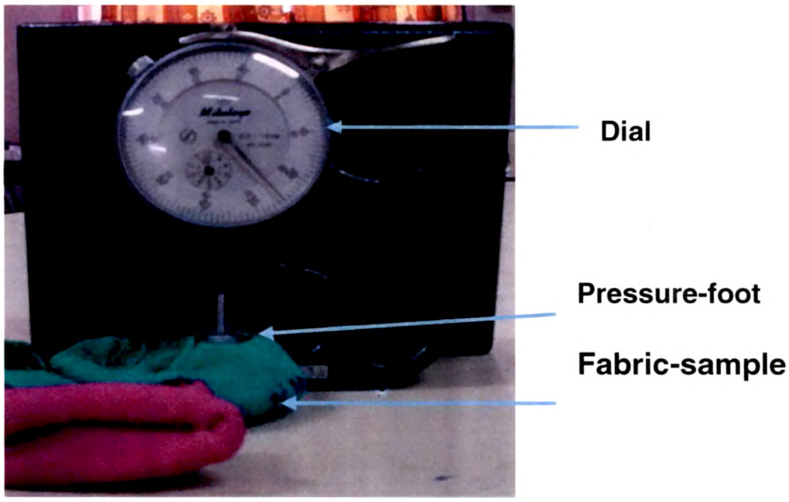
Where w is cloth weight in gm/cm²

$$\textbf{Bending Modulus q (kg/cm}^2\textbf{)} = \frac{12G \times 10^{-6}}{g^3}$$ ...equ.3.15

Where, g is the cloth thickness in cm.

Cloth thickness was measured at constant 2 gm/cm^2 pressure with Mitutoya thickness tester, Japan [figure 3.25] with 0.01mm accuracy at ten randomly selected places[61].

Figure 3.25 Mitutoya thickness tester

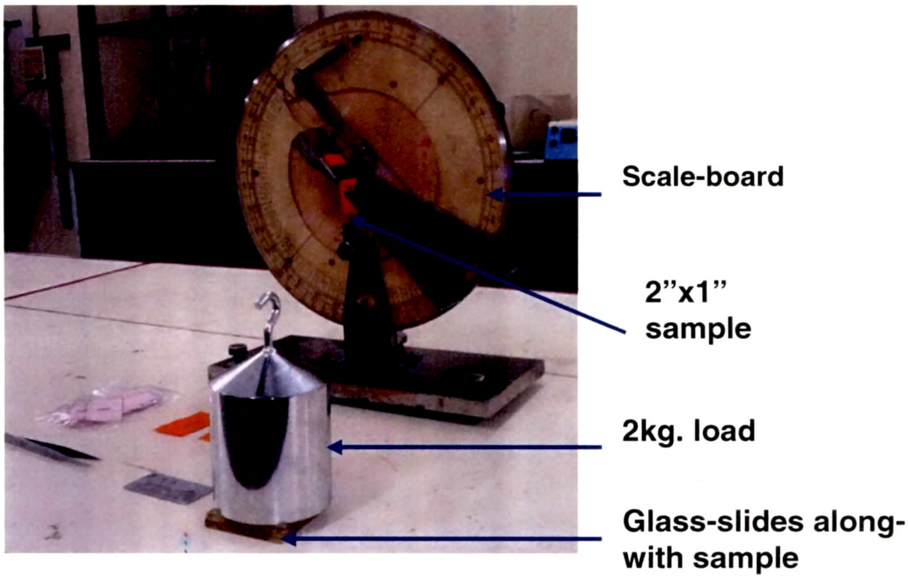


3.3.7 Crease Recovery:

Shirley Crease Recovery tester principle was used for the measure of crease recovery angle after creasing under standard load. Standard weight of 2 kilogram was applied for one minute for crease formation to the strips conditioned at standard atmosphere[61, 64].

Three specimens warp way and three weft way each of size"2 inch x 1inch" were tested. Average of three was considered.

Figure 3.26 Crease-recovery Tester



3.3.8 Tensile Properties:

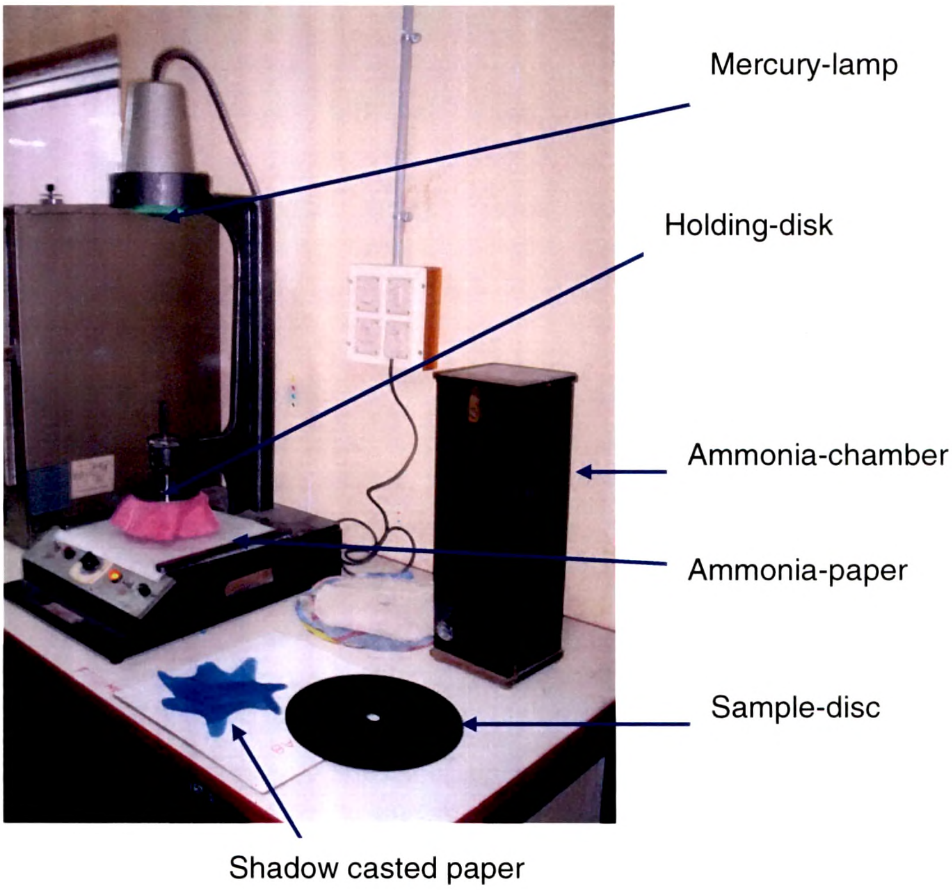
Three warp way and three weft way strips, each of the size 20cm x 1cm (after unraveling) were cut from the parent yarn as well as textured yarn fabrics conditioned at standard atmosphere. They were tested for strength and percentage breaking elongation on Instron tensile tester 1121 model C.R.E method. Test specifications used were as follows[61, 75];

- **Gauge length: 100mm,**
- **Cross head speed: 100mm/min**
- **Full-scale load: 20kg.**
- **Chart speed: 1:1**

3.3.9 Drape

BTRA Drape meter (figure 3.27) was used for measuring drape in which the warp and weft way characteristics interact and produce graceful folding.

Figure 3.27 BTRA Drape-Meter



A circular specimen of 10 inch diameter was supported on a circular disk of 5 inch diameter. Projected area of the unsupported specimen (A_s) was measured by casting a shadow on the ammonia paper of the known gram per square meter. In the present study ammonia paper of 80 gram per square meter was used. Percent drape F was calculated by using following relationship[61,64].

$$\textbf{Drape}\,(\%) = \frac{A_s - A_d}{A_D - A_d} \times 100 \qquad \text{....equ.3.16}$$

Where A_d is the area of supporting circular disk of 5inch diameter and A_D is the area of Sample circular disk of 10inch diameter.

3.3.10 Abrasion Resistance

Abrasion Tester (figure 3.28) manufactured by Henry Baer & Co. of Switzerland, working at the speed of 80 strokes per minute was used. Abradant used for the study was "TQ4 P800 Silicone Carbide (water proof) paper, electro coated, and Jawan brand". Paper was replaced with new one after each fabric sample, so as to maintain abrading surface resistance constant for all samples. End of the flat abrasion test was set as "Number of strokes required to produce hole in the 8 inch x 8 inch pre loaded sample." Constant pre-load of one pound was use throughout. Average of three readings has been considered for the study.

3.3.11 Tearing Strength:

Elmendorf type tearing strength tester (figure 3.29) was used to measure tearing strength in grams. Average of three warp way samples and three weft way samples, each of 6 inch x 3 inch was reported as a measure of tearing strength of each sample under consideration.

Figure 3.28 Abrasion-Tester.

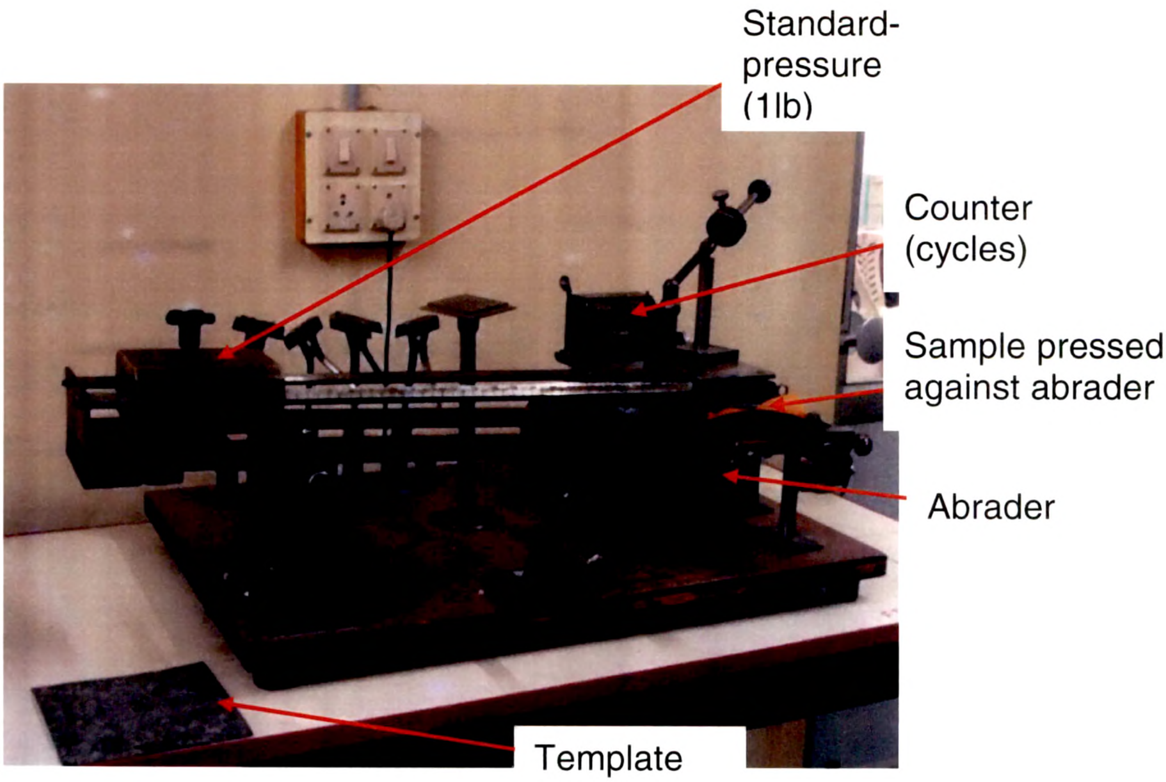


Figure 3.29 Tearing-strength Tester