CHAPTER IV

RESULTS

AND

DISCUSSION.

4.1 Introduction:

In case of zero twist textured yarns, tremendous mobility of filament segments along the yarn axis and in any direction away from the yarn axis exhibits easy deformation results in poor dimensional stability and permits a much greater area of contact with other surfaces. As a result in apparel applications false twist textured yarn offers greater friction and discomfort. With sufficient twist in the textured yarn structure, the problems are completely overcome, as it moves closer to the preferable spun yarn structure[4]. The theme of production of mechanical textured yarn begins with this theory. The novel concept of texturising not only offers distinct advantages of conventional heat set zero twist false twist textured yarn but also provides control on the mobility of the filament segments. Use of real twist for locking the newly attained crimpy configuration brings it in closer resemblance with preferable air jet textured yarn or being more realistic to the spun yarn structure. This also helps in the elimination of the need of post twisting or intermingling, as required in the case of conventional stretch yarn to overcome the problems of snagging on loom.

Production of desired mechanical crimp textured yarn on an apparatus working on the concept of mechanical bulking, demands modifications in each stage right from feeding section to winding section including drive set up. The work undertaken therefore started from the development of the laboratory model machine for the production of the mechanical textured yarn. Subsequently; after passing through several stages of development, overcoming several hurdles, evolving techniques in false twisting, magnitude of false twist, real twist, percentage under feed etc.; it becomes possible to identify suitable machine components for the process. Modifications made in the drive had allowed in overcoming the variations caused due to slippage and thus finalized set up can be used for the production of desired mechanical textured yarn.

Development of an empirical formula for optimum twist level for mechanical crimp texturising has made continuing research easy. This has facilitated in evaluating performance of newly engineered yarn, produced with best possible process-variable combination. Potential of latent properties like bulk and stability of newly engineered yarn has been best judge by translating it into fabric and passing through wet processing stage.

Obviation of costlier heat or compressed air (as used in case of conventional texturising process), allowed a considerable reduction in the production cost, maintenance and storage costs. All these added positive sides of this innovative process makes it interesting not only to evaluate the new product in terms of its structural geometry with respect to various material and process parameters and their impact on its quality performance at the yarn stage as well as fabric stage, but also have a comparative assessment of economy of product. This will help in identifying the probable domain of end users for newly developed product.

This chapter describes stage wise results as well as discussion of the entire work done in this direction. In the absence of limelight of precedence all the forthcoming discussion carried out only on the basis of basic theories involved in the world of texturising and supportive test results.

FABRICATION OF PROTOTYPE MODEL-MACHINE

4.2 Introduction

Based on design concept mentioned in section 3.1.1 an apparatus working on the concept of mechanical bulking was modified for the present experimentation. Selection of the machine components was done based on the outcome of the pioneer experimental trials. Success or failure in producing the targeted product by using these components has been also verified experimentally. Brief review of these various section wise causes, enforced the change in either design or component itself have been given here.

4.2.1 Pre-twisting Zone

Initially trials were taken with two for one twister having aluminum protection pot of 197 mm diameter. Poor yarn quality was resulted due to fusing or fraying-off the filaments and also gave excessive end-breaks. Same trend had been continued even on smoothening of the surface of aluminum pot as well as with fabricated steel protection pot (figure 3.3). Situation became more crucial at higher delivery speeds especially for finer denier filaments irrespective of its type. Higher end breakage rate was mainly attributed to the higher induced tension owing to the formation of bigger balloon for bigger size protection pot rather than rough surface as suspected initially. Although worked with lower value tensor, under feed mode of texturising had enforced filaments to contact outer rim of the protection pot at exit end continuously, resulted in increased friction, thereby fraying and fusing of filaments. Employment of spindle type twister was the first attempt made in the direction of reducing balloon size (diameter) and thereby reduced yarn tension at pre-twisting. But high speed yarn withdrawal from heavy and large supply package had increased dragging force resulted in uncontrolled vibration. Finally trials were ended in success with cup type two for one twister of 65 mm diameter. This was mainly due to smaller diameter balloon formation required to clear off the bobbin during twisting unlike the earlier one. This had helped in reducing yarn tension considerably, and thereby ended in preferable reduced end-breaks. Height of the cup is also less; facilitated in enhousing of cup well within smaller size balloon. This had prevented undue yarn rubbing with cup edges, solely responsible for yarn fraying or fusing in, as happened in earlier case. Introduction of adjustable yarn guide instead of fixed guide had given added flexibility in controlling balloon geometry to deal with yarn with different fineness.

4.2.2 Feeding Zone

Regularity of the twist flow is greatly dependent on consistency of twisting and take-up. Yarn slippage was caused due to highly polished smooth surface of steel take-up roller, giving higher twist variations in product yarn. Thus it was needed to control slippage for better twist uniformity of the product yarn. Use of randomly staggered porcelain grips of positive take-up roller had served this purpose well without causing any yarn damage. Thus it had served in securing positively inserted turns of pre-twister on confined length.

Mechanical-bulking is dealing with the over-feed of the yarn as compared to the under-feed used in mechanical crimp texturising. Speed regulation at ideally zero slippage is always preferable in getting desired uniformity of product yarn linear density. Yarn tension on under feeding was found sufficient to terminate effect of slippage. Thus feed rate could be well regularized with the use of idler roller system only. Thus nip rolls became scraped component for new concept and were eliminated from the set up.

Ease and consistency in under feed setting is important for maintaining consistency in product yarn stability and linear density. Interlinked drive system had been found efficient over existing independent drive of feed system and take-up system in this regards. It had changed on-line setting mode to off-line thereby helped in reducing initial material wastage, created during the course of furnishing setting.

4.2.3 False-twisting Zone

Uniformity of bulk, magnitude of bulk and proportion of fused or broken filaments present in the textured yarn structure is the yard stick used for defining the performance of the bulking zone. Internal frictional and negative mode of bush type false twister under higher tension was failed in achieving this target. Uniformity of the crimp textured yarn bulk is mainly influenced by the uniformity of the false-twisting. Slippage involved in the negative mode of friction twisting had not allowed it to insert ensured amount of twist level as per theoretically calculated from the drive set up.

Intensity of the bulk is purely dependent on the magnitude of the false-twist in direct proportion. Efforts made towards increasing false-twister speed had raised friction between yarn and twister. This was mainly attributed to higher yarn tension caused due to increased twist contraction, adversely affected yarn appearance also. As appearance grading of the product yarn has been credited based on the presence of percentage broken filaments, fused filaments, untextured length etc. over the yarn length tested.

Replacement of existing false-twister was done with fabricated sun and planet driven bush type false-twister in the second phase. This modification was done with the expectation that free rotation of the twister mounted on bearing can decline the friction involved in the course of twisting. But this trial was also not meet to the success. Since motor shaft itself had been modified (made hollow) to act as yarn tube, but that itself became a limitation. Longer length of yarn feed tube made not only threading a difficult task but also added resistance to yarn path, although made as smooth as possible. This had resulted in increased broken filaments. Trial was also conducted by providing glass lining to the shaft but excess smoothening had increased slippage, induced twist variation to the product yarn.

Slippage and friction were found as two biggest limitations of negative twister, directed research towards the adoption of positive mode of twist insertion, viz; magnetic pin-twister. It had proven its reliability for the faith put on it. Insertion of correct amount of input twist was become possible as per machine settings done for desired false twist level without the fear of slippage. Use of smooth pin for twisting had also reduced twister pin and yarn friction thus avoided yarn damage. Both the favourable features had promoted pin-twister over friction twister although for the same level of false-twist power consumption and noise level had increased.

Success of mechanical crimp texturising demands accumulation of predefined twist in the bulking zone for inducing desired deformation force for crimping. Twist slippage beyond the bulking zone is no more be preferable as it can change intensity of crimping. Freely rotating twist trapper wheel with one turn of yarn around it was introduced at rear extreme of bulking zone for ensuring locking of the false-twist.

4.2.4 Delivery and Winding Zone

Delivered yarn always remains under a tension due to under feed mode adopted on mechanical crimp texturising, eliminate fear of slippage. Thus additional efforts put on for controlling yarn tension by the use of idler roll system in original set up became undesirable in new set up, as it was becoming a cause for higher end breaks at delivery point. Replacement of idler roll system with nip-apron delivery system was found sufficient for constant delivery without undue end breaks.

Evaluation Of Structure and Properties of Innovative Textured Yarn.

4.3 Structure of Mechanical Textured Yarn.

Structural characteristics of innovative yarn need to be defined along with the establishment of relationship between its structure and properties at the preliminary level of research. As per Wilson et al[19]. microscopical examination gives an insight into the newly designed yarn structure with respect to various parameters of texturising, and has been used to study the relationship between structure and properties. Working in accordance, fully drawn 100 denier/48 filaments polyester yarn was textured by innovative method on lab apparatus as per described in set I of section 3.1.2 and its structure was studied on Erma scope projection microscope at the magnification of 100X.

A total of fifty yarn samples each of the size one meter were selected at random from different layers of the five bobbins for the analysis of product yarn structure. Samples were viewed on the monitor in a continuous series of 2 mm sections, the length of the sections being limited by the field of microscope's length. The photographs as well as video of magnified views of yarn sections and running yarn from monitor display were taken with the help of Sony-hadicame, having good illumination.

Newly engineered yarn's structure is analyzed from one of the snap-shot taken during the study [figure 4.1(a)]. Some microscopical views out of hundreds of snap-shots taken along the continuous length of product yarn, displaced by random intervals are highlighted in figure 4.1 (b).

It can be observed that the structure of yarn produced by this method is very regular, and the filament coils are regularly disposed along the yarn axis as well as in the space around it. Regularity of the product yarn appearance is also confirmed from the 100meter wrappings prepared from top-layer, middle-layer and bottom-layer of one of the randomly picked up bobbin out of five produced [figure 4.1 (c)].

Figure 4.1 (a) Microscopical view of mechanical textured yarn.

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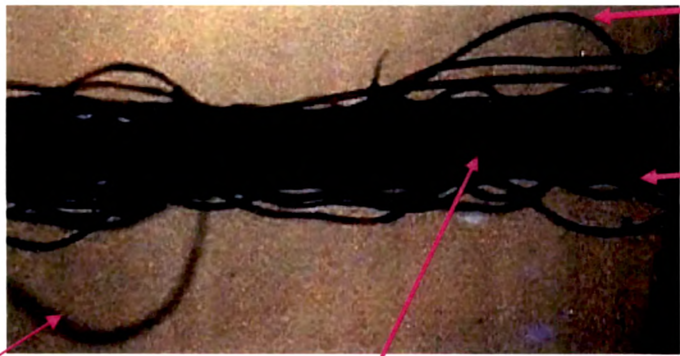
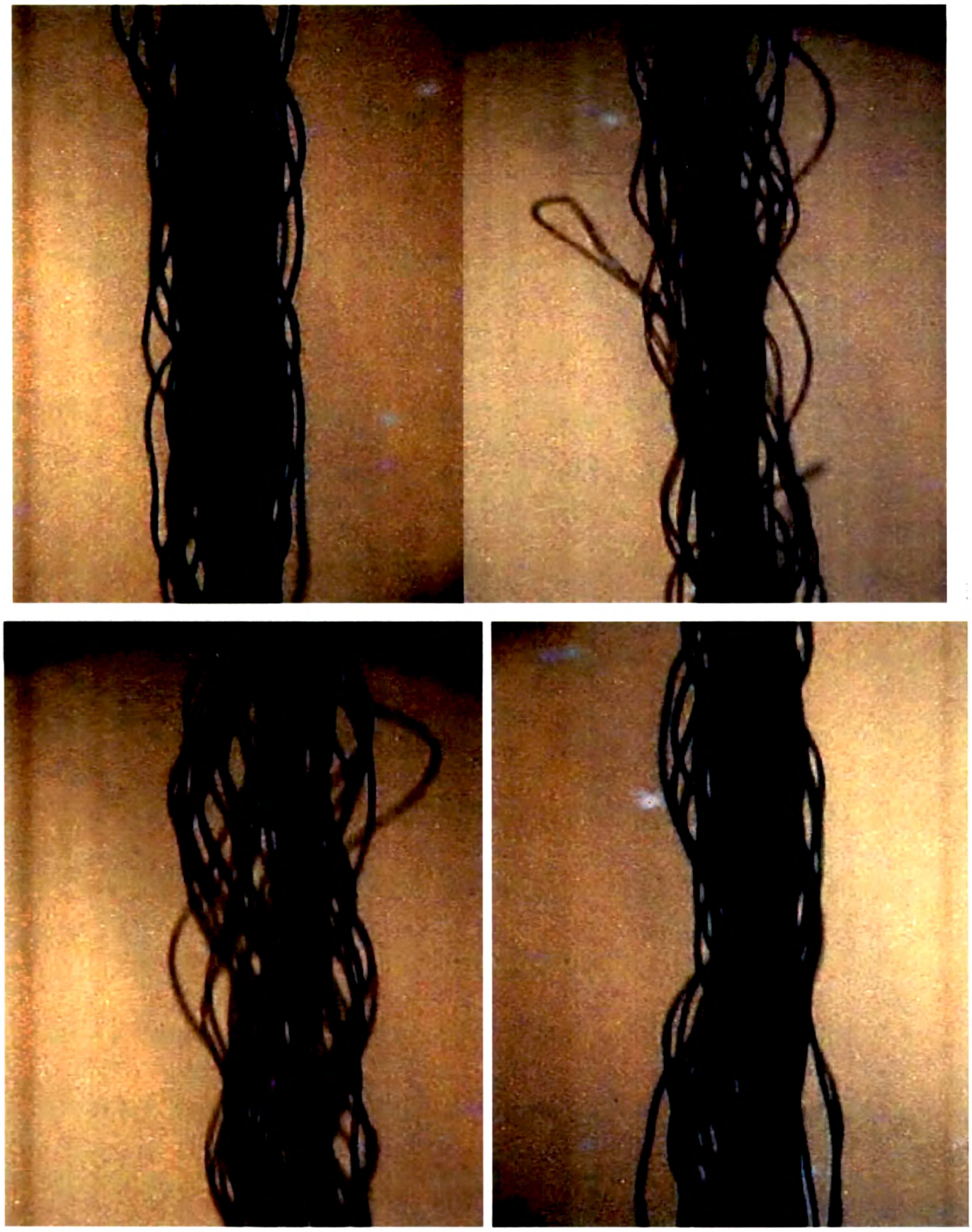


The microscopic study has shown that for newly designed yarn distinct groups of surface curls of various configurations and dimensions are locked by real twist with core yarn [figure 4.1 (a)]. This gives it a very close resemblance to spun yarn-look as well as air jet textured yarn-look. This observation is well supported by the study of co-relation between production mechanisms of air jet texturising [fig.4.2 (a)] with mechanical crimp texturising [figure 4.2 (b)].

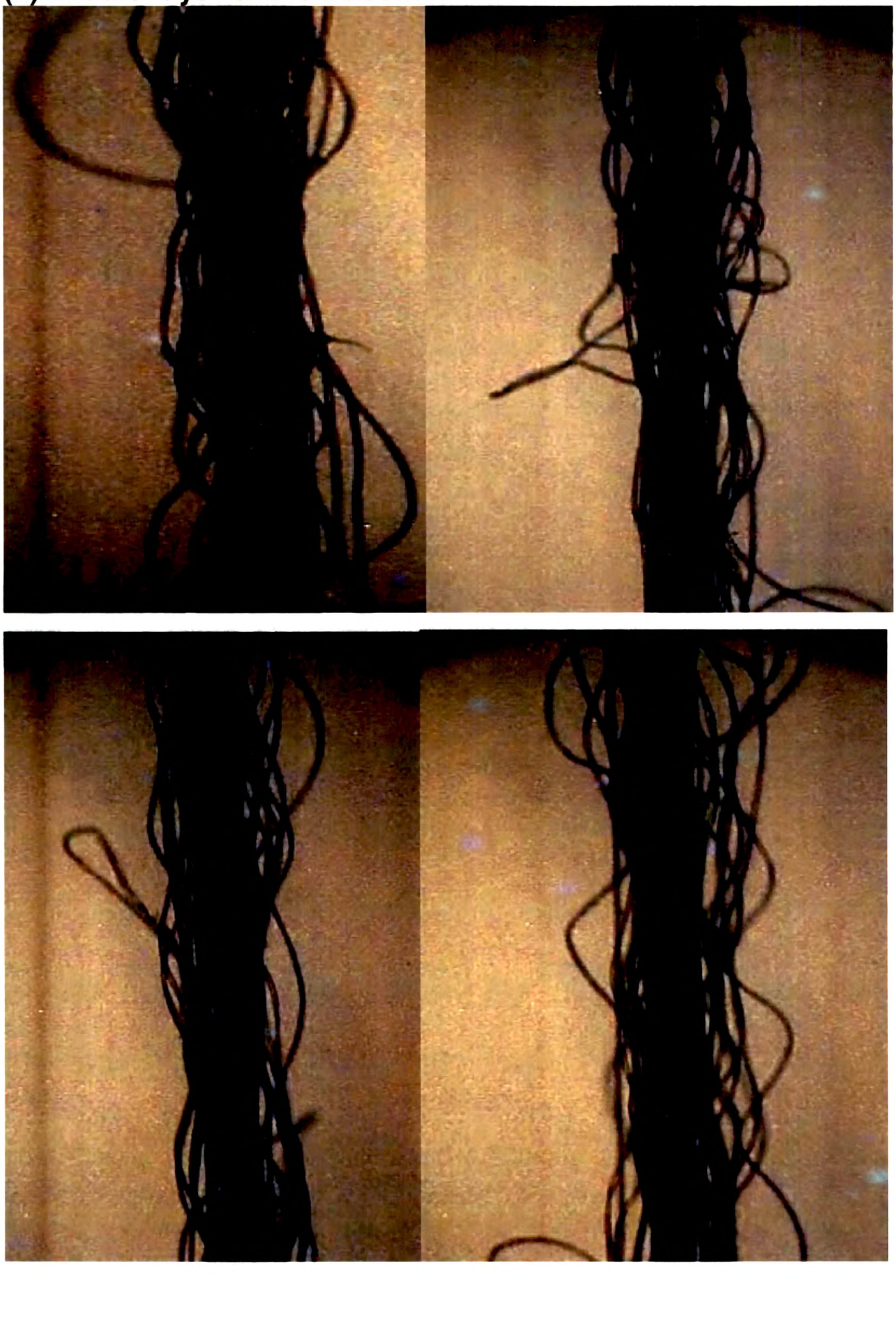
Figure 4.1 (b) Snap-shots# of Microscopical-views of Innovative Textured Yarn.

(i) Top-layer of the bobbin.

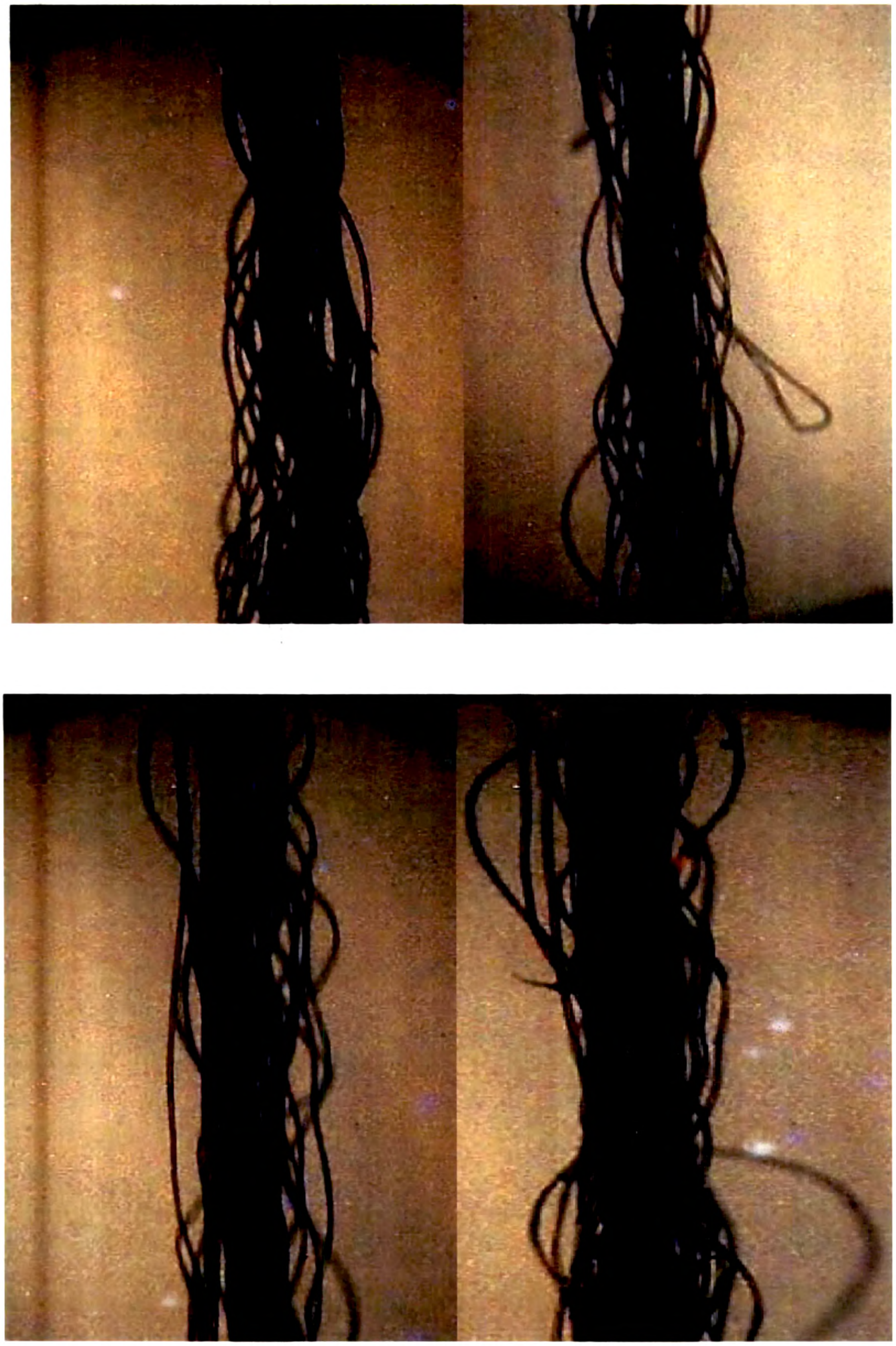


 # Snap shots were taken for 100x magnified views of 2mm section at random interval of length.

(ii) Middle-layer of the bobbin



(iii) Middle-layer of the bobbin.



(iv) Bottom-layer of the bobbin.

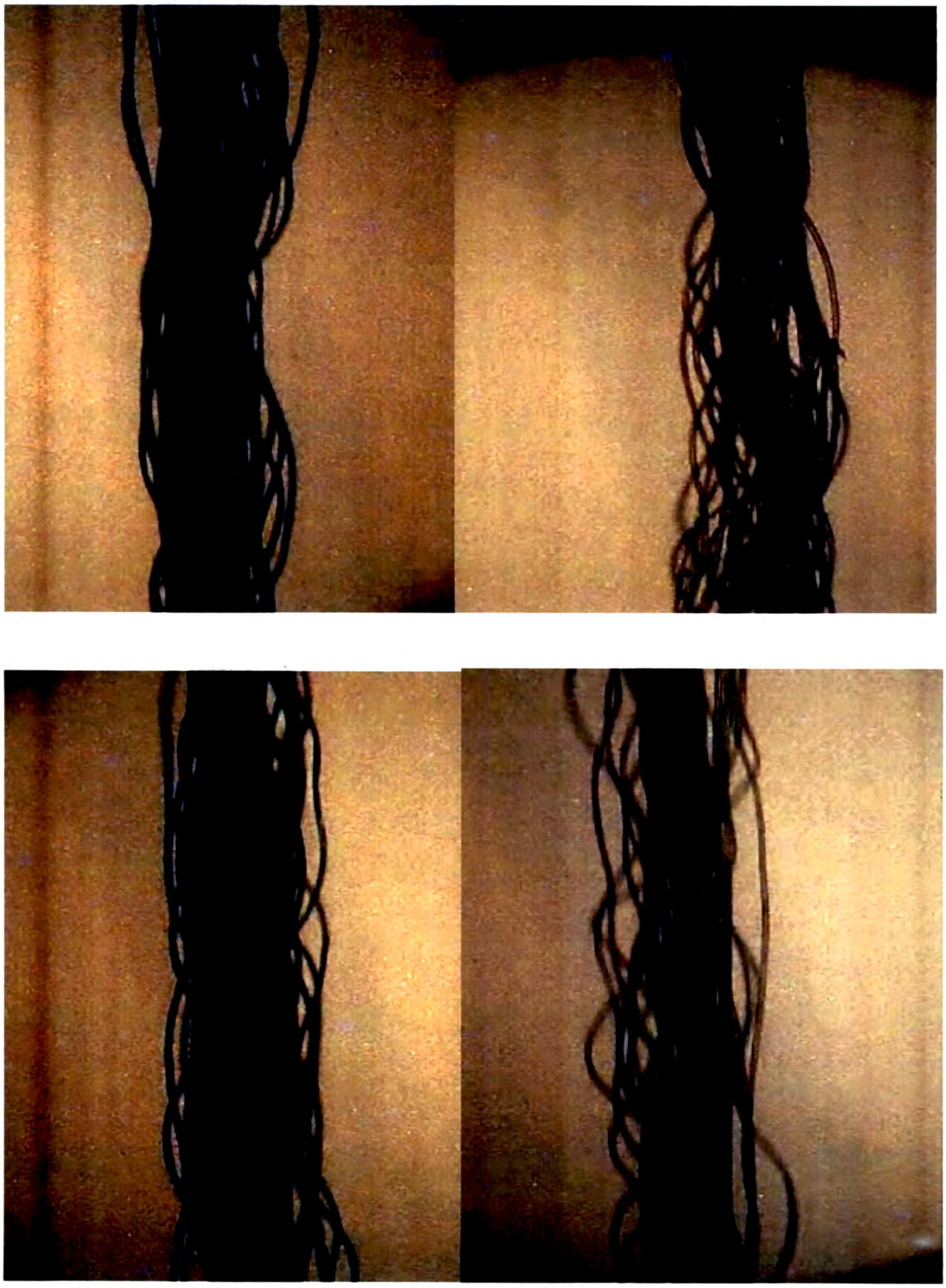
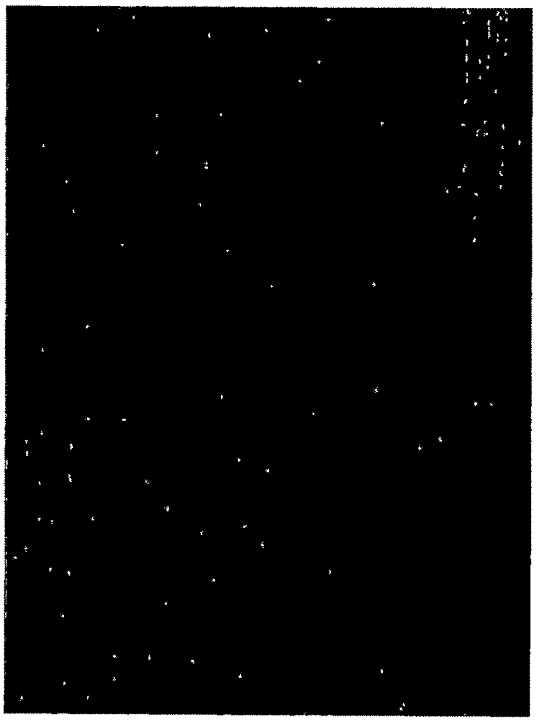
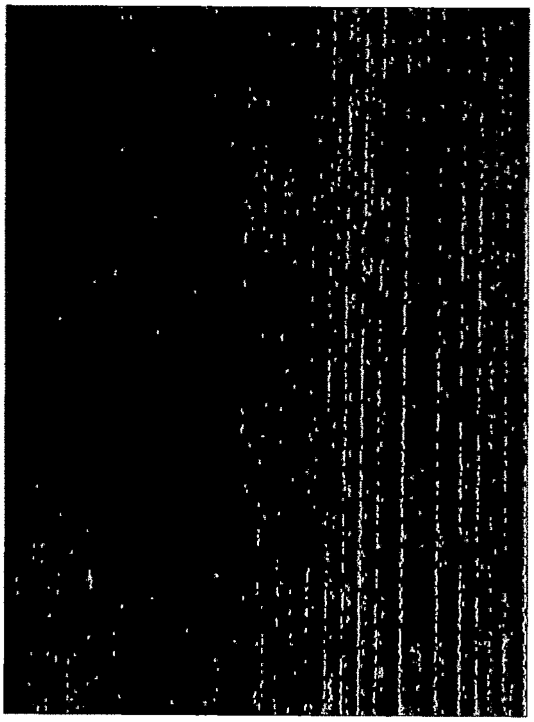


Figure 4.1(c) Innovative Textured Yarn on Wrapping Board (magnified view)

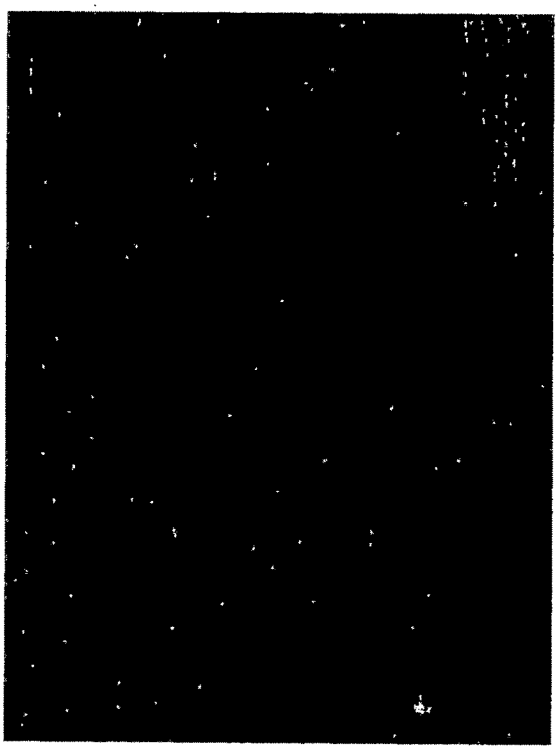
i) Top-Layer



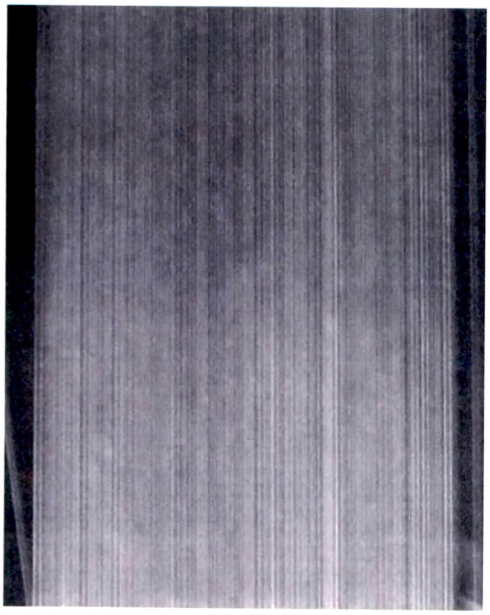
ii) Middle-Layer



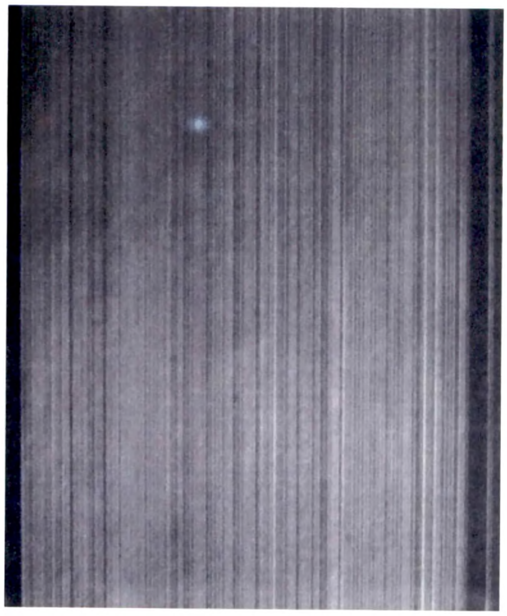
iii) Bottom-Layer (magnified-view)



iv) Top-Layer (normal-view)



v) Middle-Layer (normal- view)



vi) Bottom-Layer (normal-view)

Figure 4.2 (a) Production Mechanism of Air jet Textured Yarn.

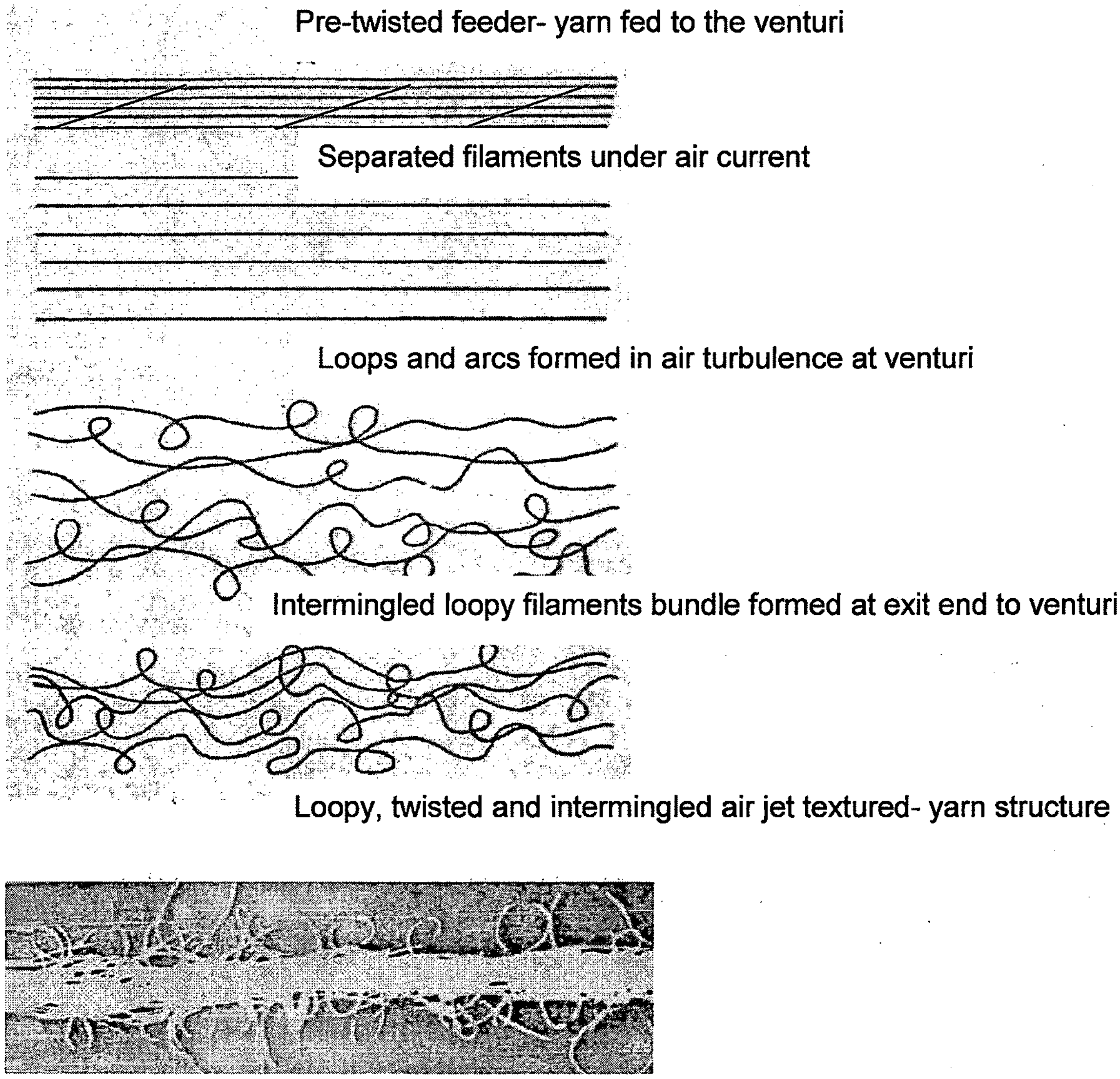
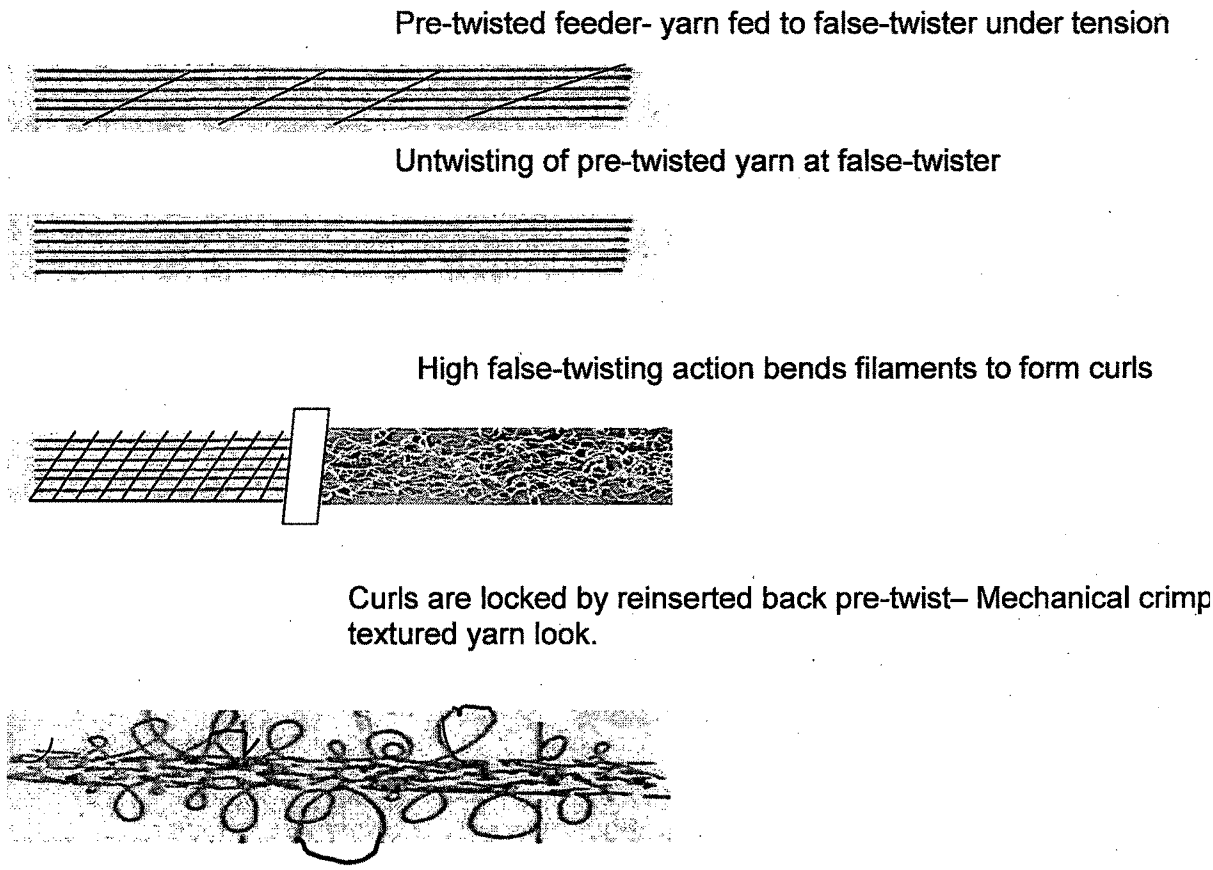


Figure 4.2 (b) Production Mechanism of Mechanical Crimp Textured Yarn.

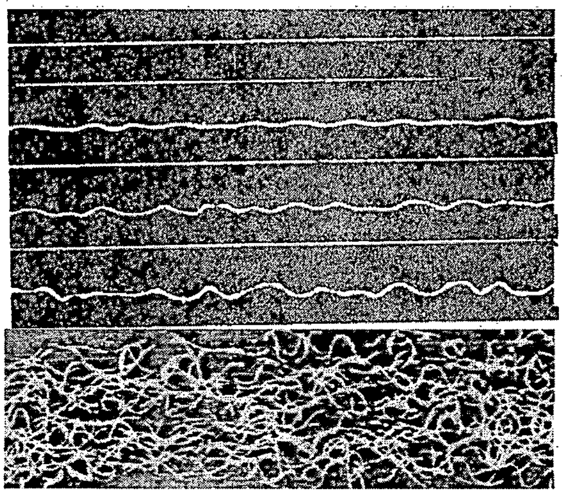


It can be observed from both the production patterns [figure 4.2 (a-b)] that amount of pre-twist has a great impact on the stability of textured structure. In addition to that intermingling of filaments caused due to air turbulence in case of air jet texturising and migration of filaments under tension in case of mechanical crimp texturising plays a decisive role for the stability of newly acquired structure. Concluding this discussion it do not seems exaggerating to mention that behaviour of newly engineered yarn for the stability of its structure goes in closer resemblance to that of air jet textured yarn.

However loops of air jet textured yarn are replaced by curls or crimps in the case of innovative textured yarn [figure 4.2 (b)]. This is mainly attributed to false-twisting action under tension, similar principle to that of false-twist texturising utilized in acquiring curls, but in the absence of heat in the new concept. Thus pattern of crimpiness acquired by newly designed product yarn can be well explained by the physics of false-twist texturising. As per that the extent of crimp and the latent crimping power of individual filaments in a false-twisted yarn vary along the length of the yarn. The crimp amplitude is a function of radial position of the filament occupied within the yarn [figure 4.2 (c)]. The radial position of the filament in turn is thus decided by the migration pattern imposed by the degree of twist and by the tension at which the twist is imparted[4].

As a consequence of this yarn produced with high false-twist level is expected to exhibit high frequency small size curls and vice-versa.

Figure 4.2 (c) Radial-Position occupied by Filaments in Yarn.



- *i) Untextured Yarn ii) Textured Yarn.*

It is expected that owing to similar method adopted for the formation of curls the newly gained structure will behave similar to false- twist textured yarn for its tensile properties, but presence of real twist in product yarn matrix likely to induce difference due to increased inter-filament friction.

Size and degree of crimpiness attained by textured yarn are the two main decisive factors for the bulkiness of zero-twist crimp textured (false-twist textured) yarn. But use of real-twist in innovative texturising again makes it to behave differently in terms of bulk from false-twist textured yarn. Even morphological changes caused due to heat-setting in false-twist texturising are absent in the new product.

Thus it is right at this stage to conclude that although crimpy structure of the new product yarn follows similar phenomenon of false-twist texturising, bulk and mechanical properties of two system yarns are no more be comparable.

Thus methods and standards followed for the measure of instability of loops of air jet textured yarns are compatibly used for the measure of instability of crimpy structure of innovative textured yarn. But due consideration is required for pre-twist level in the innovative yarn structure while evaluating it for bulk and mechanical properties with structurally very close false-twist textured yarn. Based on this phenomenon results are discussed in all forthcoming sections.

4.4 Evaluation of the Quality Parameters of Innovative Textured Yarn with standards. (Set-I: Pilot Trial)

Structural study of innovative yarn (section 4.3) has characterized it as an intermittent structure to that of false-twist textured yarn and air jet textured yarn. Based on that suitable method of measure of various quality parameters for thorough analysis of product yarn have been diagnosed (section 3.2). Following quality parameters were measured for the pilot trial product under the study by implementing recognized methods.

- Denier and Increase in denier.
- Tenacity and Reduction in tenacity
- Percentage breaking extension.
- Physical bulk
- Crimp stability
- Twist
- Percentage boiling water shrinkage
- Uniformity
- Dyeability and Strippiness.

Quality check of prototype innovative textured yarn sample was carried out at the physical testing lab in the department. The results were verified further by a ISO recognized standard lab in this field accepted in the industry. In the absence of lime-light of back-track record for this newly engineered yarn, structural-characteristics of the product yarn have provided the ground for the evaluation. Looking at the simulation in the principles adopted in attaining crimpiness (similar to false-twist texturising) and stability of crimpy configuration (similar to air-jet texturising) as per described in section 4.3 related properties of the product yarn are analyzed. Reference has been made to standards followed in reputed industries in the respective field for equivalent size textured yarn-values. However Du Pont[56] method was adopted for the measure of instability respective standard has been considered for the evaluation of instability measure of innovative textured yarn. Figure 4.3 represents the comparison of the sample values of pilot trial innovative yarn with the respective standard values for equivalent yarn identified as per the method of measure adopted during study.

4.4.1 Denier and Increase in Denier

Product yarn has executed 95 denier at the selected pre-twist and false-twist levels (figure 4.3), twenty percent higher value as compared to feeder yarn denier of 79d (after under feed of 25%). This value of product yarn denier in the present experimentation depends mainly on the degree of crimpiness achieved and the amount of pre twist used. As introduction of crimp as well as twist to the flat configuration of the parent yarn are prone to cause contraction[40]. Contraction in the length results in increased linear density. More the crimpiness and the twist level more will be the contraction, results in more increase in denier[4,19].

There is a difference in the form of raw material utilized between existing and reference system, viz; use of fully drawn yarn instead of partially drawn yarn. Thus comparison of percentage increase in denier of present textured yarn product with reference false-twist texturising system standard is not found realistic.

4.4.2 Mechanical Properties

Mechanical properties of textured yarn refer to tenacity, percentage reduction in tenacity and percentage extension values of innovative yarn. Test results for the measure of these properties for new product along with the reference standard of false-twist textured yarn have been reported in table 4.1(a)

Table 4.1(a): Mechanical Quality Parameters of Prototype Innovative Textured Sample Yarn (Set I).

Sr.No.	Property	Sample Value	Reference Standards of False twist textured yarn
1.	Tenacity of parent yarn (gpd)	3.60	4.85
2.	Tenacity of textured yarn (gpd)	2.76	3.80
3.	Decrease in tenacity (%)	22.45	21.6
4.	Parent yarn Extension (%)	35.00	50.00
5.	Textured yarn Extension (%)	28.61	25

- *gpd = gram per denier*

From the results it is quite clear that mechanical properties, viz; tenacity, percentage reduction in tenacity and percentage extension values of innovative yarn are showing good agreement with the standards of false twist textured yarn. However low tenacity value is reported for newly designed yarn as compared to standard value followed for false-twist textured yarn (figure 4.3). This is mainly attributed towards the low tenacity value of parent yarn itself [table 4.1(a)].

Although parent yarn has low percentage extension than reference standard, prototype yarn has executed better extension value than standard pointing towards better texturising (crimping) effect.

Proportionate higher drop in tenacity value for present yarn supports this presumption [table 4.1(a)].

4.4.3 Physical Bulk

Degree of crimpiness attained is the only factor influencing bulkiness of false-twist textured yarn as well as prototype yarn. Although bulking media utilized, viz; false-twisting action for attaining crimpy configuration is same in both the systems, difference in subsequent setting treatments make their bulking behaviour different. Thermodynamic mode used for setting crimping configuration for former yarn brings about morphological changes in textured yarn structure and thereby establish bulk in the form of latent property[3, 4, 46]. Mechanical mode (real-twist) has been used for the latter case yarn and in the absence of heat, newly acquired crimpy structure purely become a physical characteristic of product yarn. Thus similar to air jet textured yarn, curl size and curl frequency controls bulk of newly textured yarn. So, crimp rigidity method is not found reliable means for bulk measure.

Lacks of precision in measuring curl size and curl frequency similar to air jet textured yarn has prompted the use of more reliable bulk-factor (θ) method[40], described in section 3.2.5.2. This method was adopted for the measure of false-twist textured yarn bulk by Burnip et al.[46] However he had faced the difficulties in the measure due to higher mobility of zero-twist textured yarn, but the presence of pre-twist in pilot trial yarn has resolved the problem. Following this method bulk-factor of the order of "15.26" has been observed for prototype innovative textured yarn sample. Industrial standards for false-twist textured yarn are laid down in the form of crimp-rigidity value only. So, owing to the difference in the measures adopted, comparison of bulk value with standards of false-twist texturising system has been ignored at this stage.

4.4.4 Crimp Stability

Instability for pilot textured yarn has been measured by Du Pont[56] method. It was observed to the order of 2.5 percent. Which is well within the acceptable Du Pont limit of 5%, established for reference air jet textured yarn[56].

4.4.5 Twist

Twist for the present study refers pre-twist of innovative textured yarn. Theoretical set value of pre-twist level was 315 twist per meter, calculated from the gearing of the machine. Whereas 307 twist per meter has been measured for the textured yarn. Some difference between actual twist in the yarn and theoretical set up is likely due to mechanical limitations.

4.4.6 Percent Boiling water shrinkage

Percentage boiling water shrinkage depends mainly on the basic characteristics of parent yarn as well as presence of amorphous region in the constituent filaments of the yarn. On texturising amorphous region gets increased in direct proportion to degree of texturising attained. So, increase in boiling water shrinkage of textured yarn (2.0 %) as compared to parent yarn (4.4%) is likely. However percent boiling water shrinkage (2.0 %) of the parent yarn used in the present experimentation itself is lower than the reference standard value (8%) for equivalent 100d/48 fully drawn polyester yarn. So percentage boiling water shrinkage value reported for newly textured yarn likely to be lower than the suggested reference standard (10-12%) for respective textured yarn.

4.4.7 TKD (Tube Knitting and Dyeing) test.

Figure 4.3 (b-c) represents the results of TKD (Tube Knitting and Dyeing) test. Increased dye uptake has been found for the product yarn hose as compared to parent yarn hose. This is mainly attributed to the increased amorphous region in textured yarn due to favourable deformation, also confirms the texturising of flat feeder yarn[4, 15]. Even signs of unlevelness (barriness) in the knitted tube that has been dyed with help of carrier are not found, confirms uniformity of texturising effect [32]. Tube knitting and dyeing test result has thus confirmed the potential of new system for texturising.

Thereby it becomes interesting to evaluate innovative textured yarn, an intermediate structure to false-twist texturising and air jet texturising thoroughly.

Figure 4.3 (a) Comparision of Innovative Yarn Quality Parameters with Standards.

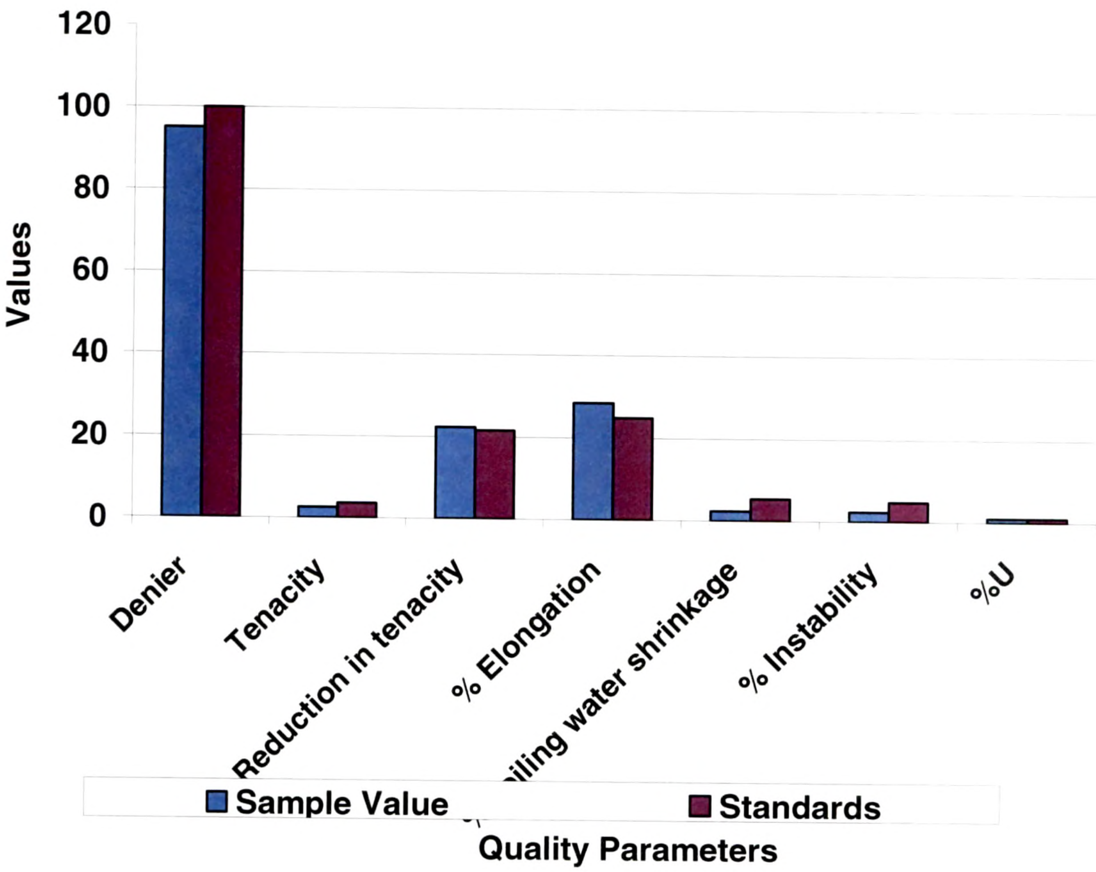


Figure 4.3 (b): Tube Knitting and Dyeing Sample of Parent Yarn.

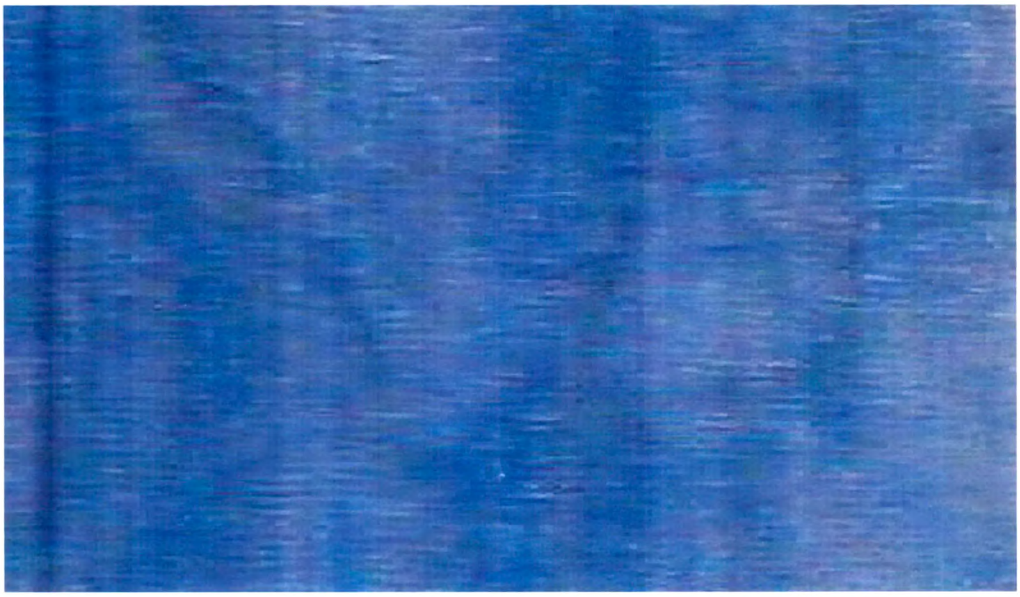
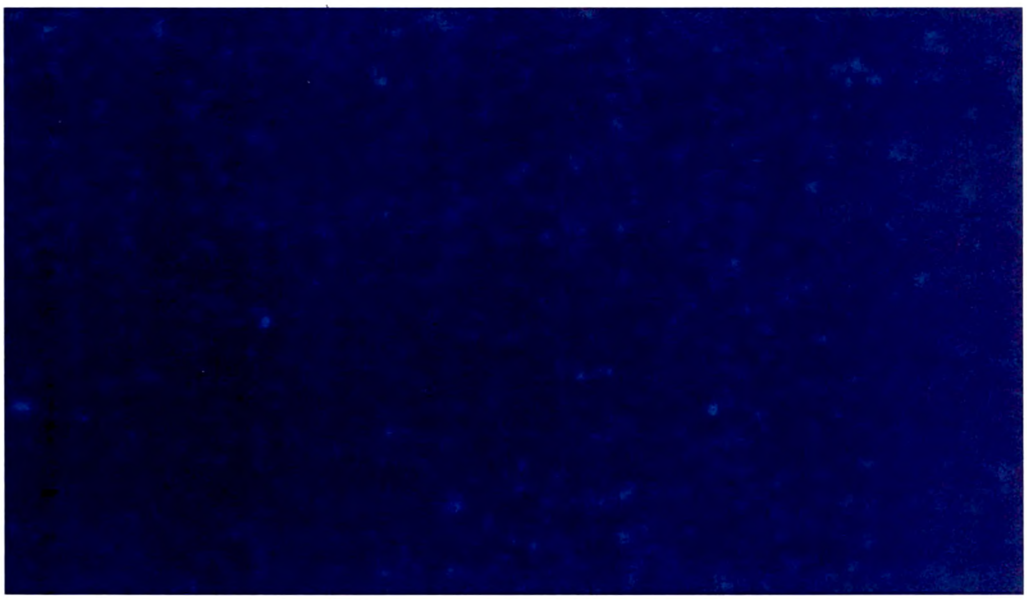


FIG. 4.3 (c): Tube Knitting and Dyeing Sample of Textured Yarn.



Effect of Process-Variables and Material-Variables On Structure and Properties of Innovative Textured Yarn.

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

An innovative textured yarn is similar to spun yarns in terms of its appearance and physical characteristics. This similarity arises from the unique texturising process in which a flat synthetic multifilament yarn has given a spun-like structure with a compact core and surface curls occurring at irregular intervals along its length (section 4.3). Apart from the structural characteristics the instability, linear density and strength of the product yarn determines its performance. Such characteristics are affected by various process parameters and supply yarn properties. The effect of these parameters on the final yarn properties have been investigated using instability, linear density, and strength tests, together with microscopical photographs for visual assessment of the yarn structure.

Pre-twisting and false-twisting of the flat feeder yarn are the most critical operations encountered during this process of mechanical crimp texturising. The magnitude of either of twist inserted during texturising influences bulk, crimp, strength and extension at break characteristics of the end product. Experiment has been conducted as per given in section 3.1.2.2, (set-II, Group: A) for studying the effect of these major process variables on the new type of textured yarn.

Delivery speed and bulking-zone length are the next variables in the sequence of importance. Their impact on the newly engineered yarn has also been identified in this section.

4.5.1 Effect of False-twist on the Performance of Textured Yarn. (Group: A)

Effect of false-twist on the performance of the innovative textured yarn has been studied at four selected levels. Effect of false-twist varies depending upon the amount of pre-twist used during texturising. So, in this set of experiment four groups (table 3.3) have been made, viz; Group-1: sample A1- sampleA4,

Group-2: sample A5-sample A8,

Group-3: sample A9- sample A12,

Group-4: sample A13- sample A16.

Each group composed of four samples. They were produced at increasing magnitude of selected false-twist level in a sequence at an established pre-twist level for a group (table 3.3). Pre-twist value has been kept constant for a particular group, but its value was increased by 2 tpi for the next group followed in ascending order of sequence, viz; 2 tpi(79 tpm) for group-1, 4 tpi (158 tpm) for group-2, 6tpi (236 tpm) for group-3 and 8 tpi (315 tpm) for group-4. However false-twist levels pattern followed for constituent samples were replica of previous group.

Results are therefore discussed first by the virtue of product yarn performance for different false-twist level used during production process for constant pre-twist level. Latter effect of varying the pre-twist for identical false-twist level is diagnosed.

Following this pattern in the first step of evaluation only results of first group (sample A1- sample A4) are considered. Table 4.2 (a-b) represent the same. Just considering these following observations were made.

Table 4.2 Effect of false-twist on the textured yarn. (Group: A)

(Parent yarn 100denier/48fils, underfeed of 25%,

Delivery speed = 50m/min, Bulking zone length = one inch)

Pre-twist = 78.7tpm

(a) Texturising Properties

Sample-code & description	Twist (tpm)	Denier	Increase in Denier (%)	Boiling water shrinkage (%)	Bulk Factor (θ)	DuPont Instability (%)
A1, 1970F.T.	81	91.5	15.8	4.08	16.1	4.65
A2, 2364F.T.	78	91.8	16.2	4.36	16.3	4.43
A3, 2560F.T.	84	92.3	16.8	4.38	19.9	4.21
A4, 2757F.T.	79	93.4	18.2	5.05	24.3	3.91

- F.T. = False-Twist in tpm, tpm =twist per meter, gpd = grams per denier

---

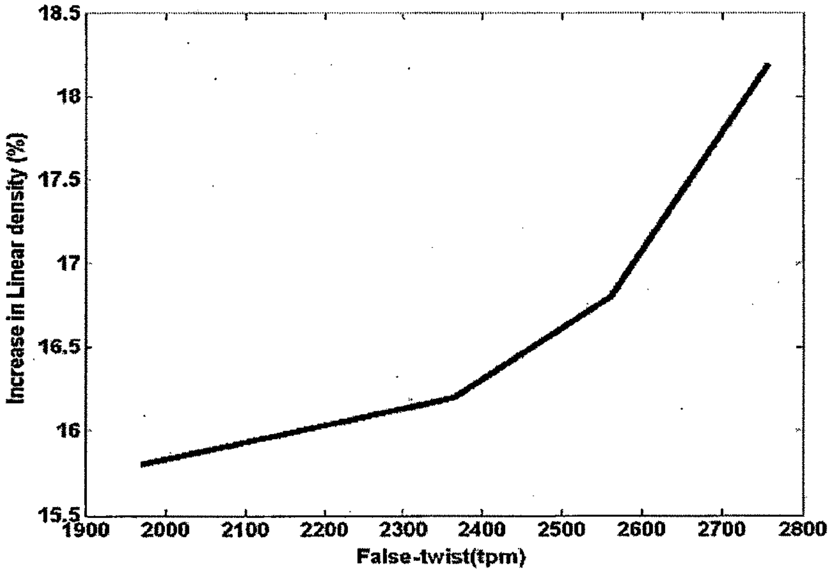
4.5.1.1 Increase in Linear density and Physical Bulk

It can be observed from the results [table 4.2(a)] that on mechanical crimp texturising, the resultant yarn increases in linear density and bulk as compared to feeder yarn. This is mainly attributed to contraction caused to longer length of synthetic filaments due to crimping and pre-twisting compacting them into shorter lengths with an entangled, stable structure. This shortening causes the volume (bulk) and linear density (linear density can be defined as the mass per unit length of a yarn) of the yarn to increase proportionately. This argument is substantiate by figure 4.4(a-b).

Figure 4.4 Effect of False-twist on Texturising properties.

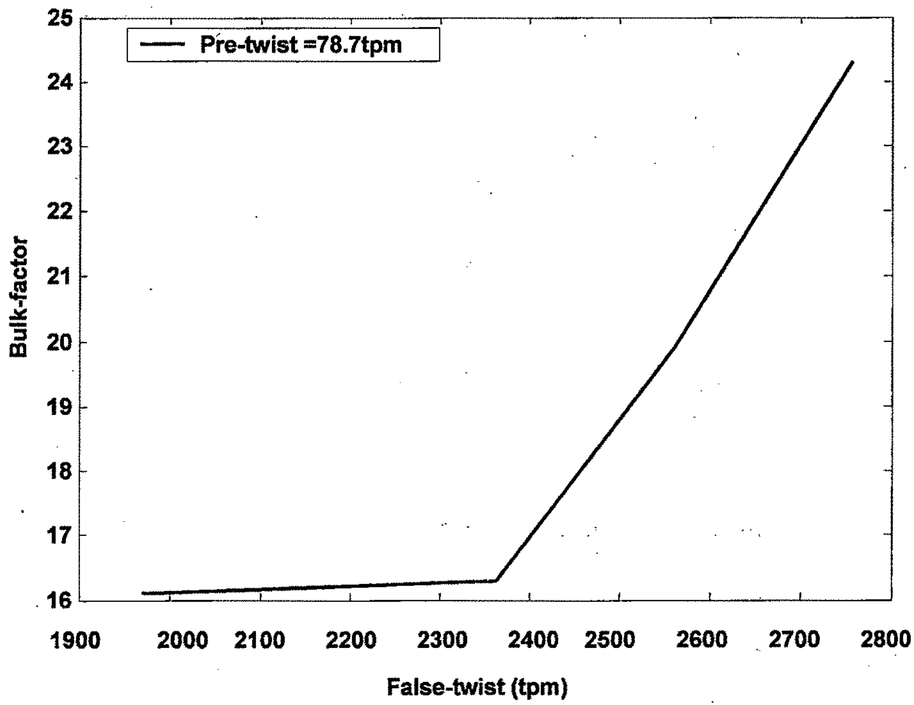
(Pre-twist =78.7 tpm)

(a) Textured Yarn Denier



(b) Textured yarn Bulk-factor

Effect of False-twist on Bulk-factor of Textured yarn



Degree of crimpiness has increased with the increase in false-twist level from 1970 tpm to 2757 tpm. These follows from the increased number of small curls as depicted by photographs of microscopical-views [figure 4.5 (a)].

Figure 4.5 (a) Photo-graphs Of Microscopical-views.

(I) Sample A1

False-twist: 1970tpm

(ii) Sample A4

False-twist: 2757tpm

Figure 4.5 (b) Photo-graphs of Tube Knitted and Dyed samples.

(I) Sample A1

(ii) Sample A4

This behaviour can be well explained by the basic twist-theory of filament yarn described by Goswami et al[4]. and Hearle et al[50]. According to that filaments are bent into helical forms on twisting. For the identical linear density (C) and specific volume (Vy) of yarn, number of turns of twist per unit length (N) decides angle of twist 'α'. Higher the turns per unit length more will be the twist angle (helix angle) and thereby more will be the deformation. Going in agreement sample A4 produced at highest false-twist level in a group has exhibited increased curls density [figure 4.5 (b)]. Thus it is convenient to conclude at this stage that for constant pre-twist, with the increase in the false-twist level, product yarn increase in the bulk and linear density.

4.5.1.2 Percent Boiling water shrinkage

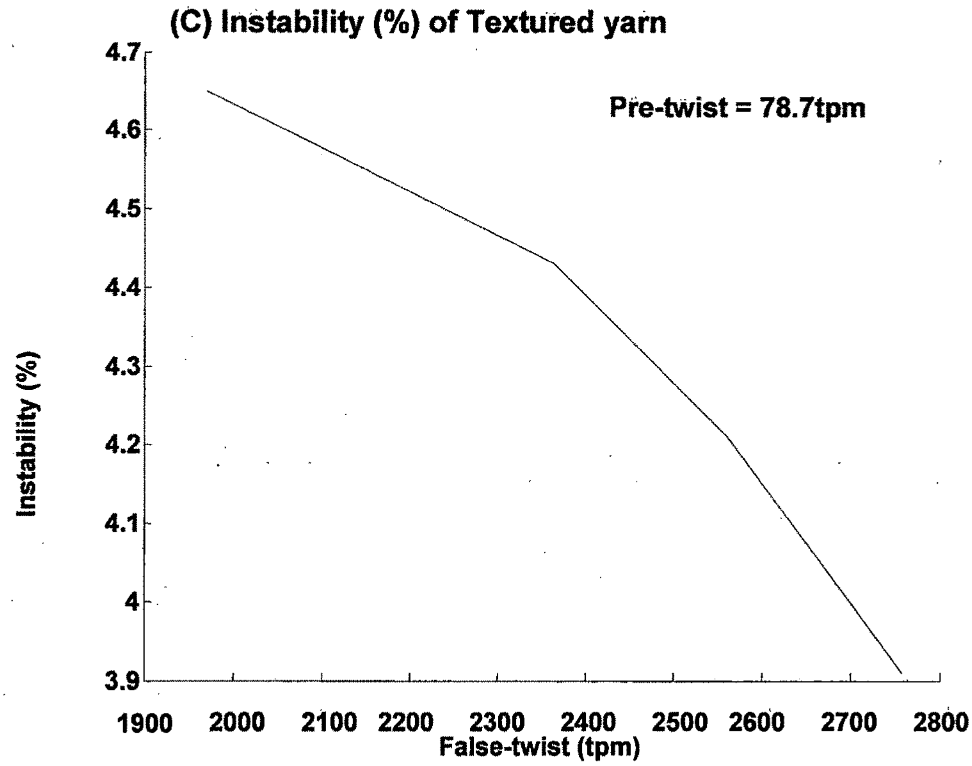
Percent boiling water shrinkage has been increased for textured yarn as compared to parent yarn for all the samples under consideration as per the results shown in table 4.2(a). Increment is higher for textured yarn produced at higher false-twist level for a selected pre-twist level [figure 4.4(d)]. This is mainly attributed to the proportionate increase in the amorphous region in textured yarn structure as compared to flat feeder yarn on achieving better conditions of texturising[3]. Going in agreement to this phenomenon dye uptake of the knitted hose (TKD-test) made up of sample A4 (better textured yarn at high false-twist level) is found to be higher [figure 4.5 (b)].

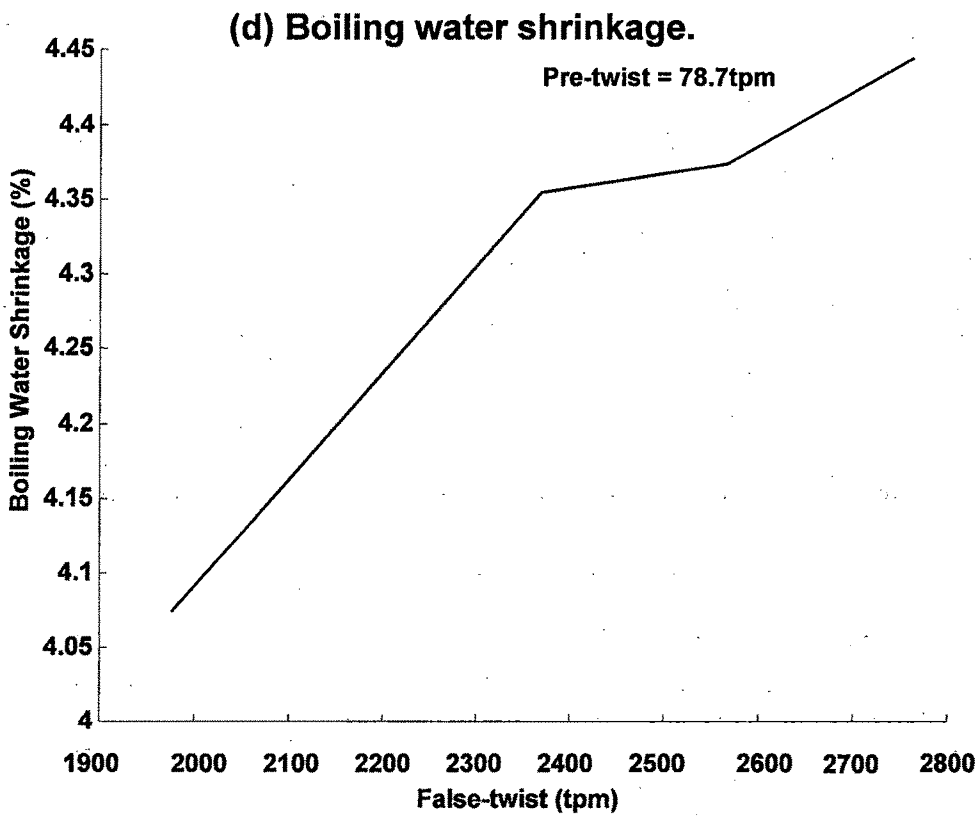
4.5.1.3 Percent Instability

Curls or crimps can be pulled out easily would be disadvantage in fabric forming process, since the bulk of the yarn could be reduced and the possibility of fabric irregularity increased. Owing to the similarity in the production process (section-4.3), instability of air jet textured yarn and that of newly designed yarn is affected by the amount of pre-twist inserted and degree of intermingling attained due to filament migration during the course of bulking[15, 31].

Figure 4.4 Effect of False-twist on Texturising properties.

(Pre-twist =78.7 tpm)





Showing good agreement to this phenomenon yarn sample A1, produced at lowest false-twist (1970 tpm) has executed highest instability amongst all [table 4.2(a) and figure 4.4 (c)].

This is mainly attributed to higher mobility of loosely packed yarn structure produced at selected low level of locking-twist. Less intensive mingling of long curls occurred at low false-twist level figure 4.5 (a)] has added to mobility of product yarn and made it further instable. This argument found support from the reduction in instability value observed with the increase in false-twist level for identical pre-twist [figure 4.4 (c)].

However this higher value of instability is well within Du Pont[56] acceptance limit of 5 percent, established for air jet textured yarn.

4.5.1.4 Twist

Pre-twist level of 78.7 tpm has been calculated from the respective drive set-up used for two for one twister and take-up system on the lab-apparatus. Due to mechanical limitations of the drive some variations in practically measured [table 4.2(a)] and theoretical set values are likely.

4.5.1.5 Mechanical Properties

Mechanical properties of the textured yarn refer to its tenacity, percentage extension and percentage reduction in tenacity of textured yarn as compared to parent yarn. Sample values measured for the group under consideration have been reported in table 4.2(b) as well as presented graphically in figure 4.6(a-b).

Table 4.2 Effect of false-twist on the textured yarn. (Group: A)

(Parent yarn 100denier/48fils, underfeed of 25%,

Delivery speed = 50m/min, Bulking zone length = one inch)

Pre-twist = 78.7tpm

(b) Mechanical-Properties

Sample code	Tenacity (gpd)	Reduction in Tenacity (%)	Extension (%)
A1	2.83	17.14	25.50
A2	2.78	20.51	26.92
A3	2.69	23.14	28.12
A4	2.59	26.00	29.98

- ***gpd = grams per denier***

Figure 4.6 (a) Effect of false-twist on Tenacity of Textured yarn

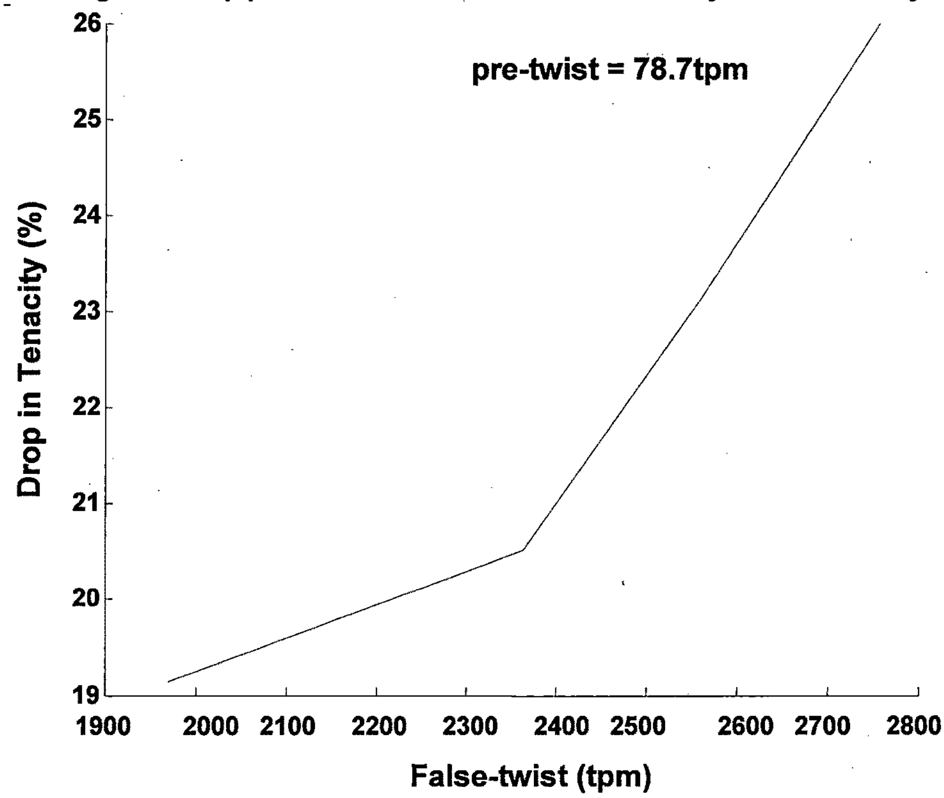
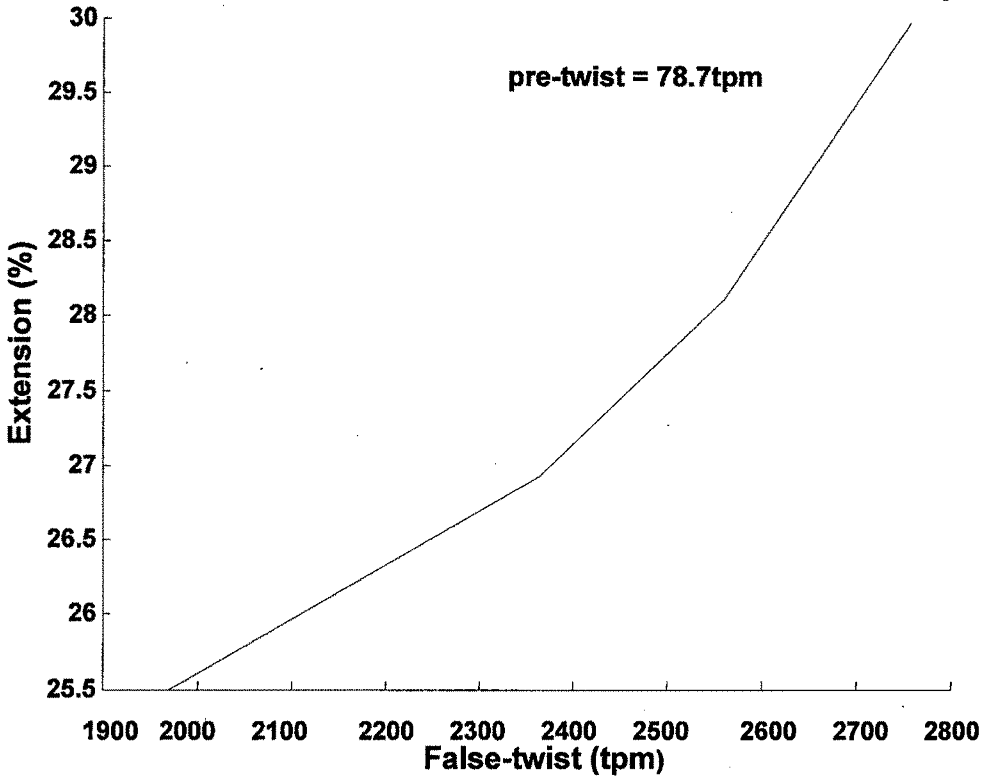


Figure 4.6 (b) Effect of false-twist on Extension of Textured yarn



It can be observed from the results [table 4.2(b)] that textured yarn produced at highest false-twist, viz; sample A4 has executed highest extension and maximum reduction in tenacity [figure 4.6(a)].

Mechanical properties of newly mechanical textured yarn are thus greatly influenced by the kind and the amount of strain deformation that individual components of the yarn-structure have suffered. For identical raw-material used, increase in the false-twist level has caused the filaments not only to attain higher rotational velocity at the texturising zone but also allowed to undergo higher bending-deformation. This has made the filaments to reverse their positions more frequently (increased intermingling caused due to higher migration) within the yarn matrix and lead towards the formation of more number of small size crossed curls for samples A4 [figure 4.5

(b)]. Thus less number of straight filament segments has been left behind to share the applied load. So, higher drop in the tenacity value with the increase in false-twist level (for sample A4 in a group) is likely [figure 4.6(a)]. Even presence of higher number of small curls [figure 4.5 (b)] due to better texturising conditions attained has also allowed the same (sample A4) to show highest extension as compared to other textured yarns in the group [figure 4.6 (b)]. Thus for identical feeder yarn used, extension behaviour of textured yarn has gone in closer resemblance to Grosberg[75] . According to his finding extension of the textured yarn reported is the outcome of the straightening of the curls and the extensibility of the feeder yarn.

It becomes interesting now to study the load-elongation behaviour of this newly engineered yarn. So, the forgoing section deals with the tensile behaviour of the innovative textured yarn observed during the study.

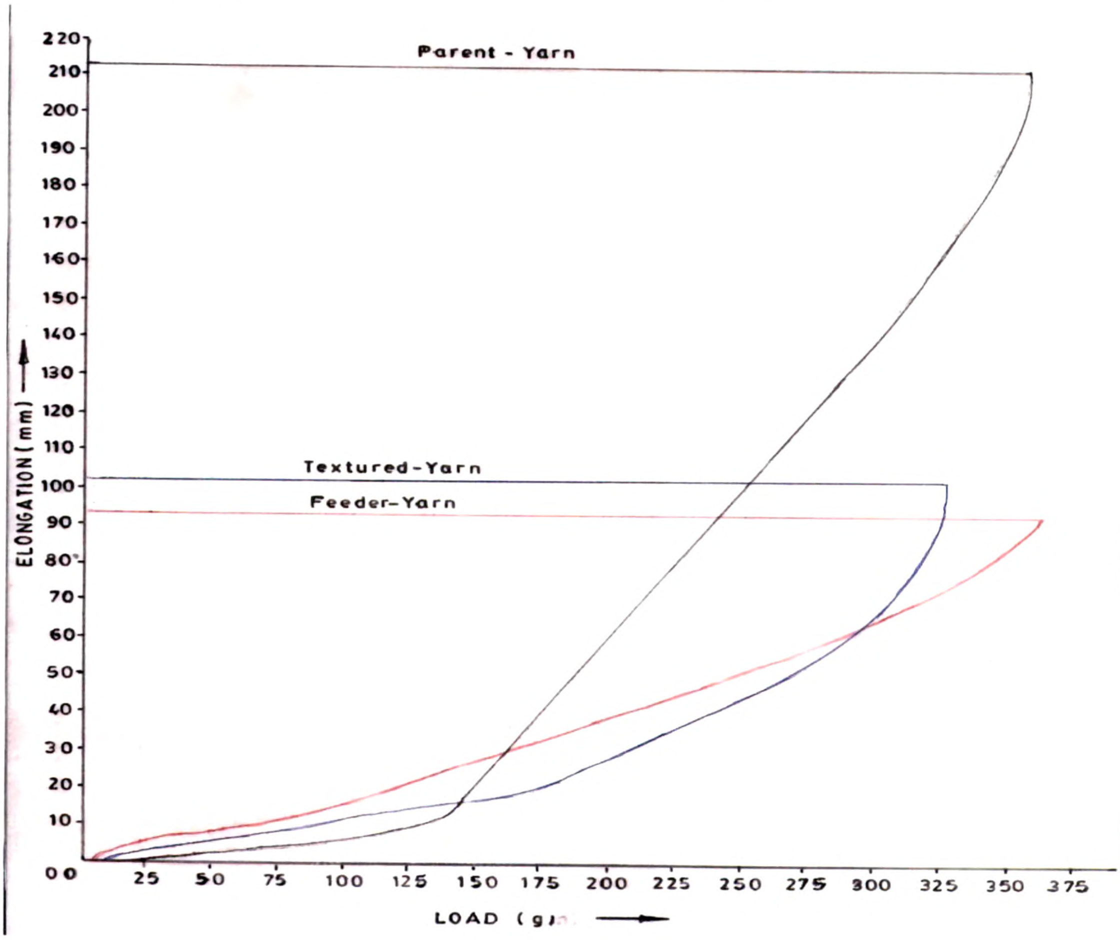
4.5.1.6 Tensile Behaviour of Innovative Textured Yarn.

Comparison of the load elongation curves [figure 4.7(a)] of the parent yarn (untextured), feeder yarn (drawn and pre-twisted) and textured yarns reveal striking differences.

i) Parent Yarn Tensile Behaviour

All the filaments in a parent yarn simultaneously share the applied load to the yarn, and they first deform elastically. When the load is increased beyond the elastic limit, all of the filaments are then plastically deformed, exhibiting an increasing strength under this increasing load up to the yield point where they start to elongate rapidly. When the stress in an individual filament exceeds its breaking stress, it will break regardless of the other filaments' conditions. Therefore, in a parent yarn, the filament break singly at different times, probably due to slight variations in their diameter, and some of the filaments appear to elongate more than others. Nevertheless, for the purpose of the strength tests, the load that causes most of the filaments to break is taken as the breaking load for the yarn, and the corresponding elongation is regarded as the breaking elongation.

Figure 4.7 (a) Comparison of Load-Elongation Curves



ii) Feeder Yarn Tensile Behaviour

Feeder yarn refers the drawn and pre-twisted parent yarn. The behaviour of feeder yarn against the applied tensile load is similar to that of parent yarn in terms of initial elastic deformation followed by plastic deformation. But presence of real-twist in yarn structure and drawing caused due to under feed differ it in terms of its breaking load and elongation values.

Drawing action improves filament orientation, and thereby increases breaking load value but elongation diminish in direct proportion to the amount of under feed done[3].

On the contrary twisting of filaments exerts lateral forces that increases the inter-filament friction; delay the rupture, and thereby increases breaking load as well as elongation[4].

Net effect of both the factors [figure 4.7 (a)] resulted in increased breaking load but reduced elongation of the feeder yarn as compared to its parent yarn.

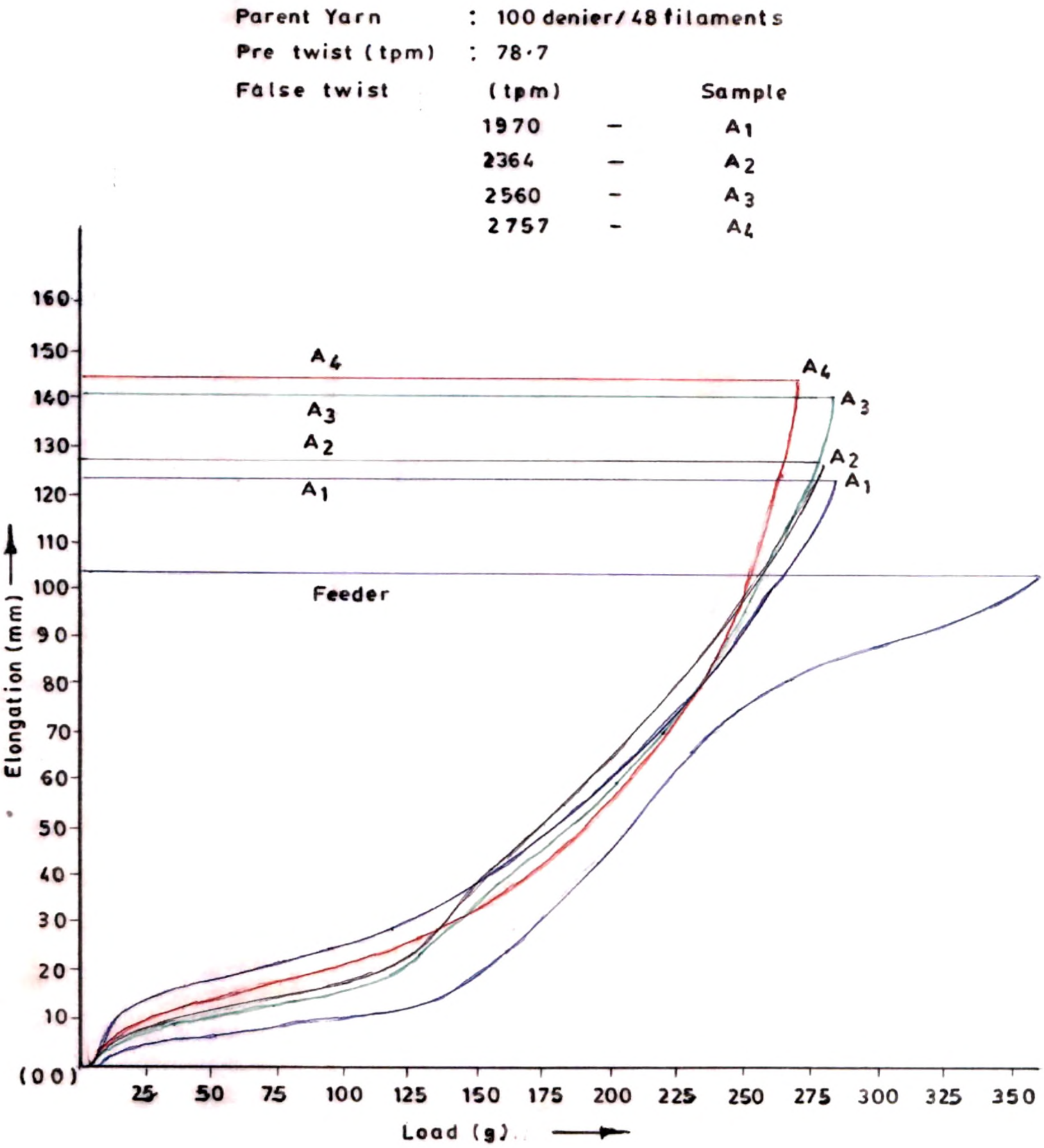
iii) Innovative Textured Yarn Tensile Behaviour

Innovative textured yarn, however exhibits totally different load elongation characteristics. The crimped filaments are randomly entangled (due to intermingling) and locked by pre-twist at regular interval in the newly acquired textured yarn structure [figure 4.1]. Some of these local entanglements and curls are removed under the applied load. So, the deformation of a textured yarn starts with permanent elongation. No, hardening of the textured yarns occurs as the loading increases, because none of the individual filaments are continuously subjected to the applied load during the entire test period. All the filaments exhibit entangled curls and twisted sections intermittently along their lengths. But these are separated by straight portions of filaments. At any section of the yarn, at any particular instance, only these straight portions will resists the applied load. However, when the curls associated with these particular filaments have been opened under the applied load, their effective lengths are increased; consequently some other, less straight slack filaments in the same region may become subject to the applied load and in turn contribute to carrying it.

Degree of entanglement of these load bearing filaments solely depends on the intensity of migration achieved during bulking. Migration increases in direct relation to the tension imposed during false-twisting. Thus at higher false-twist level formation of well entangled high frequency small size curls are likely. At low pre-twist level, lateral binding forces are less, facilitates in increasing the breaking elongation due to opening of higher number of curls before rupture as compared to flat feeder yarn [figure 4.7(b)].

These load bearing filaments are also locked firmly due to entanglement (mingling caused due to migration) and real-twist (pre-twist). It is most likely that only fewer load carrying straight filaments were left behind for the yarn carrying more effectively entangled filaments (due to higher false-twist). These surrounded filaments and exerting lateral forces that increases the inter filament friction at this section. This load bearing firmly entangled filaments will then rapidly reach the breaking point simultaneously within a very short time, and consequently an almost instantaneous breakage of the yarn will occur at this section.

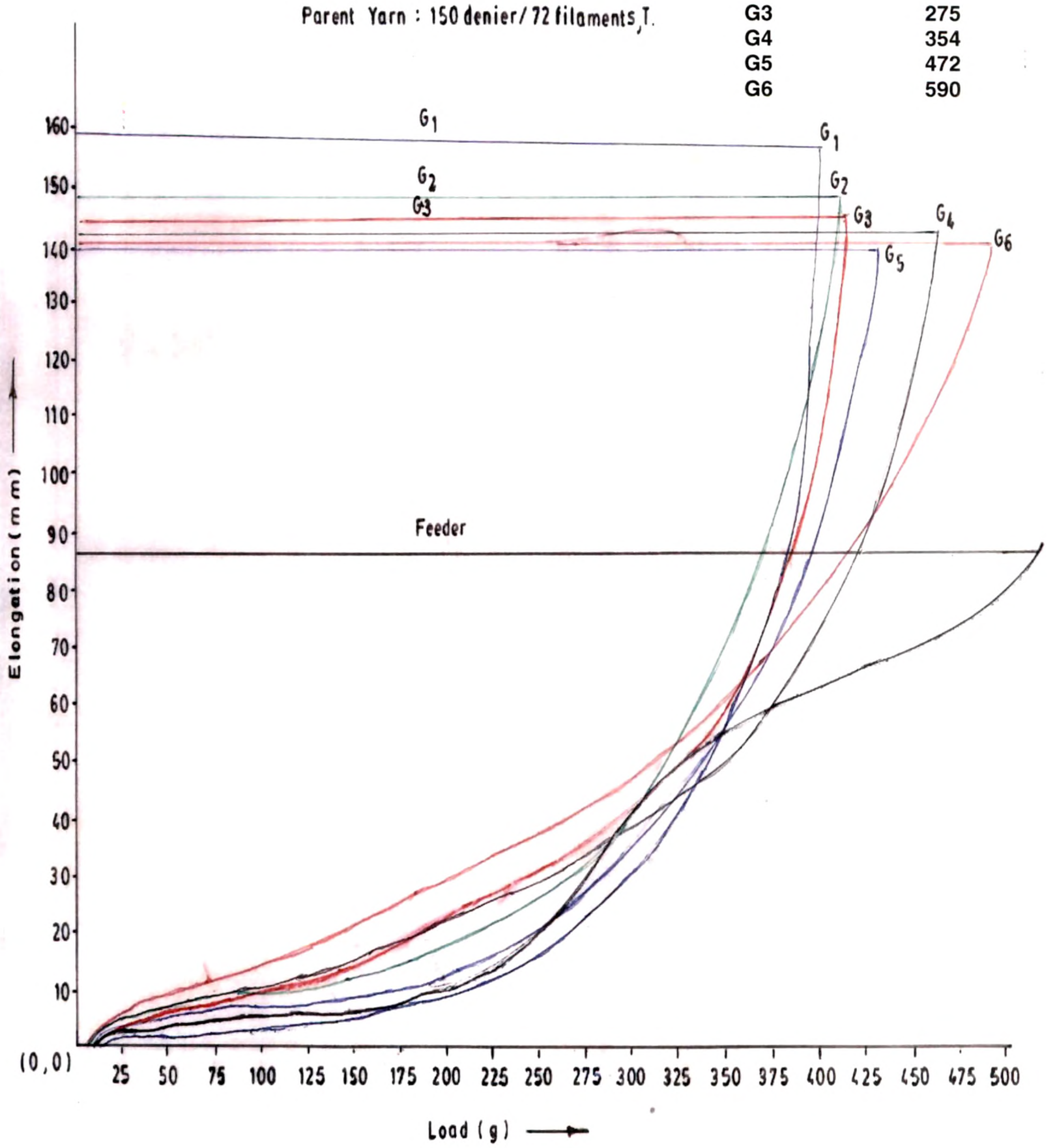
Figure 4.7 (b) Effect of False-twist on Load-Elongation Behaviour of Textured Yarn.



If the pre-twist value is higher along with higher value of false-twist employed, then locking will be more firm due to further increase in inter-filament friction. Such product executes lowest elongation value for higher breaking load employed [figure 4.7(c)].

Figure 4.7 (c) Effect of Pre-twist on Load-Elongation Behaviour of Innovative Textured yarn.

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



The characteristics of load-elongation curves of an innovative textured yarn and a spun staple cotton yarn are found similar.

4.5.2 Effect of Pre-twist on the Performance of Textured yarn.

Discussion done in previous section is dealing with only first group of the experimental set-up. As mentioned earlier also in that group only false-twist values were changed by keeping pre-twist constant. Similar trend has been observed for rest of the three groups with the change in false-twist level for the constant pre-twist employed in that group. Table 4.3 (a-b), table 4.4 (a-b) and table 4.5 (a-b) represents test-results obtained for group-2 (samples A5-A8), group-3 (Samples A9-A12) and group-4 (samples A13-16) samples respectively.

Contribution of pre-twist has yet not been evaluated. Thereby in the second phase of discussion all four groups (sample A1- sample A16) have been considered. Test results are discussed with reference to change in quality parameters observed with pre-twist level.

Table 4.3 Effect of False-twist on the Textured Yarn. (Group: A)

(Parent yarn 100denier/48fils, underfeed of 25%,
delivery speed = 50m/min, Bulking zone length = one inch)

Pre-twist = 157.5 tpm

(a) Texturising Properties

Sample-code & description	Twist (tpm)	Denier	Increase in Denier (%)	Boiling water shrinkage (%)	Bulk Factor (θ)	DuPont Instability (%)
A5, 1970 F.T.	147	91.6	15.9	4.58	10.8	4.12
A6, 2364 F.T.	160	91.9	16.3	4.76	12.9	3.82
A7, 2560 F.T.	163	92.6	16.9	5.01	18.5	3.78
A8, 2757 F.T.	158	93.5	18.7	5.31	22.8	3.66

- F.T. = False-Twist in tpm, tpm =twist per meter.

(b) Mechanical Properties

Sample code	Tenacity (gpd)	Reduction in Tenacity (%)	Extension (%)
A5	2.90	19.14	25.98
A6	2.55	25.14	27.68
A7	2.53	27.71	29.68
A8	2.44	30.24	32.51

- gpd = grams per denier

Table 4.4 Effect of False-twist on the Textured yarn. (Group: A)

(Parent yarn 100denier/48fils, underfeed of 25%,

delivery speed = 50m/min, Bulking zone length = one inch)

Pre-twist =236.2 tpm

(a) Texturising properties

Sample-code & description	Twist (tpm)	Denier	Increase in Denier (%)	Boiling water shrinkage (%)	Bulk Factor (θ)	DuPont Instability (%)
A9, 1970 F.T.	240	92.9	17.5	4.76	09.7	3.02
A10, 2364 F.T.	228	92.9	17.5	4.78	12.5	2.89
A11, 2560 F.T.	229	93.2	17.9	4.87	16.2	2.72
A12, 2757F.T.	243	94.2	18.9	5.12	20.3	2.67

- F.T. = False-Twist in tpm, tpm =twist per meter.

(b) Mechanical properties

Sample code	Tenacity (gpd)	Reduction in Tenacity (%)	Extension (%)
A9	2.58	26.28	26.00
A10	2.56	26.86	27.12
A11	2.42	30.86	28.12
A12	2.34	33.14	30.10

- gpd = grams per denier

Table 4.5 Effect of False-twist on the Textured yarn. (Group: A)

(Parent yarn 100denier/48fils, underfeed of 25%, delivery speed = 50m/min, Bulking zone length = one inch)

Pre-twist =315.0 tpm

(a) Texturising properties

Sample-code & description	Twist (tpm)	Denier	Increase in Denier (%)	Boiling water shrinkage (%)	Bulk Factor (θ)	DuPont Instability (%)
A13, 1970F.T.	320	93.4	18.6	4.95	08.7	2.80
A14, 2364 F.T.	317	93.8	18.7	4.37	10.6	2.04
A15, 2560 F.T.	299	93.9	18.8	4.53	13.9	1.65
A16, 2757 F.T.	310	95.8	21.3	4.55	19.9	1.20

- F.T. = False-Twist in tpm, tpm =twist per meter.

(b) Mechanical properties

Sample code	Tenacity (gpd)	Reduction in Tenacity (%)	Extension (%)
A13	2.66	24.00	25.31
A14	2.60	25.71	27.04
A15	2.58	26.28	28.06
A16	2.55	27.14	29.57

- gpd = grams per denier

4.5.2.1 Increase in Linear density and Physical Bulk

It can be observed that for constant false-twist level, rise in the linear density is found to be more with increase in pre-twist level [figure 4.8 (a)]. This is mainly attributed to added contribution of twist-contraction to constant degree of crimpiness attained by same reference material at identical false-twist level. Twist-contraction increases with increase in pre-twist level[2, 4, 40]. More the contraction more will be the shortening in the length causes the volume and linear density to increase. Thereby highest rise in density has gone on the account of sample-A16, produced at highest pre-twist level and higher false-twist level [table 4.5(a)].

Figure 4.8 (a) Effect of Pre-twist on Linear-density of Textured yarns

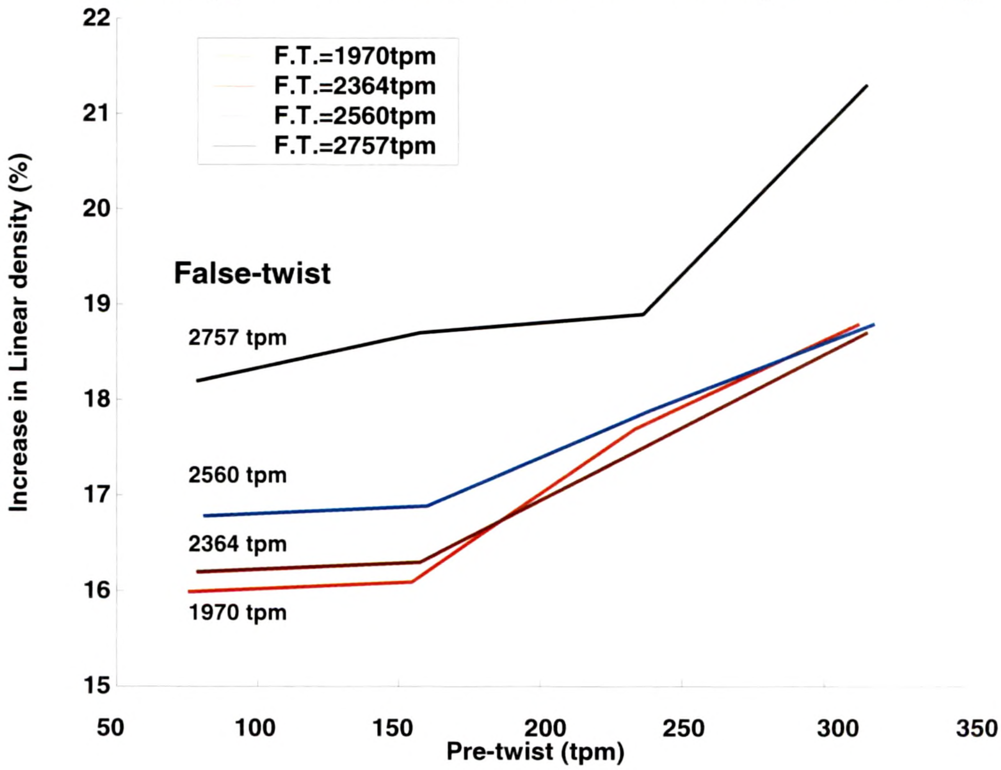
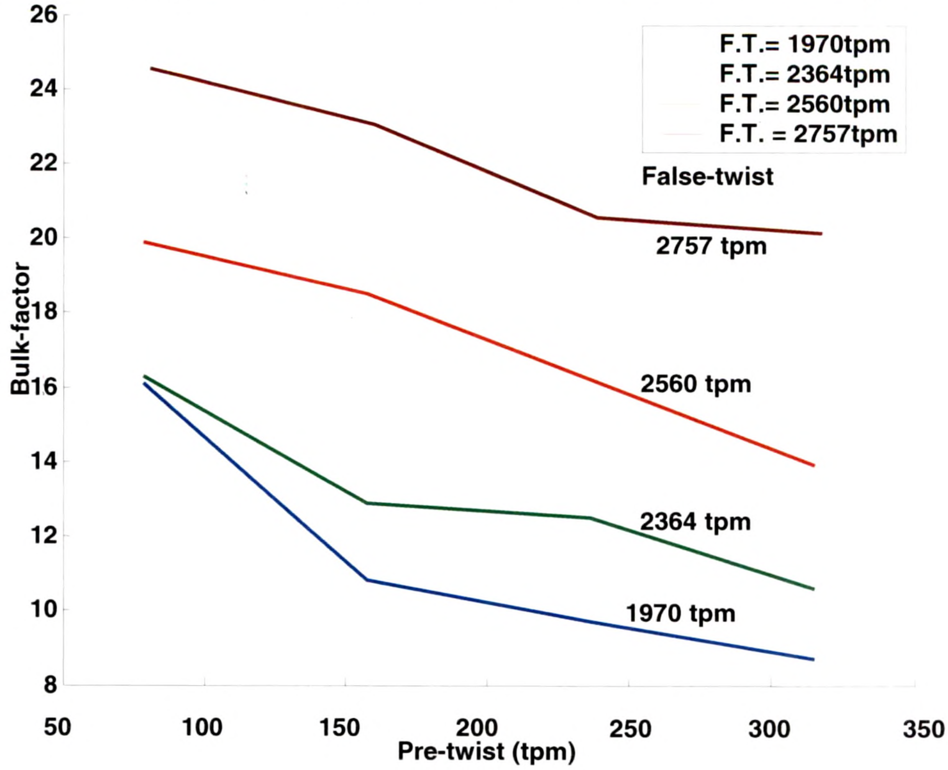


Figure 4.8 (b) Effect of Pre-twist on Bulk-factor of Textured yarns



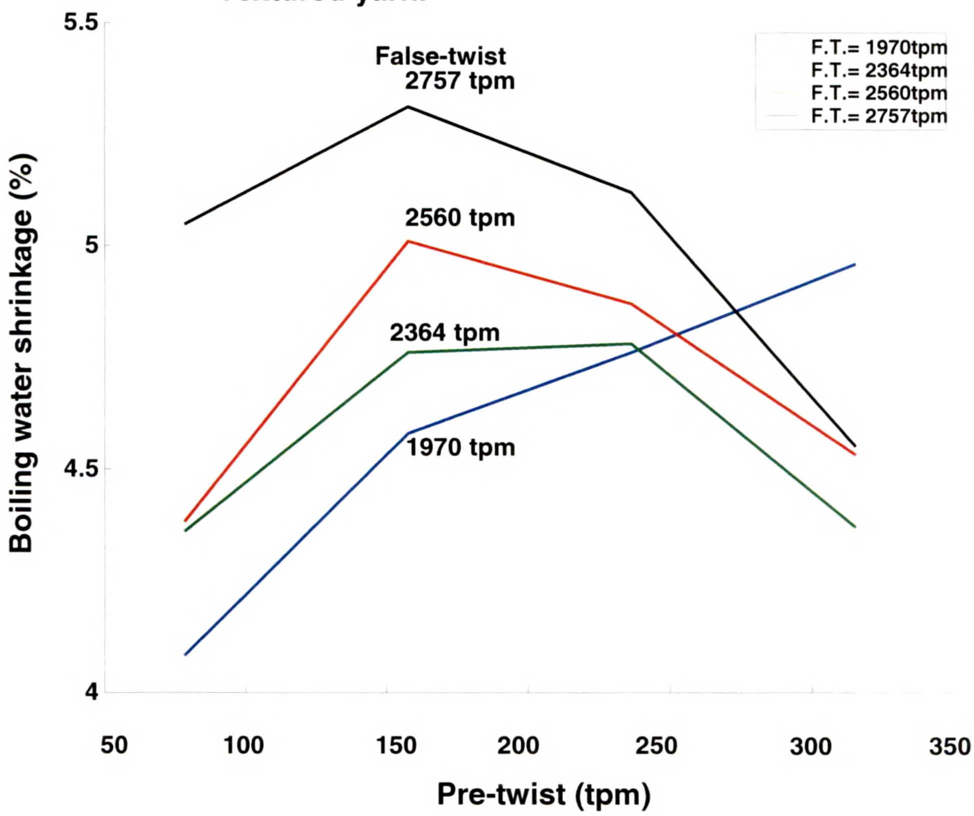
However bulk-factor at the given constant false twist level get reduced with the increase in the pre-twist level [figure 4.8 (b)]. This is mainly attributed to increased compactness (packing) achieved at higher locking-twist[3, 4]. Thus highest bulk-factor has been reported for loose and voluminous structure of sample A4 among all the samples under consideration is likely. Highest dye pick up observed for knitted and dyed hose of sample A4 due to increased voluminisity, supports the test value of bulk-factor.

4.5.2.2 Percent Boiling water shrinkage

It can be observed from figure 4.8 (c) that product yarn shrinkage has increased unanimously with increase in pre-twist up to 157.5

tpm for all the false-twist levels. Increase in shrinkage value is found to be higher for yarn textured at higher false-twist level. All the yarns produced at low false-twist (1970 tpm) have continued the trend even afterwards for high pre-twist values. But rests of the samples produced at higher false-twists have shown declination in the shrinkage value. Again amplitude of declination is more for yarns textured at higher false-twist level.

Figure 4.8 (c) Effect of Pre-twist on Boiling water shrinkage of Textured yarn.



This behaviour is mainly attributed to the resultant effect of extent of texturising and degree of compactness achieved during the course of texturising. Product yarn undergone higher deformation has executed higher percent boiling water shrinkage. Thus yarn produced at higher false-twist level has executed higher shrinkage as compared to yarn produced at lower false-twist.

Presence of pre-twist packs the constituents closely in yarn structure. Higher packing coefficient is observed for yarn having higher twist, resulted in more compact yarn structure[4]. Supporting this argument increase in pre-twist level has shuffled the structure towards higher compactness leaving behind lesser interstices for water to interact. Thus drop in the shrinkage value with the increase in pre-twist value is likely.

Degree of mingling attained is higher for higher false-twist level due to increased migration. These increased mingling has added to yarn compactness at a given pre-twist level. Thus higher drop in shrinkage value for yarn textured at higher false-twist level is expected with the increase in pre-twist.

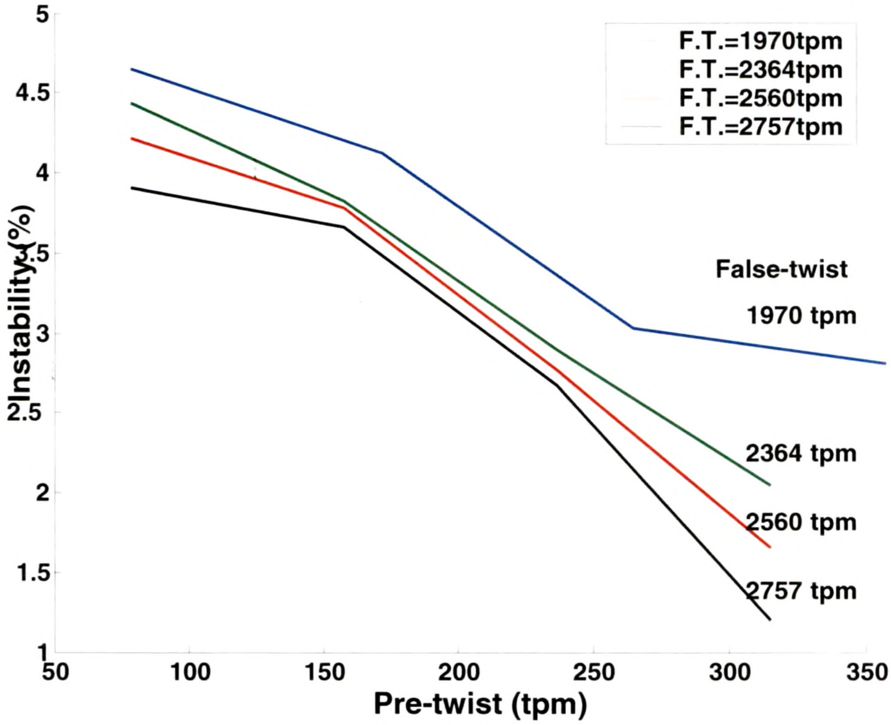
However at lower false-twist (1970 tpm), yarn shrinkage has increased at higher pre-twist also. This may be facilitated by the lack of compactness achieved due to poor mingling.

4.5.2.3 Percent Instability

One might anticipate a more stable entanglement, i.e. less instability for yarn textured at higher false-twist as well as pre-twist. Figure 4.8(d) depicts the same. Highest stability is reported for textured yarn produced under better texturising conditions (higher false-twist) with higher locking twist, viz; sample A16.

This is mainly the outcome of increased lateral forces at higher pre-twist level for textured yarn. Substantiate the arguments of previous section yarn A16 with higher mingling (higher false-twist 2757 tpm) along with higher pre-twist (315 tpm) has executed lowest value of instability [figure 4.8 (d)].

Figure 4.8 (d) Effect of Pre-twist on Instability of Textured yarns



4.5.2.4 Mechanical Properties

Tenacity of the textured yarn drops on texturising due to the diversion from the yarn axis on texturising. It can be observed from figure 4.9 (a) that drop in the tenacity increases up to pre-twist 236 tpm. But further rise in pre-twist value stops declination and on the contrary reduces drop in tenacity. This is mainly due to increased inter-filament friction with the increase in pre-twist value.

Reduction is steeper for samples produced at higher false-twist level (2757 tpm) as compared to other samples. This is attributed to added share coming from better intermingling observed at higher false-twist.

Figure 4.9 (a) Effect of Pre-twist on Textured yarn Tenacity

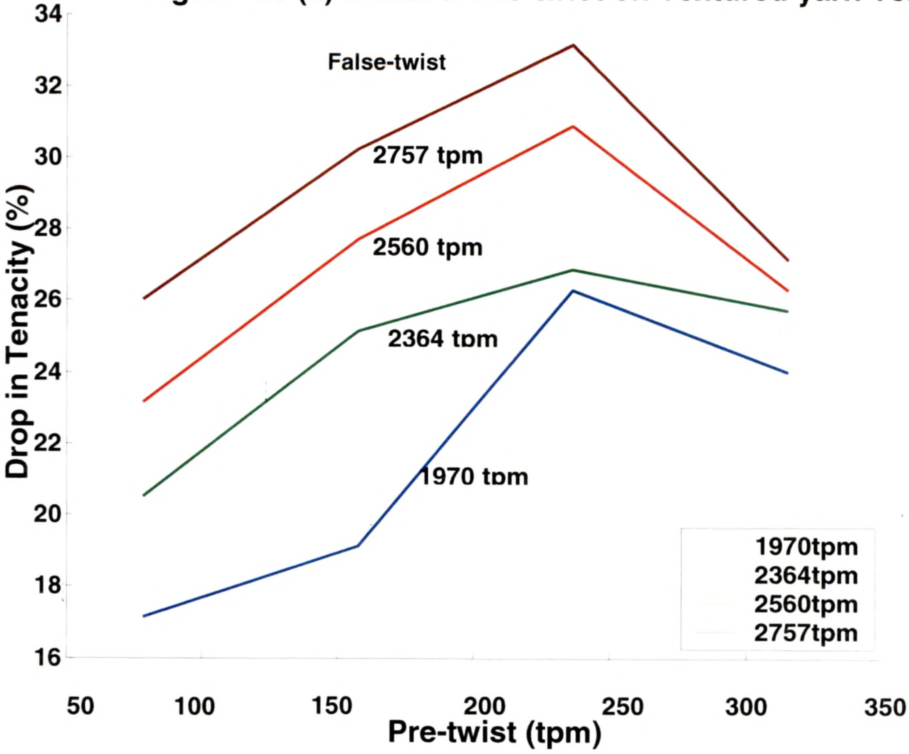
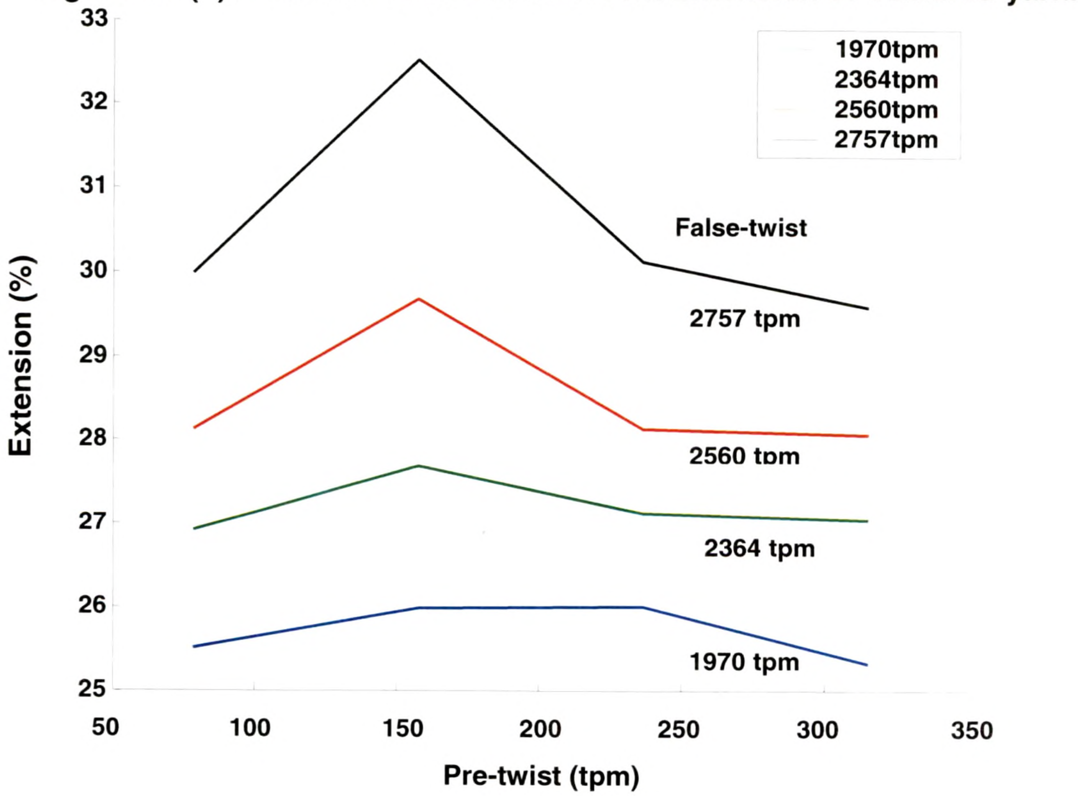


Figure 4.9 (b) Effect of Pre-twist on Percent Extension of Textured yarn.



However drop in tenacity remains well above 20 percent for all the samples under consideration [figure 4.9 (a)]. Thus it is due to increased compactness, and thereby cannot be interpreted as deterioration in texturising quality[31]. Almost identical extension value maintained [figure 4.9 (b)] and increased linear density [figure 4.8 (a)] for all the samples observed depicted increased compactness of yarn.

4.6 Effect of Delivery Speed (Group- B: Sample A17-A20))

Delivery speed has a direct impact on the production rate of any machine. So for innovative concept it becomes imperative to identify the impact of increasing texturising speed on the performance of newly engineered yarn. Since the machine developed in the present study is the lab model, the delivery speed values chosen for the study are no more be comparable to the commercial machine's output speeds.

Test results of the study are reported in table 4.6 (a-b). Photographs of tube knitting and dyeing (TKD) test and microscopical-views illustrating structural characteristics of product yarn are given in fig.4.10.

Table 4.6 (a) Effect of Delivery Speed on Texturising Properties

(Parent yarn100 denier/48fils., after drawing due to underfeed is 79d, Pre-twist =158 tpm, False twist = 1970 tpm, Bulking zone length = 1 inch)

Sample code	Delivery Speed (m/min)	Pre-twist (tpm)		Increase in Denier (%)	Boiling Water Shrinkage (%)	Bulk-factor (θ)	Instability (%)
		Theoretical values	Measured values				
A17	50	158	147	15.3	4.58	10.8	4.12
A18	100	158	156	16.8	5.13	12.3	3.62
A19	150	158	149	16.4	5.06	11.9	4.03
A20	200	158	151	16.4	5.07	11.2	4.01

- **tpm= twist per meter.**

4.6.1 Increase in Linear density, Instability and Bulk.

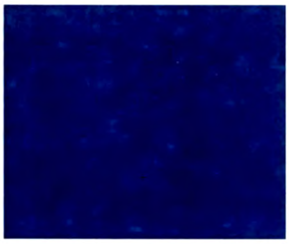
It can be seen from the results [table 4.6(a) and figure 4.11] that by increasing the texturising speed from 50 m/min to 100 m/min yarn denier as well as bulk factor have increased along with desirable reduction in instability percentage. But further increase in speed from 100m/min to 200 m/min causes slight declination in denier and bulk values.

Instability of yarn has increased with the speed from 100m/min to 150m/min. But latter on remains almost constant for the further rise in delivery speed to 200m/min.

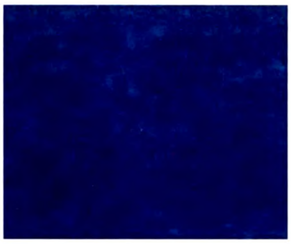
Figure 4.10 Photographs

(a) Tube Knitted and Dyed hoses

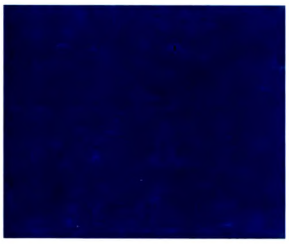
Sample A17



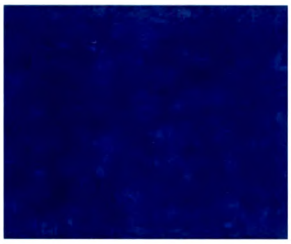
Sample A18



Sample A19

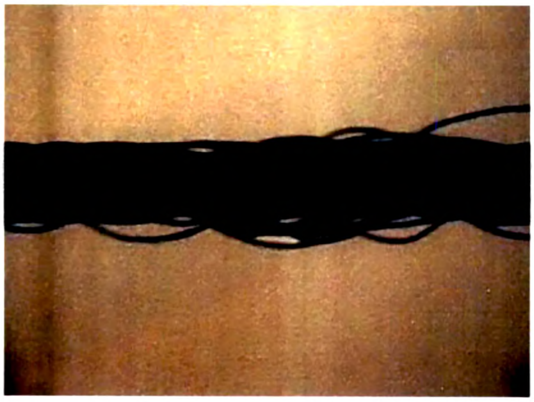


Sample A20

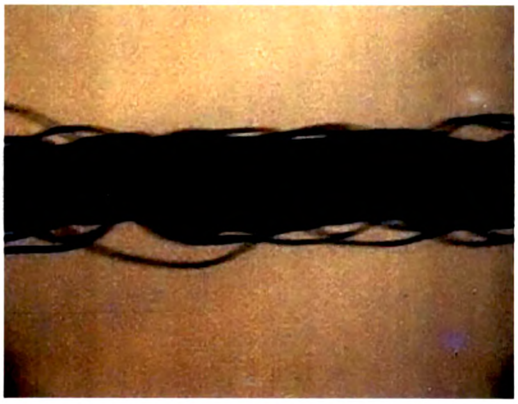


(b) Microscopical view

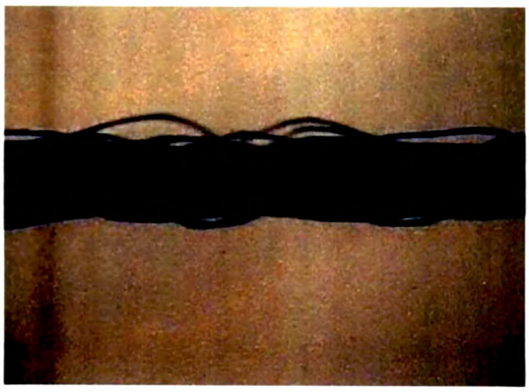
Sample A17



Sample A18



Sample A19



Sample A20

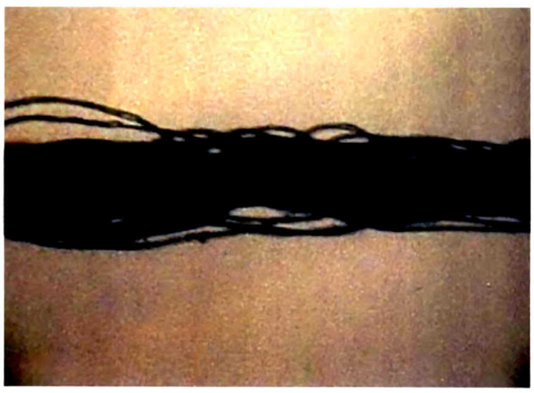
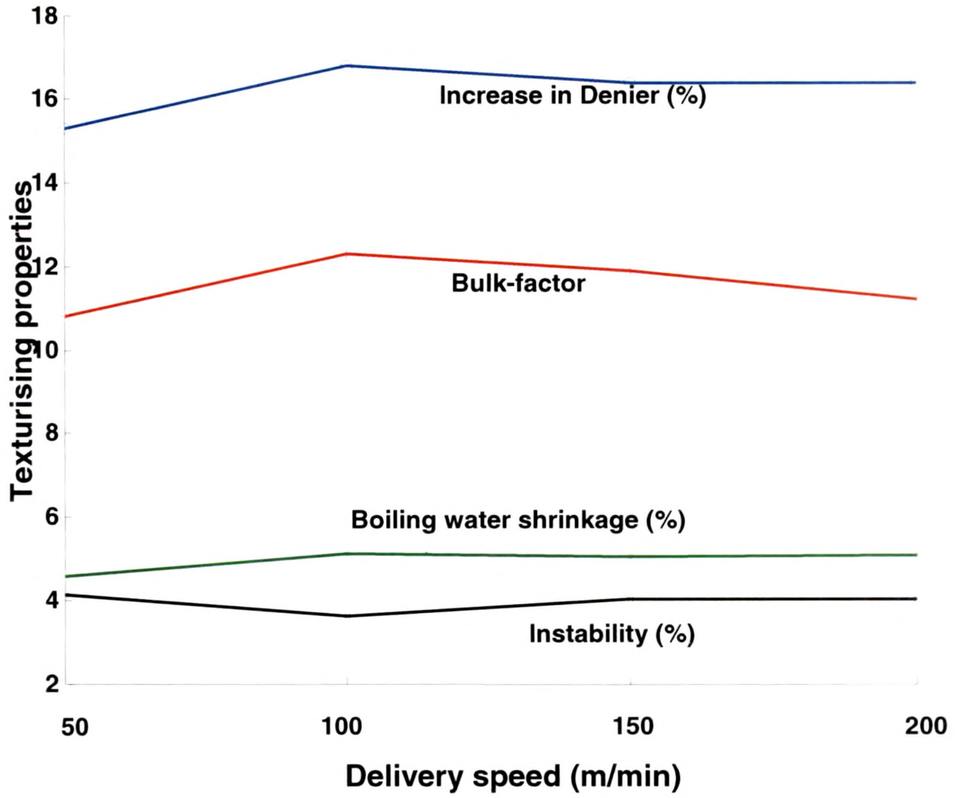


Figure 4.11(a) Effect of Delivery speed on texturising Properties.



Photographs of microscopical views [figure 4.10 (b], illustrate the product yarn structure attained at different delivery speeds used during the study. As depicted by photograph, uniform and better intermingled curls of high frequency are found for sample A18; (produced at 100m/min delivery speed) as compared to other samples under consideration. Thus favorable rise in linear density, higher bulk and reduced instability of the product yarn at 100m/min is probably lying in the better texturising conditions attained at that speed.

There is some reduction in bulk and linear density but not markedly. Even slight increase in instability not enough to cross acceptance level. So, it is not exaggerating to mention that the texturising at 200m/min has not adversely affected product yarn quality.

Uniformity of structural characteristics and dye shade at almost identical dye up take [figure 4.10 (a-b)] also indicates absence of adverse effect during texturising course carried out at higher speed. So, it is convenient to conclude that for the lab apparatus 200m/min delivery speed is viable.

4.6.2 Pre-twist

As mentioned earlier also due to mechanical limitations for constant process parameters and identical reference material, some difference in theoretically set pre-twist value and measured pre-twist value is likely.

4.6.3 Percent Boiling water shrinkage

Boiling water shrinkage percentage was increased from 4.58 to 5.13 percent [table 4.9(a)] with the increase in delivery speed from 50m/min to 100m/min. This is mainly attributed to better texturising attained at 100m/min delivery speeds as mentioned in section 4.6.1. No change is observed in shrinkage value for further rise in delivery speed [figure 4.11]. Thus it is going in closer resemblance to conclusion that there is no adverse effect on texturising properties of yarn for the selected speed levels.

Table 4.6 (b) Effect of Delivery Speed on Mechanical Properties

(Parent yarn100 denier/48fils., after drawing due to underfeed is 79d, Pre-twist =158 tpm, False twist = 1970 tpm, Bulking zone length = 1 inch)

Sample code	Delivery speed (m/min)	Tenacity (gpd)	Reduction In Tenacity (%)	Extension (%)
A17	50	2.90	19.14	26.50
A18	100	2.43	30.5	29.39
A19	150	2.64	24.5	28.87
A20	200	2.78	20.5	27.68

- ***gpd = gram per denier***

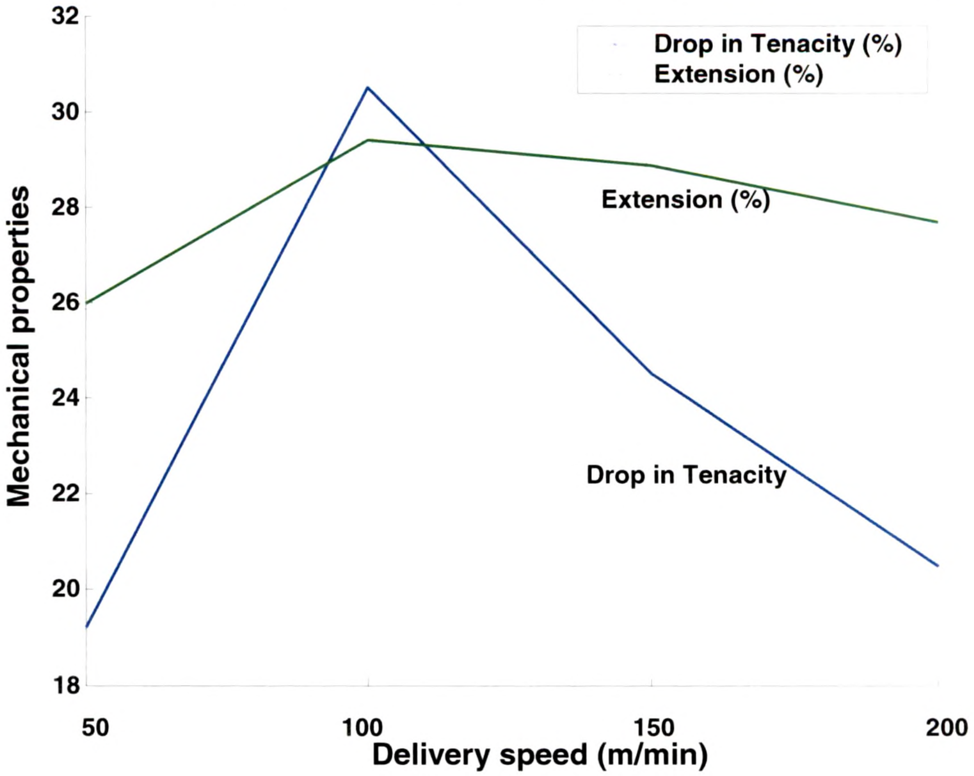
4.6.4 Mechanical Properties

Highest drop in tenacity and highest extension value have been executed at 100m/min [figure 4.11(b)]. This substantiate argument that better texturising is attained at 100m/min speed as mentioned in section 4.6.1.

However with further increase in delivery speed extension as well as drop in tenacity get reduced [table 4.6(b) and figure 4.11(b)]. They are the indicative of deterioration in texturising quality.

Hence these values are better than those reported for textured yarn obtained at 50m/min delivery speed [figure 4.11 (b)]. So, in no way this declination can be interpreted as failure of the lab apparatus in texturising at selected higher speeds.

Figure 4.11 (b) Effect of Delivery speed on Mechanical Properties.



Thus it can be comfortably concluded that for the selected speed levels (within the limitations of lab model machine), increase in the texturising speed has not shown any adverse effect on the performance of the newly engineered yarn. Compatibility with commercial texturising system on production rate point of view can be well judged only after translation of lab module to full flange commercial machine.

4.7 Effect of Bulking-zone Length (Group- C: sample A21-A24)

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)] as per defined in section 3.1.1.3. Experiment was conducted on lab apparatus by varying bulking zone length (table 3.5). Test results of the same are given in table 4.7(a-b).

Table 4.7 (a) Effect of Bulking zone Length on Texturising Properties.

(Parent yarn 100denier/48 fils. after drawing due to underfeed of 25% is 79d, Pre-twist = 315 tpm, False twist = 1970 tpm)

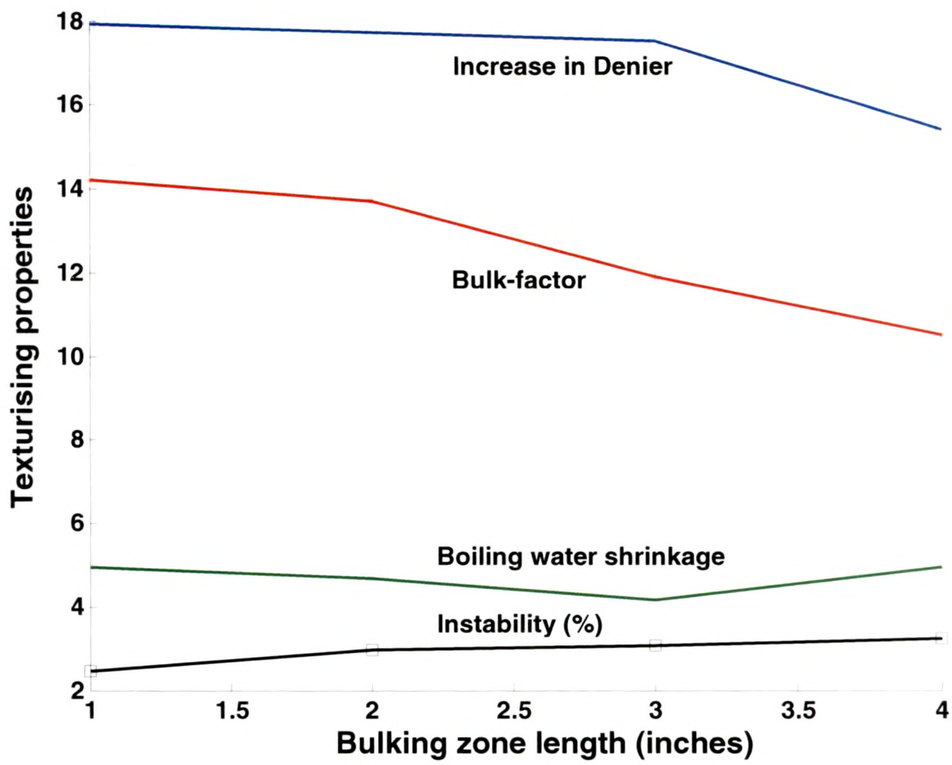
Sample code	Bulking zone length	Pre-twist (tpm)		Increase in denier (%)	Boiling water shrinkage (%)	Bulk-factor (θ)	Instability (%)
		Theoretical values	Measured values				
A21	4"	315	322	15.4	4.95	10.5	3.25
A22	3"	315	328	17.5	4.17	11.9	3.08
A23	2"	315	334	17.7	4.68	13.7	2.98
A24	1"	315	346	17.9	4.95	14.2	2.45

- **tpm = twist per meter, fils. = filaments**

4.7.1 Increase in Linear density and Bulk

It can be observed from figure 4.12 (a) that better texturising values are obtained at one-inch bulking zone length, viz; higher increase in linear density as well as bulk of the product yarn.

Figure 4.12 (a) Effect of Bulking zone length on Texturising properties



The attributing factor for this behavior can easily be identified from the structural characteristics of the product yarn [figure 4.13 (b)]. Presence of well mingled small size high frequency curls in the structure of textured yarn produced at one inch bulking zone length have caused more contraction due to higher crimping of flat feeder yarn, and thereby attributed to proportionate increase in denier as well as bulk of product yarn [table 4.7(a)]. More increased twist density of the respective product yarn as compared to other samples under study supports this argument. These results are also going in agreement to Wilson et al[19].who has reported that increase in bulk value is recorded with reduction in bulk zone length for false-twist texturising.

The possible explanation of increased crimpiness at shorter bulking zone length is lying in the study of conditions prevailing between false twist spindle-pin to the twist-trapper wheel at the texturising zone. When pre-twisted filament bundle leaves the twist trapper wheel under tension, opening of the pre-twist starts right from the point of exit. As soon as they are opened up completely retwisting begin in the opposite direction due to false-twisting action. Enough yarn tension should be maintained during this course of translation so as to develop the desired torque at high level of false twisting, facilitates 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. However at the point of completion of untwisting and beginning of retwisting yarn becomes slack in the bulking zone due to release of extra length of twist contraction. Situation becomes more crucial for long length bulking zone; as release in length on untwisting is more, gives higher drop in yarn tension. More drop in yarn tension before retwisting, delays the generation of desired magnitude of torque required for bending deformation. Delay in the torque generation for the constant false twisting rate and delivery rate results in poor crimpiness, gets reflected in terms of declination of texturising values. As texturising quality depends solely upon how best individual filament undergoes bending deformation caused at established torque in the texturising zone. More the torque more the differential tension developed in filaments present in centre to surface layers of yarn matrix causes frequent migration; thereby increased reversals. Thus product yarn so obtain possesses increased degree of intermingling of curls within the yarn matrix, lead towards the preferable texturising properties.

4.7.2 Percent Instability

It can be seen from figure 4.11(a) that percent instability gets reduced with the shorter bulking zone length. At identical pre-twist level improved stability of the newly acquired structure is attributed to increased inter-fiber friction due to better mingling [figure 4.12 (b)].

4.7.3 Percent Boiling water shrinkage.

Increase in boiling water shrinkage [table 4.7(a)] as well as dye uptake of knitted hoses [figure 4.12(a)] on texturising are as per expectation. This is due to increased shuffle towards amorphous region on texturising. But no particular trend can be located for boiling water shrinkage behavior of the product yarn with respect to change in bulking zone length.

Table 4.7 (b) Effect of Bulking zone Length on Mechanical Properties.

(Parent yarn 100denier/48 fils. after drawing due to underfeed of 25% is 79d, Pre-twist = 315 tpm, False twist = 1970 tpm)

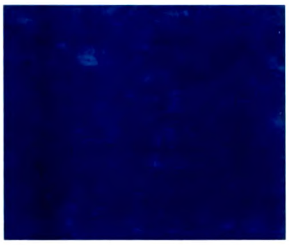
Sample code	Tenacity (gpd)	Reduction in Tenacity (%)	Extension (%)
A21	2.58	26.91	26.31
A22	2.78	20.5	27.77
A23	3.05	12.9	31.33
A24	3.10	11.4	34.48

- **gpd = grams per denier, tpm = twist per meter, fils. = filaments**

Figure 4.13 (a) Photographic-views

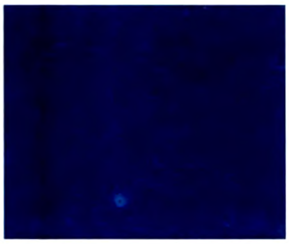
a) Tube Knitted and Dyed hoses

Sample A21

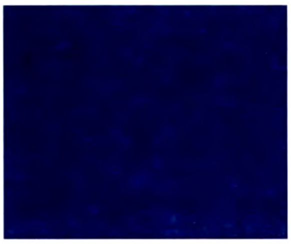


Sample A22

Sample A23



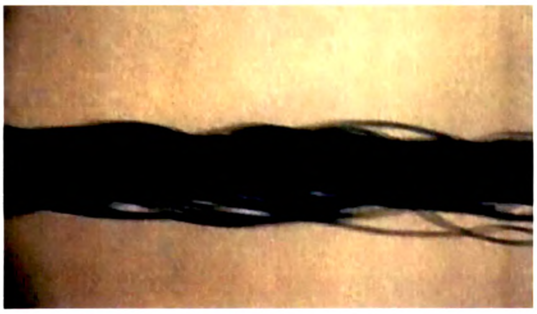
Sample A24



b) Microscopical-view

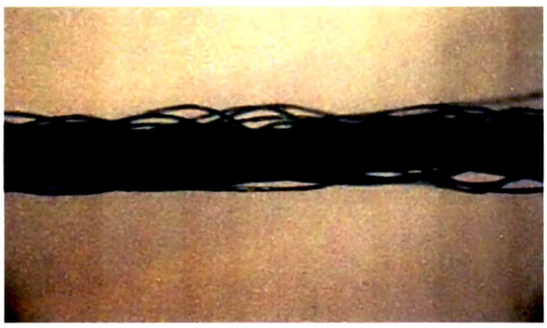
Sample A21

Sample A22



Sample A23

Sample A24



4.7.4 Mechanical Properties.

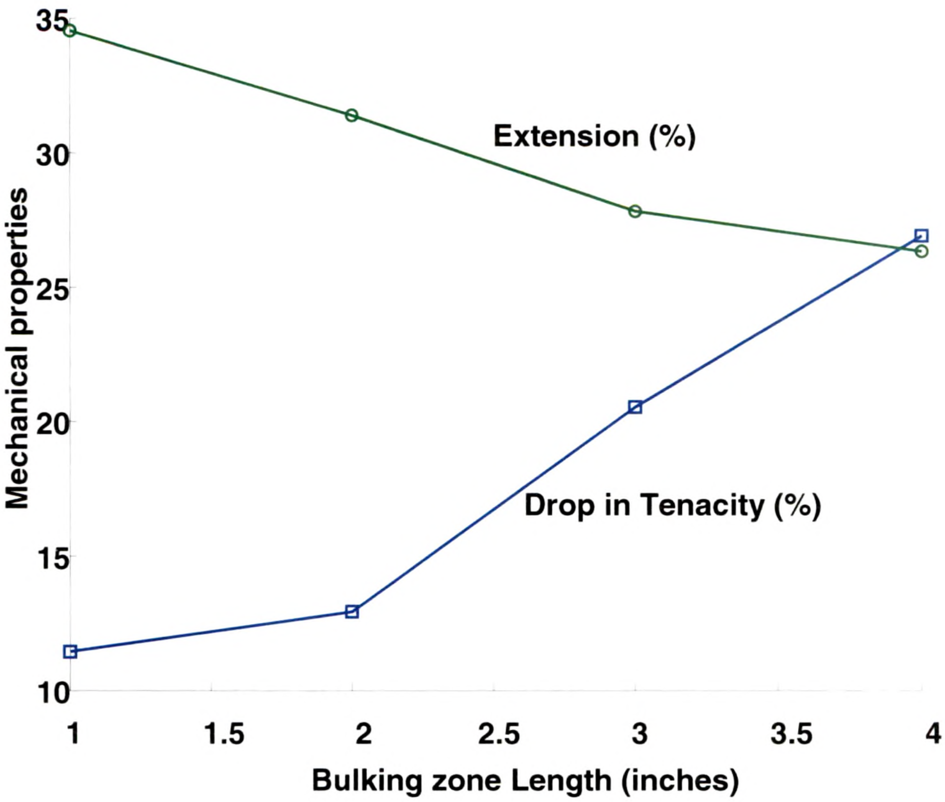
Increased deviation of constituents from yarn axis owing to better texturising caused at shorter bulking zone length was expected to show more reduction in yarn tenacity and increase in elongation at the constant pre-twist level. But contradictory to expectation, tenacity value has been increased instead of reduction [table 4.7 (b)]. However percentage extension has been increased as per expectation [figure 4.12 (b)].

This contradictory behaviour in tenacity is mainly attributed to the formation of well-intermingled higher number of small curls [figure 4.13 (b)] under the action of higher distortion forces (tension), locked well within the structure at selected pre-twist of 315 tpm and executed higher tenacity. Thereby drop in tenacity has shown descending trend against the expectation.

Shortening of bulking zone length cannot be interpreted as undesirable parameter for innovative texturising, as better texturising values are reported on its account [figure 4.12 (a)]. Not only that product yarn extension value get increases as bulking zone length get reduced [figure 4.12 (b)], mainly attributed to the increased presence of higher number of small curls [figure 4.13(b)]. Better texturising values and extension value achieved at smallest bulking zone length (one inch) considered for the study substantiate these arguments.

Thus over all product performance indicates that as bulking zone length gets reduced from 4-inch to 1-inch, quality parameters of the innovative yarn get shifted towards the desirable one.

Figure 4.12 (a) Effect of Bulking zone Length on Mechanical properties.



This experimentation was restricted to upper value of 4-inch bulking zone length only on laboratory model machine. As further increase in bulking zone length beyond this value was resulted in inherent balloon formation. Finally get resulted in unfavourable increased end-break. This was due to excess tension drop on higher twist-contraction length release on untwisting. Whereas reduction in bulking zone length beyond 1-inch, yarn tension on retwisting became so high that it was causing increased end-breakage rate. Thus one inch bulking zone length is found to be optimum for lab apparatus for getting better texturising results.

4.8 Development of an Empirical Formula for Calculating Optimum False-twist Level (Group: D).

It was found from the results of experiments carried out in section-4.5, better texturising condition can be attained at higher false-twist level for innovative texturising process. As a consequence of that product yarn execute preferable texturising properties like higher bulk, increased linear density as well as improved stability. No doubt during this course of transformation, straight constituent filaments occupy crimpy structure and their tenacity value gets reduced. The drop in tenacity value is no more be objectionable if product yarn has enough strength to sustain the stresses of the forthcoming processes[4, 31] . Thus it becomes necessary to identify optimum false-twist level for the given type and fineness of supply yarn, so as to obtain product yarn with preferable texturising properties along with moderate tenacity to deal with the process stresses next in a sequence.

Looking at the simulation in the production principle in attaining crimpy configuration between innovative concept of texturising and false-twist texturising, the back track record of the latter has been checked for the same. Many theoretical and empirical formulae have been advanced to determine the optimum twist (K tpm) in false-twist texturising for yarns of different linear density[2, 40] (section 2.5.2). Although production principle is same for both the systems, innovative concept of texturising has replaced thermodynamic mode by mechanical mode for setting newly attained configuration (section 4.3). So, these formulae need modification before implementing for newly structured mechanical crimp texturising process.

Since optimizing any given yarn property almost always affects other yarn characteristics, and therefore Heberlein's Advance formula[51] (equ.2.11) has been selected as a base for this set of experimentation as it gives consideration for the same [working with three variable coefficients, viz; i) 800, ii) 2,70,000 and iii) 60]. Based on the outcomes of series of experiments carried out on different fineness polyester yarns (section 3.1.2.2) at different false-twist levels and pre-twist levels, the variable coefficient (2,70,000) of Heberlein's formula has been modified to develop empirical formula for the newly designed concept.

4.8.1 Optimization of False-twist at constant Pre-twist.

Fully Drawn polyester yarns of different fineness, viz; 100d/48fils., 150d /72fils., 200d/96fils., 250d/120fils. and 300d/144fils. were used in first part of experimentation. The values of false-twist level (tpm) at which filament rupture begin for a selected constant pre-twist level (twist factors 24 $tex^{1/2}$.turns/cm) were measured practically. They are reported in table 4.8 as highest false-twist H (tpm).

Filament rupture during the texturising is an undesirable feature. Therefore the allowable optimum twist level has been defined as false-twist K (tpm) value 2.5% less than the level at which filament rupture starts for all yarns under study. Practically their significance was checked by carrying out texturising and observing product yarn under microscope. These values of optimum twist K twist per meter (tpm) were substituted in Heberlein's advance formula (equation 4.1), for respective yarn denier D and variable constant "X = 2,75,000" of an advance formula (equation 4.1) has been modified for innovative texturising system.

Table 4.8 Experimentally Derived Values of Highest False Twist Level (H) for Different Yarn Fineness (D).

[Constant Pre-Twist factor = 24 $tex^{1/2}$.turns/cm]

Yarn Denier D	dpf	Highest F.T. Level H (tpm)	Calculated Optimum F.T. K (tpm)
30	2.14	5940	5792
50	1.39	5012	4887
60	10	4660	4544
75	2.08	4238	4132
100	2.08	3714	3621
150	2.08	3020	2945
200	2.08	2598	2533
250	2.08	2307	2249
300	2.08	2110	2057

- $K = 800 + \frac{X}{D+60}$ ....equation 4.1

  ; X is the variable coefficient.
- ***H = false-twist level beyond which Filament Rupture Starts Due to Obliquity Effect,***
- ***dpf = denier per filament, F.T. = False-Twist***

The restructured formula so obtained is established as an empirical formula for mechanical crimp texturising (equation 4.2) for polyester yarns.

$$K = 800 + \frac{4,50,000}{D+60} \quad \text{...........equation 4.2}$$

Further repeated trials were also taken with the same materials to ensure the reliability of so calculated optimum twist level in achieving maximum bulk along with the assurance of absence of objectionable broken filaments in product yarn matrix. Bulk-factor measure and visual yarn structure analysis were used as analysis tools for this purpose.

Trials were also conducted with polyester yarns having different filament-fineness (denier per filament), viz; 10d (60d /6fils.), 2.14d (30d /14fils.), 2.08d (75d /36fils.), and 1.39d (50d /36fils.) by keeping rest of the process parameters constant. Test results of these trials are also added to table 4.8.Values are reported in the ascending order of magnitude of denier for the ease of study. Similarly calculated optimum false-twist value K tpm for each yarn has been substituted to basic equation 4.1 to derive respective variable constant X. Analysis of these values also goes in closer resemblance with experimentally derived variable constant X = 4,50,000 of empirical formula (equation 4.2). Thus it approves reliability of such derived empirical formula for polyester yarns of different fineness at selected pre-twist level for innovative texturising system.

4.8.2 Optimization of False-twist at Variable Pre-twist.

Experiments were conducted with 100d/48fils. Fully drawn polyester yarns at four different basic twist levels, viz; twist factor ($tex^{1/2}$.turns/cm) of 2.4, 6, 12 and 24 respectively for verifying significance of this newly established formula at different pre-twist level for mechanical crimp texturising. Results of the same are reported in table 4.9. Analysis of so derived optimum twist level at different pre-twist level with respect to basic Heberlein's Advance formula (equation 4.1) also justify the use of newly set-up variable constant X = 4,50,000 for innovative system of texturising.

Thus it is not exaggerating to establish equation-4.2 as an empirical formula for deriving optimum false-twist level K tpm (twist per meter) for polyester yarns with different fineness D (denier) in case of mechanical crimp texturising process.

Table 4.9 Experimentally Derived Values of Highest False Twist Level (H) at Different Pre-Twist Level.

[Parent yarn used is 100d/48fils. Fully Drawn Yarn.]

Pre-Twist {Twist factor tex $^{1/2}$.turns/cm}	Highest F.T. Level H (tpm)	Optimum F.T. Level K (tpm)
2	*3719*	*3626*
4	*3726*	*3633*
6	*3716*	*3623*
12	*3722*	*3629*
24	3714	3621

- $K = 800 + \dfrac{X}{D+60}$ ....equation 4.1

  ; X is the variable constant.
- ***H = false-twist level Beyond which Filament Rupture Starts Due to Obliquity Effect.***
- ***tpm = turns per meter, F.T. = False-Twist.***

4.9 Mathematical Derivation of Empirical formula for Optimum False-twist K (tpm) for the Innovative Texturising Process:

Practically derived values of optimum false-twist level K (tpm) for different polyester fineness were used as base for checking reliability of newly developed formula. Steps used for the development of Empirical Formula were as follows.

Polynomial curve fitting (Polyfit) program of MATLAB has been used for this purpose

p = polyfit(x,y,n) finds the coefficients of a polynomial p(x) of degree n that fits the data, p(x(i)) to y(i)), in a least squares sense.

The result p is a row vector of length n+1 containing the polynomial coefficients in descending powers

$$\mathbf{P(x) = p_1\, x^n + p_2\, x^{n-1} + \ldots\ldots + p_n\, x + p_{n+1}} \quad \ldots\ldots\ldots\ldots\text{equation 4.3}$$

- Where "P(x)" is the Dependent variable; in the present case it is "K" in tpm (twist per meter). Where K is representing optimum false-twist level. Dependent variable has been defined as, "A variable to be evaluated from the known value of the second variable." Here it is "X".
- "X" is known as Independent variable. In the present study yarn denier (D) is independent variable. It is a variable whose physical value is known.

- "n" is the degree of polynomial. Its value can be chosen such that theoretically plotted curve fits very close to the curve formulated by using practically feed data.
- p_1, p_2........p_{n+1} are variable coefficients.

"p = polyfit(D,K,n)", programme has been used. Where known values of "D" and "K" has been defined from the practical results [table 4.8]. While value of "n" has been used as one initially and plotted the polyfit curve with the "plot(D,K,'o',D,f,'-')" command. Curve so obtained has been checked for close fit to practically derived points. If it is not found close fit value of "n" has been increased from 1 to 2. The same cycle has been repeated until desired close fit has been attained. In the present case desired close fit has been attained at degree of polynomial n = 3. Polyfit curve along with practical feed data (indicated as small circles) so developed has been illustrated in figure 4.14.

After confirming for close-fit, variable coefficients p_1, p_2....p_{n+1} were derived with the command, "p = polyfit(D,K,3)". This command provides coefficients in the approximating polynomial of degree 3 (in the multiple of 10^3). Substituting values of p_1, p_2, p_3 and p_4, so obtained in equation (4.3) desired formula (equation 4.4) can be obtained.

$$K\ (tpm) = 7153.8 - 54.6D + 0.2\ D^2 \quad \text{........(4.4)}$$

Figure 4.14 Polyfit Curve for Optimum twist (K tpm) and Yarn fineness (D)

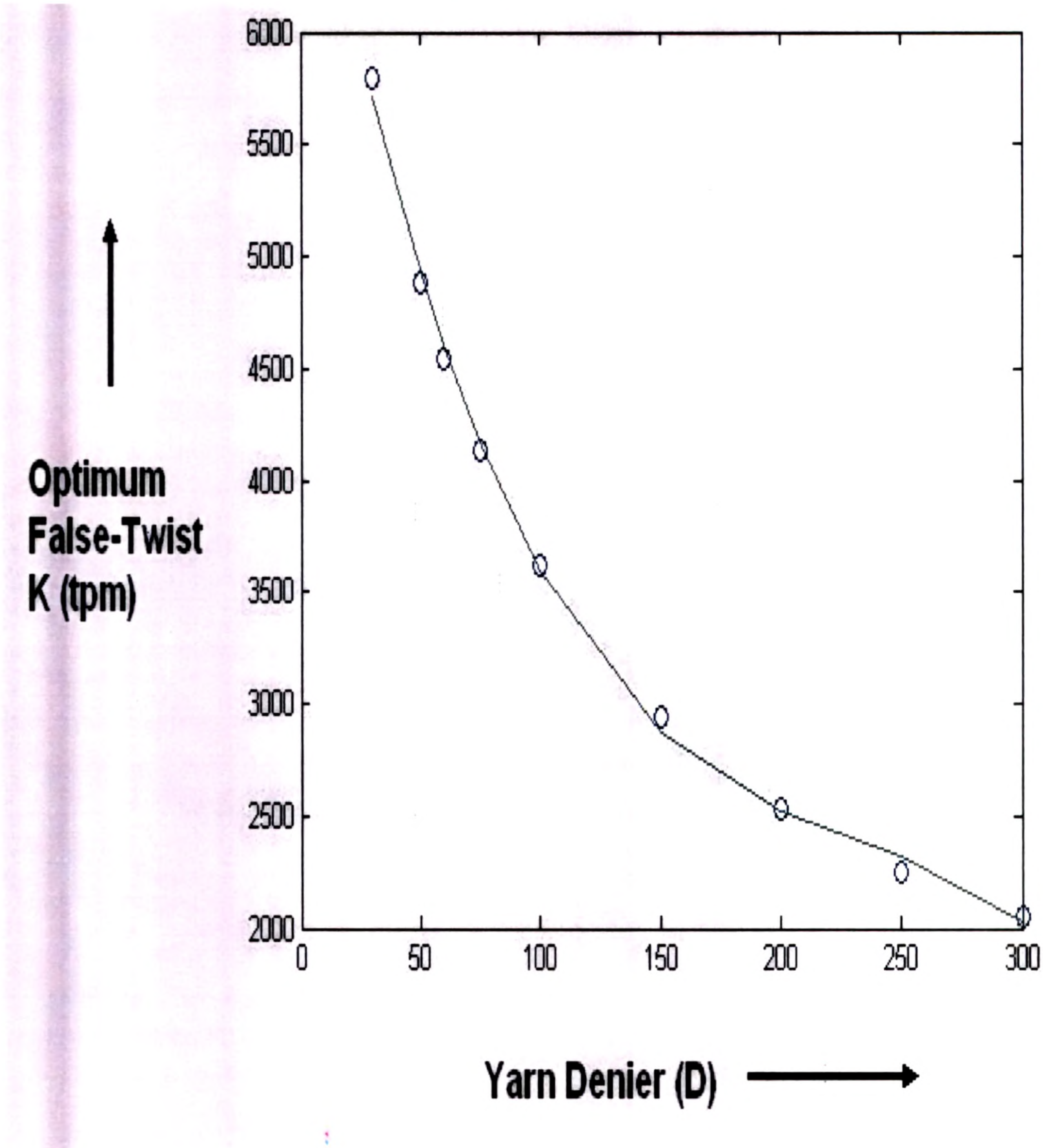


Figure shows plotting of the theoretical curve by mat lab program for equation-4.4. Circles are indicating practically derived points. A good correlation has been found between them satisfies the basic condition of mathematical equation formulation with the help of practically measured values.

Equation so obtained has been verified for its accuracy also. Command "f = polyval(p,D)" identifies optimum twist value from polyfit curve in tpm for given yarn fineness "D." Followed by command "table = [D' K' f' (K-f)']" display table carrying the actual values of "yarn fineness D", "Optimum twist K tpm", "polyfit curve optimum twist f tpm" and "error in estimation (K-f)". Definitely following basic mathematical rule error should be as low as preferable. Practical results obtained are fulfilling this requirement.

Thus equation 4.4 can be established as empirical formula for evaluating optimum twist level K (tpm) for known yarn fineness (D) in denier, in case of innovative texturising of polyester yarn.

MATLAB programme used during this study along with it's input and output obtained has been given in Appendix-3.

4.10 Confirmation Trial: Effect of Pre-twist Level at Optimum Process Variables.

Results of earlier experiments (section 4.5 to section 4.7) have identified preferable values for process variables of the innovative texturising process. Development of empirical formula (equation 4.4) has provided solid ground for calculating optimum false-twist (K tpm) for polyester yarn of known fineness (D denier). As optimum limit of the pre-twist is the subjective matter. At the outset of the evaluation of innovative textured yarn with respect to various process variables, it becomes interesting to see the effect of pre-twist on the textured yarn performance, produced at optimum process-variables defined for lab apparatus. Once the relationship between pre-twist and textured yarn quality parameters is well-defined, it becomes customer's choice to select suitable value of pre-twist as per the suggested end-use.

For the Purpose of ease of visualization of changes occurred during process white 100denier/48filaments parent yarn was replaced with 150denier/72filaments parent yarn. This yarn is dope-dyed yarn (green colour) and having the same filament fineness as that of previously used parent yarn. Thus introduction of material variability in experiment has been avoided.

The usefulness of such textured yarn depends a great deal on the stability of the newly acquired crimpy structure during the bulking process. Once these curls are removed there is no build-in mechanism for their reformation, as occurs in stretch bulked yarns. The loss of crimp during subsequent processing, such as weaving, finishing, can become detrimental to fabric quality. While the better comfort related properties of the textured yarn fabric are influenced by the bulk as well as linear density of the constituent yarns.

As can be seen from the outcome of experiments (section 4.5) pre-twist used in mechanical crimp texturising is going in inverse proportion to bulk and in direct proportion to stability. Degree of intermingling achieved is another major factor contributing to the stability of textured yarn structure, so obtained. It increases in direct relation to false-twist used. So, highest degree of crimping and intermingling can be attained at optimum false-twist level. This allows the product yarn to execute preferable higher bulk and highest possible contribution to stability of textured structure. But these deformation caused under optimum texturising condition should not decline tenacity to a greater extent that it can not sustain forthcoming stresses[15].

So, impact of change in pre-twist level on important texturising parameters like the bulk, extension and instability at the optimum bulking (false-twisting) conditions need to be evaluated with respect to drop in tenacity of the product yarn.

Present experimentation was carried out with optimum bulking zone length and delivery speed, identified from earlier experiments. Optimum false-twist (K tpm) was calculated by using equation 4.4 for the selected yarn denier (D). Yard stick used for characterization of textured yarns so produced was product yarn bulk, linear density, instability and strength, together with structural properties such as curl size, curl frequency and degree of entanglement.

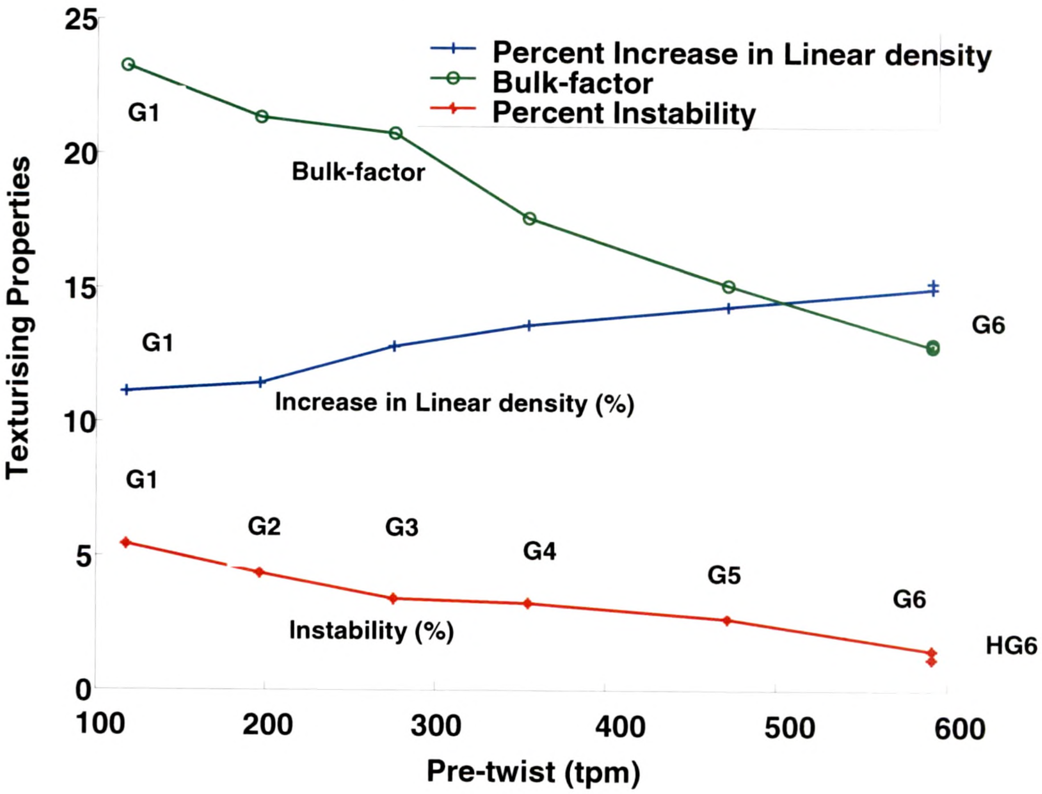
Test results of this study are reported in table 4.10 (a-b). Photographs of microscopical-views illustrating structural characteristics of product yarn are given in figure 4.15 (a-g)

4.10.1 Increase in the Linear-density and Bulk.

It can be observed that rise in product yarn denier is more at higher pre-twist level. Whereas bulk value get increased with the reduction in pre-twist level [figure 4.16(a)]. They are going in consequence to the earlier results (section 4.5).

Figure 4.16 (a) Effect of Pre-twist on Texturising Properties at Optimum Process-parameters

(Optimum False-twist = 2942tpm)



Increased linear density with increase in pre-twist is attributed to increased shortening of yarn length on higher twist-contraction as mentioned earlier (section 4.5) also. For identical crimpiness (constant false-twist) twist-contraction increases in direct proportion to pre-twist employed to the product yarn. Thus highest linear density rise recorded in the account of textured yarn with higher pre-twist is likely [table 4.10 (a)].

At optimum false-twist used for reference material, identical crimpiness was achieved for all the samples, but yarn became more compact at higher pre-twist level and bulk get diminished [figure 4.16 (a)].

Table 4.10 (a) Effect of Pre-Twist Level on Texturising Properties (at Optimum Process-parameters).

(Parent yarn 150 denier/72 fils. Feeder yarn at 15% underfeed is 130d with 17.3% extension, Optimum False-twist (tpm) = 2942)

Sample Code	Pre-twist (tpm) Theoretical Values	Pre-twist (tpm) Measured Values	Increase in Denier (%)	*Boiling water shrinkage (%)*	*Bulk-factor (θ)*	*Instability (%)*
G1	118	166	11.0	5.28	23.2	5.39
G2	197	283	11.7	5.22	21.3	4.33
G3	276	358	12.8	5.12	20.7	3.39
G4	355	410	13.4	5.34	17.6	3.21
G5	472	486	14.3	6.42	15.1	2.61
G6	591	622	15.0	6.61	12.8	1.48
HG6	591	630	15.2	4.96	12.9	1.12

- **tpm = twist per meter, fils. = filaments**

4.10.2 Percent Instability.

It can be seen from figure 4.16(a) with the increase in pre-twist instability value get reduced. This is mainly attributed to better locking of identical degree of intermingled curls achieved with the increase in pre-twist level.

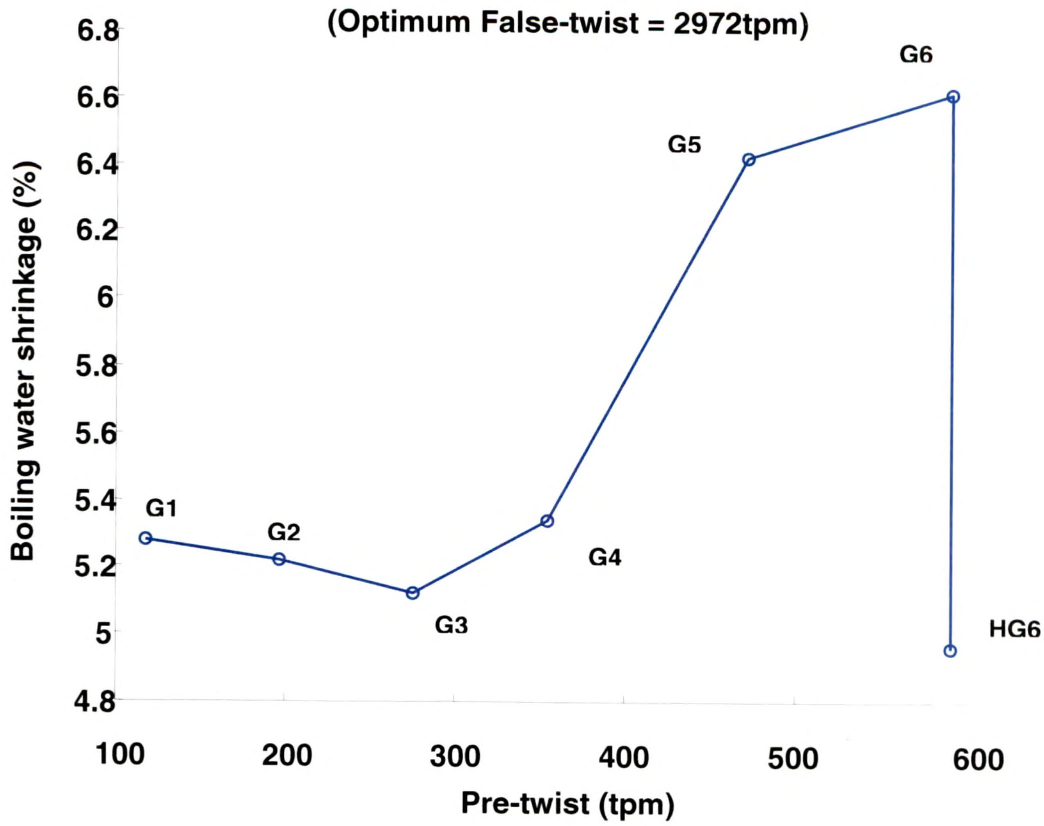
Sample G1 (produced at lower pre-twist) has executed instability value beyond the acceptable 5% Du Pont[56] limit [table 4.10(a)]. This slightly higher value of instability (5.39%) can probably be arises from the greater number of loosely locked curls at lower level of pre-twist used [figure 4.15(b)]. Thus increasing the likelihood of curl removal, but in no way can this increased instability can be interpreted as a degradation of texturising quality. The ensuing considerations of other properties like drop in tenacity, bulk and linear density of the textured yarn [figure 4.16(a)] substantiate this argument.

4.10.3 Percent Boiling water shrinkage.

Unlike the results of previous set of experiment (section 4.5) in the present experiment percent boiling water shrinkage has been increased uniformly along with pre-twist level except sample G2 [figure 4.16 (b)].

This difference is mainly attributed to the optimum false-twist used in the present experimentation. Incorporated to that low bending-rigidity of trilobal cross-section filaments of 150denier/72 filaments, instead of circular cross-section filaments in the latter case has allowed yarn to undergo more deformation at higher pre-twist level. Thereby more shift of product yarn towards amorphous region has facilitated better interaction with water although structure became more compact at higher pre-twist level.

Figure 4.16 (b) Effect of pre-twist on Percent Boiling water shrinkage



Increased dye uptake found for tube knitted and dyed (TKD) samples [figure 4.15 (a)] along with the increase in pre-twist level supports this presumption. Thus it is right to mention at this stage of evaluation that boiling water shrinkage of the innovative textured yarn is the out come of the compound effect of basic characteristics of the parent yarn used and degree of deformation attained during the course of texturising.

Figure 4.15 (a) Photo-graphic views of Textured Yarns.

(I) Tube Knitting and Dyed Hoses

(a) Sample G1

(b) Sample G2

(c) Sample G3

(d) Sample G4

(e) Sample G5

(f) Sample G6

(g) Sample HG6

b) Microscopical-views

Sample G1

Sample G2

Sample G3

Sample G4

Sample G5

Sample G6

Sample HG6

4.10.4 Pre-twist

Theoretically desired value of pre-twist has been set by considering the drive set up used for twisting media (two for one twister) and take-up roll. However practically measured values (measured from product yarn on twist tester) of pre-twist are differing. Difference is higher for sample G2 and sample G3, +86 tpm and +82 tpm respectively. This behaviour is probably the outcome of contraction caused due to crimping. Loose structure produced at low pre-twist level can contract easily, shortening the length and increases twist density. This argument found support from the proportionate rise recorded in linear density and bulk value of the respective yarns.

However sample G1 produced at lowest pre-twist level has exhibited less difference (+48) as compared to sample G2 and sample G3. This is mainly due to highest mobility of the structure, not allowed it to secure firmly increased twist density at lower locking twist. Highest bulk value but lowest linear-density reported in its account supports this presumption.

Shuffle towards higher pre-twist level has reduced the gap between measured and theoretical twist values in descending order of magnitude. This must be the out come of degree of compactness achieved by product yarn structure. Higher the twist higher the compactness, and thereby product yarn structure moves closer to jam-structure [figure 4.15 (b)]; not facilitate further increase in the concentration of twist per unit length. The assumption gets validity from the decrease in instability value observed with the increase in pre-twist level of the product yarn [table 4.10(a)].

4.10.5 Mechanical Properties

Drop in the tenacity value and percent extension are expectedly highest for textured yarn produced with lowest pre-twist [table 4.10 (b)].

Table 4.10 (b) Effect of Pre-Twist Level on Mechanical Properties of Textured Yarn Produced at Optimum Process-variables.

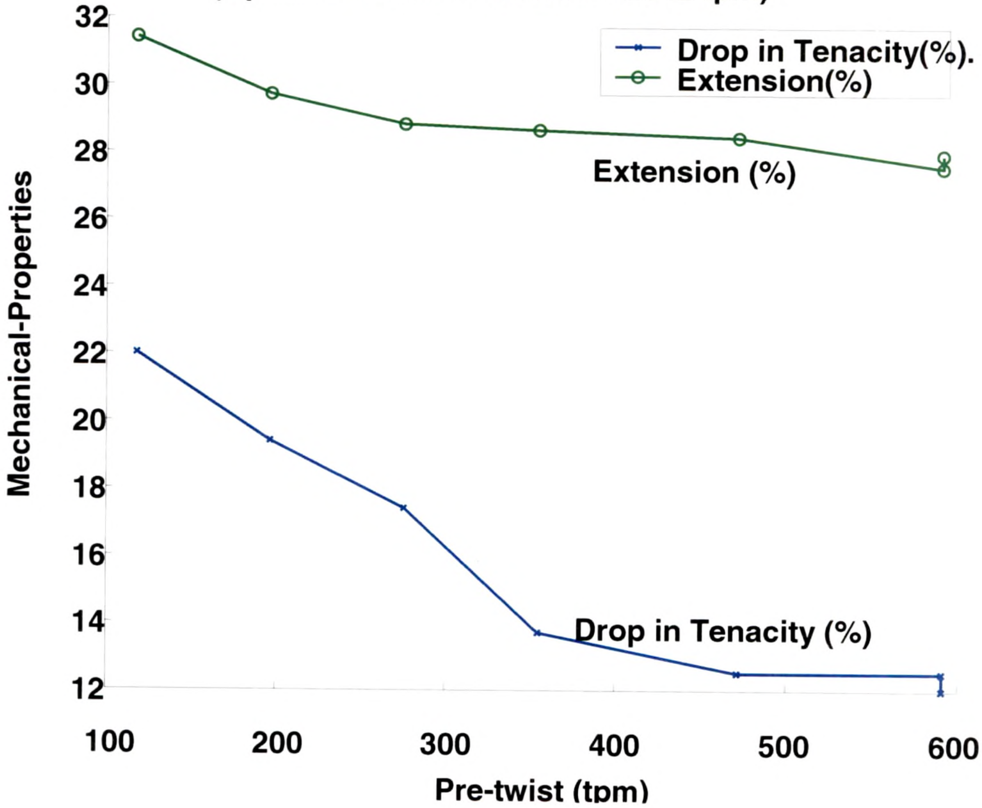
(Parent yarn 150 denier/72 fils. Feeder yarn at 15% underfeed is 130d with 17.3% extension, Optimum False-twist (tpm) = *2942)*

Sample code	*Tenacity (gpd)*	*Reduction in Tenacity (%)*	*Extension (%)*
G1	2.73	22.0	31.4
G2	2.82	19.4	29.7
G3	2.89	17.4	28.8
G4	3.02	13.7	28.6
G5	3.07	12.5	28.4
G6	3.06	12.5	27.5
HG6	3.08	12.0	27.9

- **gpd = gram per denier, , tpm =twist per meter, fils. = filaments.**

Hence false-twist level is kept constant, degree of crimpiness and intermingling achieved are almost identical for all the samples, and thereby in the presence of low magnitude lateral forces (pre-twist) higher drop in tenacity is likely. The same unfavourable situation becomes favourable in terms of extension at break. As at low pre-twist level newly engineered yarn is loose and easily extensible because of low degree of locking of high frequency curled filaments, allowed it to undergo highest extension value before rupture [figure 4.16 (b)]. Table 4.10 (a) depicts highest instability on its account substantiate highest mobility of the structure. Apart from the increase in lateral forces with the increase in pre-twist level, yarn structure becomes compact [figure 4.15 (b)], not facilitated in easy opening of curls before rupture. So, although tenacity of the product yarn has increased extension was dropped with the increase in pre-twist.

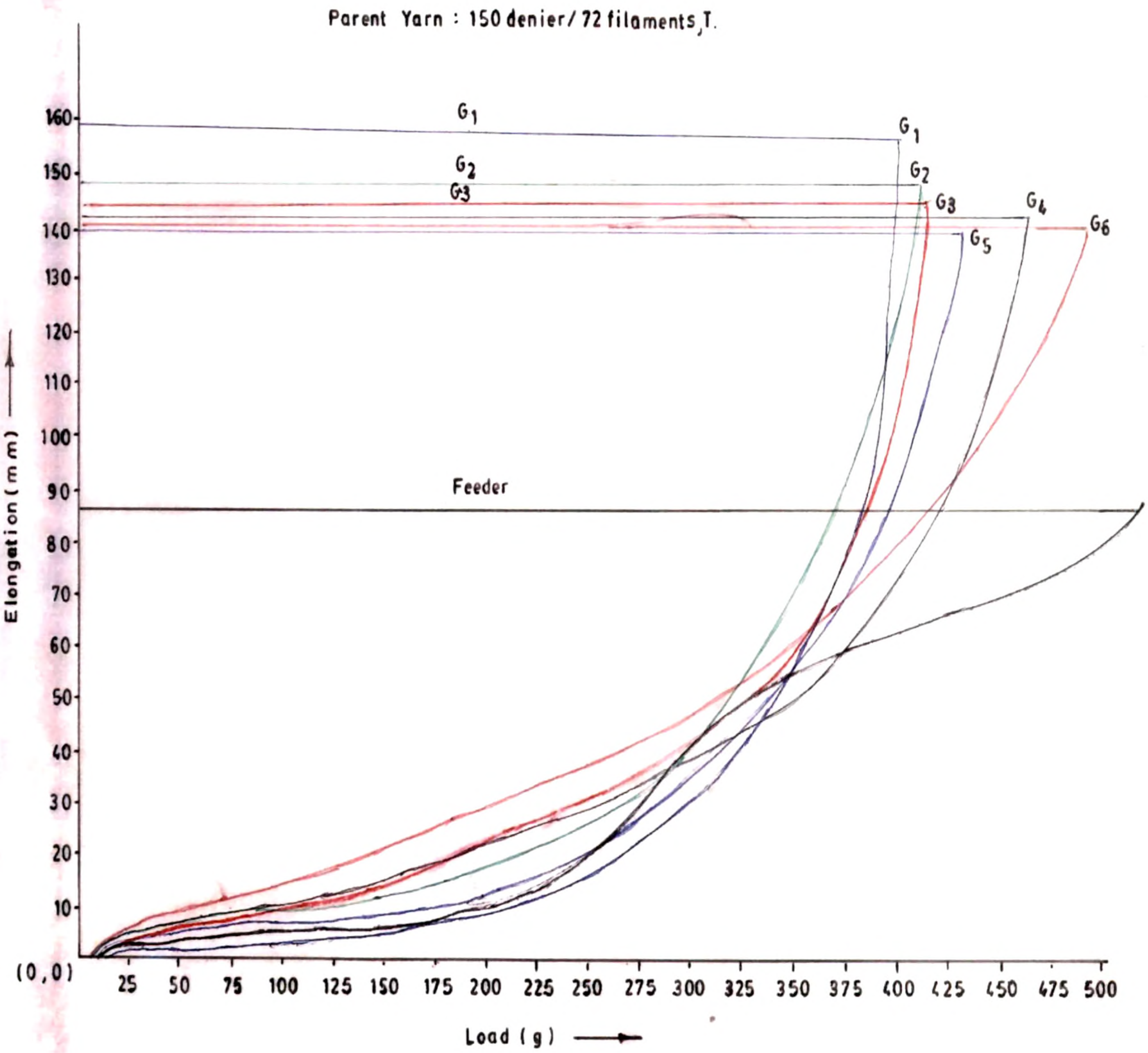
Figure 4.16 (c) Effect of Pre-twist on Mechanical Properties (Optimum False-twist level =2942 tpm)



The scanned image of the load-elongation behaviour obtained for all the samples along with feeder yarn (flat and drawn parent yarn) from Instron tensile strength tester has been shown in figure 4.7 (c). It supports the discussion.

Impact of pre-twist on load-elongation behaviour of innovative textured yarn has already been discussed in section 4.5. The diagram is intentionally repeated to streamline the discussion on mechanical properties.

Figure 4.7(c) Effect of Pre-twist on Load-Elongation behaviour of Innovative Textured Yarn.



Thus it is convenient to conclude that pre-twist has a direct influence on latent properties like bulk, feel. These properties are the subject of the choice of consumer, the ultimate end-users. For optimum false-twist level pre-twist value can be thus set accordingly to satisfy the need of the targeted customer.

4.10.6 Effect of Post Heat-setting.

Post heat-setting becomes an integral part of modern air jet texturising for acquiring additional stability to textured yarn structure for thermoplastic yarn[15]. So, looking at the simulation in the locking system used, one trial was made by giving post heat treatment to sample G6 to check its influence on the instability, linear density and bulk of the newly designed structure. Test results of heat-set sample HG6 are given along with other samples in table 4.10 (a-b) and presented graphically in figure 4.16 (a-c). Photo-graphic view of microscopically measured yarn structure has been executed in figure 4.15 (b).

4.10.6.1 Linear-density and Bulk of Post Heat-set Yarn (HG6)

Heat-relaxation was caused due to post heat setting that has increased contraction. This further shortening has resulted in the slight rise in linear density and bulk value of the post heat-set sample-HG6 as compared to non heat set equivalent textured yarn sample G6 [fig.4.16(a)]. Increased pre-twist concentration per unit length supports the argument [table 4.10(a)].

4.10.6.2 Instability and Mechanical Properties of Post Heat-set Yarn (HG6)

Instability of the heat set yarn is found to be lower than equivalent non-heat set yarn G6 almost by 25 percent. This is mainly due to increased inter-filament cohesion on heat setting. The development of latent power of crimp on heat setting was also resulted in the increment of tenacity as well as extension values [table 4.10(b)], substantiate the argument.

4.10.6.3 Percent Boiling water shrinkage of Post Heat-set Yarn

Stabilization of shrinkage on post heating has shown reduction in boiling water shrinkage of the product yarn [figure 4.16(b)] as per expectation.

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

The work reported in this section is aimed at finding the influence of supply yarn parameters, viz; the material, linear density per filament, number of filaments, filament cross-sectional shape, and applied spin finish on final properties of textured yarns. The effect of these parameters on the instability, linear density, strength, bulk and yarn structural properties like type and frequency of curls of newly engineered yarn are ascertained.

4.11.1 Effect of Raw-Material Characteristics (set-III).

Nylon and Polyester were the only two yarn materials used. Properties of these supply yarns used are given in table 3.7 of section 3.1.2.3. While investigating the effect of raw-material parameter on the yarn properties, the process and machine parameters were kept at reference conditions.

Test results for the measure of texturising properties and mechanical properties are given in table 4.11(a) and table 4.11(b) respectively.

Effect of raw material characteristics on the structure of the product yarns were studied by using microscopical views taken on Erma-scope at 100x magnification. The photographic views of the typical yarns, illustrating the visual surface characteristics of these textured yarns are given in figure 4.17.

Different supply yarns have different fineness (although tried to keep approximately constant, but restricted by availability), tenacities and breaking elongations (table 3.7), and thereby giving absolute denier, tenacity and percent extension values that would not be informative for the comparison purposes. So, the percentage increase in denier, percentage drop in tenacity and percentage increase in extension from the respective feeder yarn (drawn and flat yarn) values have been used for evaluation.

Table 4.11(a) Effect of Raw-material parameters on Texturising properties.

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

Property	Type of Yarn					
	Nylon			Polyester		
Sample code and Denier/fils.	N1 160/48	N2 70/24	N3 44/24	P1 150/72	P2 100/48	P3 70/36
1. Increase in denier (%)	09.65	10.20	10.85	10.92	09.98	12.31
2. Pre-twist (tpm)	198	195	218	206	195	204
3. Boiling Water Shrinkage (%)	9.47	10.07	9.02	5.62	5.7	6.6
4. Instability (%)	2.56	2.46	2.10	3.38	2.06	2.20
5. Bulk-factor (θ)	19.96	21.16	24.89	25.43	22.96	26.91

- N = Nylon, P = Polyester, tpm = twist per meter, fils. = filaments.

Figure 4.17: ***Photographs of Microscopical-view of Textured Yarn.***

Nylon 160d/ 48, B. ***(Sample: N1)***

Nylon 70d/ 24, B. ***(Sample: N2)***

Nylon 44d/ 24, S.D. ***(Sample: N3)***

Polyester 150d/72,B. ***(Sample: P1)***

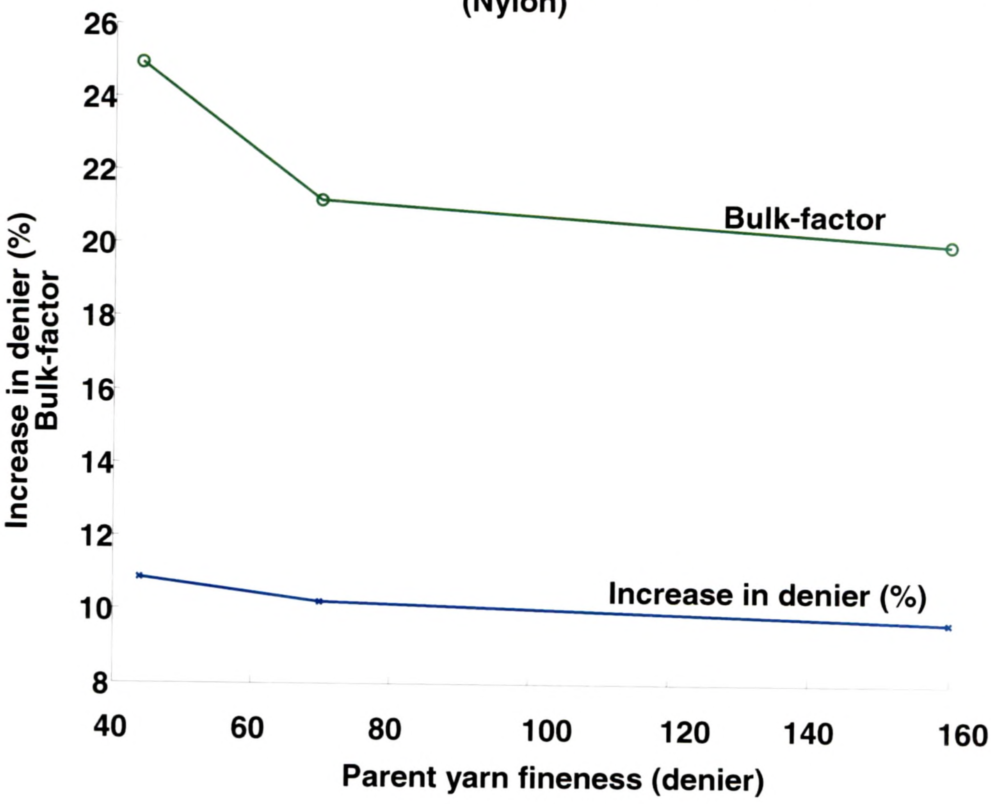
Polyester 100d/48,S.D. ***(Sample: P2)***

Polyester 70d/36,S.D. ***(Sample: P3)***

4.11.1.1 Increase in Linear-density and Bulk

Higher values of bulk factor (Θ) and increase in linear density values are reported for yarns consisting of finer filament for both the polymer yarns under consideration [table 4.11 (a) and figures 4.18 (a-b)]. Structural characteristics of product yarns verify the observation [figure 4.17].

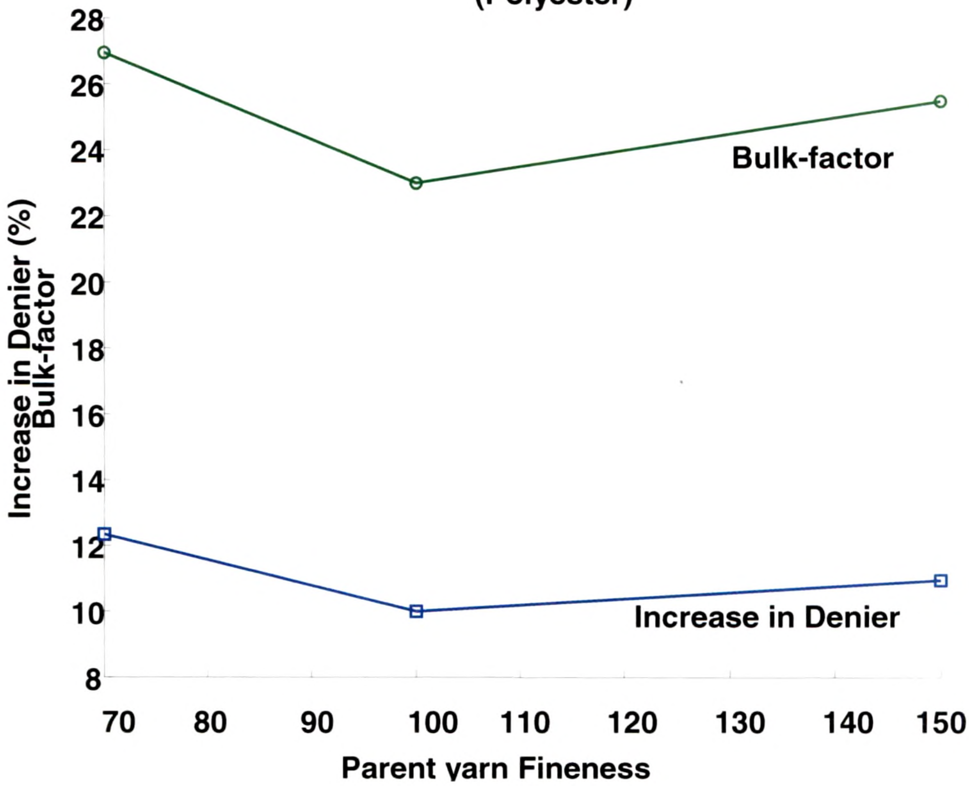
Figure 4.18 (a) Effect of Raw-material on Textured yarn denier and Bulk (Nylon)



It is observed that textured yarns produced with finer filaments (nylon sample-N3, 44d/24fils., and polyester yarn sample-P3, 70d/36fils.) possess higher small size curls as compared to coarser denier filament yarns in the respective group.

This behaviour is mainly due to attainment of higher helix angle in association with low bending and twisting rigidities of finer filaments at the comparable false-twist level. This has allowed the filaments to undergo higher bending deformation thereby acquire increased crimp frequency. Higher differential in filament tension from core to sheath has boosted migration behaviour during false-twisting, and thus resulted in more number of small crossed curls [figure 4.17].

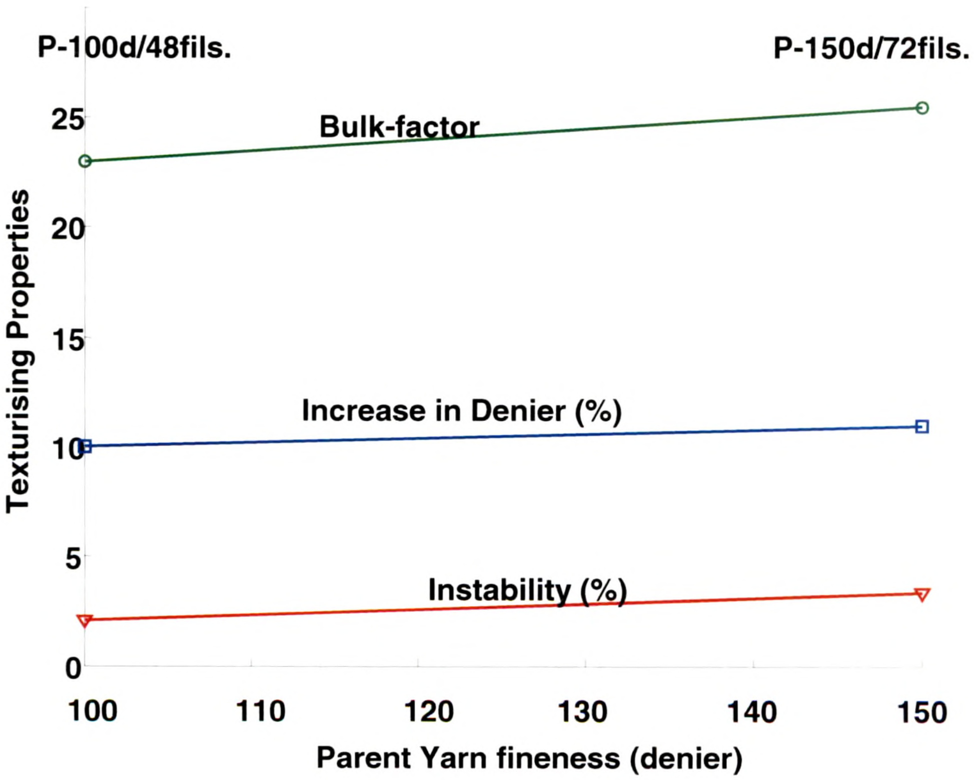
Figure 4.18 (b) Effect of Raw-material on Textured Yarn Denier and Bulk. (Polyester)



Increased crimpiness has allowed the yarn to undergo more contraction, thereby more shortening in length, resulted in increased volume and linear density for the product yarn as compared to other samples under consideration. This is also going in closer resemblance to the findings of Chaudhari et al[28]., Acar et al[29], and Istvan Kerenyi[30] who have reported that finer filament yarn can textured well as compared to yarn with coarser constituents, as the denier of the filaments increases they become more rigid and naturally the tendency of changing configuration also reduces.

It can also be noticed from the results [table 4.11(a) and figure 4.18 (b)] that polyester yarns of different size but having identical filament fineness (2.08 denier) have behaved differently during texturising. Yarn with trilobal cross-sectional filaments (sample P1; 150d/72fils.) has shown higher intensity of texturising over yarn with circular cross-section filaments (sample-P2; 100d/48fils.). More increase in linear density and bulk has been reported in the account of coarser (150denier) yarn [figure 4.18(b) and figure 4.19].

Figure 4.19 Effect of Filament Cross-section and Finish on Texturising properties. **(Filament fineness = 2.08 denier)**



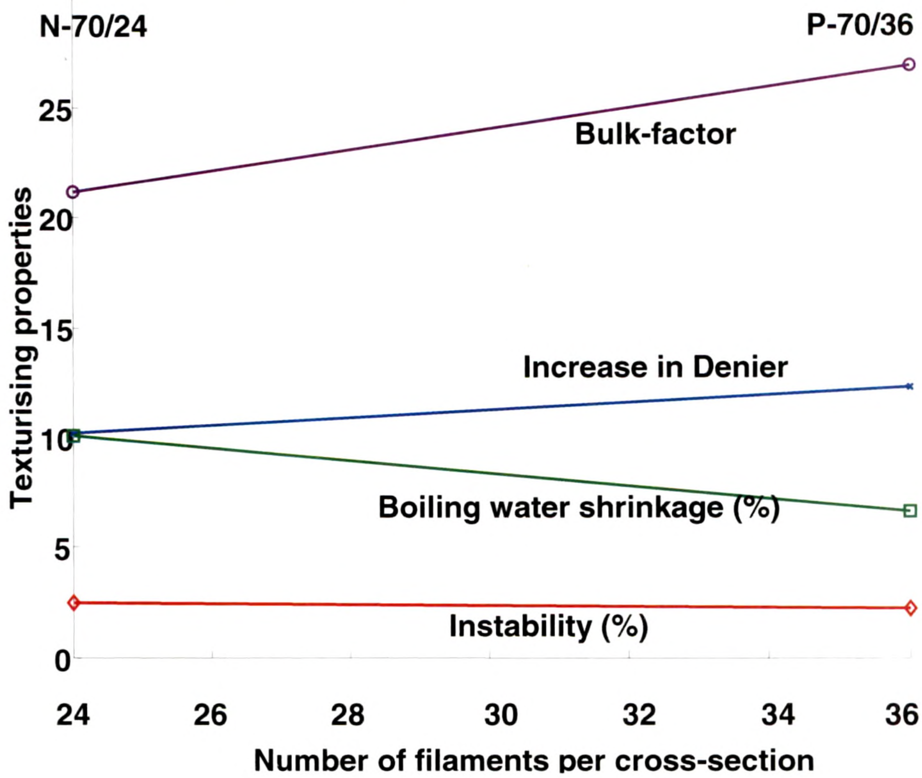
This difference in the behaviour is mainly attributed to presence of brighter finish trilobal constituent filaments. Hence the rigidity of the trilobal filaments are lower compared to circular filaments, they can be bent easily during crimp formation[3, 4, 37,52]. Higher filament deviation from yarn longitudinal axis and frequent movement of the flexible filaments (migration) during false-twisting has resulted in the formation of higher number of small crossed curls [figure 4.17]. Thus it was resulted in increased linear density and bulk of the product yarn, although it is coarser.

Moreover, the inherent bulkiness of yarns due to less close packing of the trilobal filaments[47, 53] the air interstices are more in the structure. This has enhanced the bulk-factor of product yarn further. In the absence of availability of such comparable samples for nylon group, practical significance of this theory for it remains unchecked.

Thus filament cross-section and spin-finish have played a decisive role over the filament fineness as well as yarn fineness.

Tensile modulus of polyester (4.5 N/tex) is higher than nylon (1.7-3.3 N/tex). Higher bending and torsional stiffnesses of the polyester, expectedly makes migration and bending more difficult for acquiring crimpy configuration for polyester as compared to nylon[2, 4]. So, for the equivalent 70denier supply yarn higher increase in the textured yarn denier and bulk for nylon is expected. But against this theoretical prediction higher rise in linear density and bulk has been observed for textured 70denier polyester yarn as compared to equivalent nylon yarn [table 4.11(a) and figure 4.20].

Figure 4.20 Effect of Type of material and Filament fineness on Texturising Properties.



This contradiction from theoretical expectation is mainly arrived from the difference in the constituent filament fineness. Although yarn fineness is same, constituent filament fineness was different (table 3.7). Thus high tensile modulus but fine denier (1.9 denier) filaments polyester yarn has undergone more bending deformation during texturising than flexible coarse denier (2.9 denier) filaments nylon yarn.

This goes in simulation to the findings of Acar et al[29, 31]., who have reported that bending and torsional stiffness are directly proportional to the second moment of area about a diameter and to the polar second moment of area respectively. Therefore, the smaller the second moment of areas, the smaller the forces and torques required to bend and twist the filaments respectively.

Thus filament fineness has played a decisive role over total yarn fineness in confining texturising properties of mechanical crimp textured yarn.

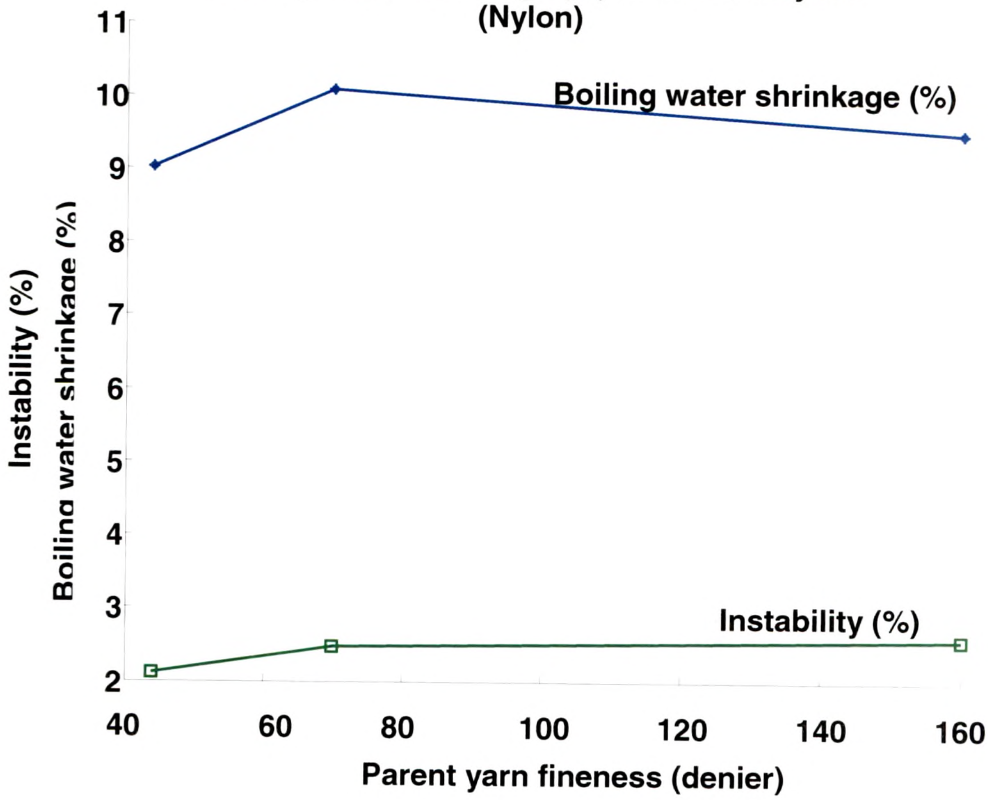
4.11.1.2 Percent Instability

It can be observed from the test results [table 4.11(a)], better texturised nylon yarn (with finer filaments) has executed better stability. The low instability value at the fine filament end of the range is mainly attributed to the enhanced texturising effect [figure 4.21(a-b)]. This has given rise to the interfilament friction that holds the entangled curls together under the applied loads. As the filaments get coarser, the entanglement and curl formation deteriorate, producing yarns with fewer curls and poorly entangled cores resulting in an increase in yarn instability.

However for polyester compared to better textured 70denier/36 filaments yarn 100denier/48fils. yarn has executed lower instability value. This higher instability value of finer denier polyester yarn probably arises from the greater number of curls, increasing the likelihood of curl removal. So, it can't be interpreted as the degradation of texturising quality. It should be looked along with increase in linear density value [table 4.11(a) and figure 4.18(b)], which substantiate the argument.

Similar behaviour is also observed for polyester yarns with identical filament fineness (2.08 denier). Although well-texturised (section 4.11.1.1), trilobal cross-section constituent filament 150d/48fils. yarn has shown higher instability value as compared to 100d/48fils. textured yarn [figure 4.19 and figure 4.21 (b)].

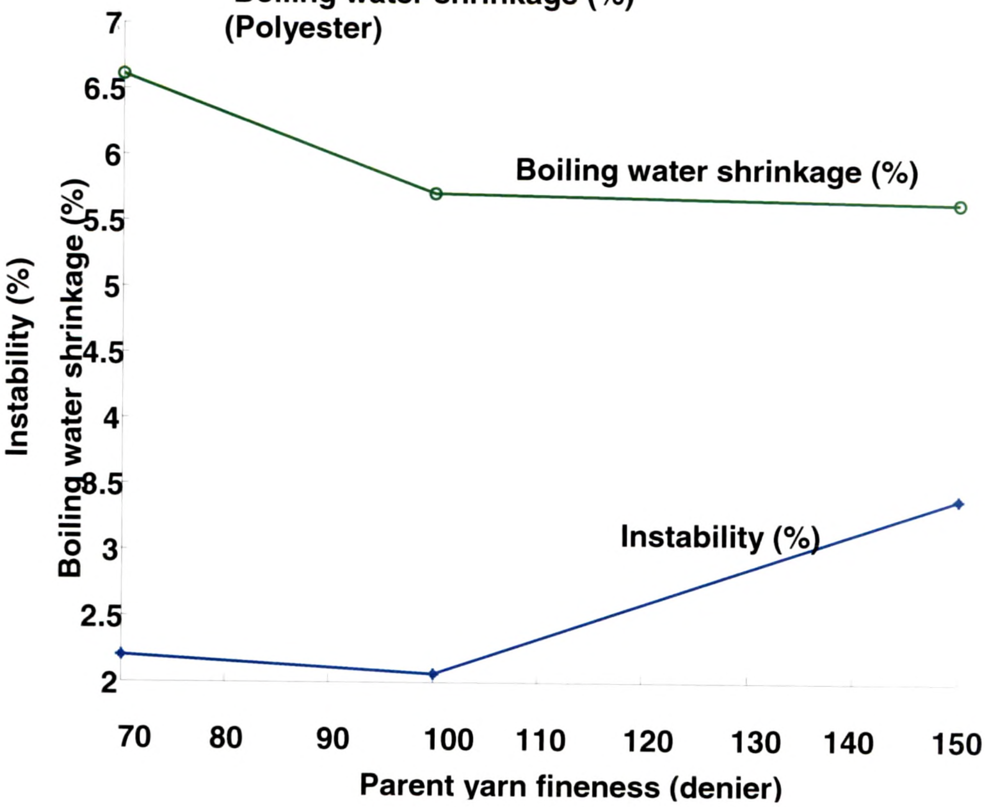
Figure 4.21 (a) Effect of Raw-material on Instability (%) and Boiling water shrinkage (%) of Textured yarn (Nylon)



This is again the consequence of formation of higher number of curls [figure 4.17]. However instability values in both the cases are well within the acceptable limit[56].

Better stability is shown by 70denier polyester yarn as compared to equivalent size nylon yarn under consideration [table 4.11(a) and figure 4.20]. Presence of more number of finer filaments during bulking has played a decisive role in this case. Enhanced degree of intermingling has resulted due to more number of participating finer filaments. This is also going in closer resemblance with findings reported for air jet textured yarn by Acar et al[29]. and Demier et al[31].

Figure 4.21 (b) Effect of Raw-material on Instability (%) and Boiling water shrinkage (%) (Polyester)



4.11.1.3 Percent Boiling water shrinkage

It can be observed that trilobal nylon filament viz; 70d/24fils. yarn, has executed higher boiling water shrinkage in nylon group [figure 4.21 (a)]. Whereas 70d/36fils. polyester yarn has exhibited highest boiling water shrinkage in polyester group [figure 4.21 (b)].

This is mainly attributed to the extent of shrinkage of textured yarn during hot water treatment. It basically depends upon polymer characteristics on getting wet and degree of deformation attained during texturising process. This phenomenon has found to be true for polyester group. 70 denier/36 fils. yarn with higher parent yarn shrinkage (5.6%) and better texturising [table 4.11(a)] has executed highest boiling water shrinkage.

But in case of nylon group, 44 denier/24filaments yarn, better textured and having identical boiling water shrinkage of parent yarn (8.5%) has executed comparatively lower shrinkage as compared to trilobal cross-section nylon (70 d/24fils.). This may be due to trilobal cross-section coarser filaments of 70denier yarn, provided more interstices for water to interact. This argument found support from Krause[47] and Bock[53] who concluded that the inherent bulkiness has been executed by the yarns due to less close packing of the trilobal constituent filaments, and thereby the air interstices are more in the structure.

Thus bending stiffness of filament, cross-section of filament and parent yarn affinity for water have played a decisive role in confining yarn boiling water shrinkage in the present study.

So, it becomes convenient to conclude at this end of discussion that for a given type of material, the individual filament fineness, its flexibility (cross-sectional shape) and number of constituent filaments per cross-section together decides texturising quality for a given yarn in case of innovative texturising.

4.11.1.4 Pre-twist

Some difference in theoretically set-up pre-twist value and measured pre-twist value is likely due to mechanical limitations of drive and degree of contraction attained on texturising.

4.11.1.5 Mechanical Properties

As mentioned before due to difference in tenacity and extension values of yarns under consideration, percentage change from feeder yarn values are preferred over the absolute values [table 4.11(b)].

Table 4.11 (b) Effect of Raw-material parameters on Mechanical properties.

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

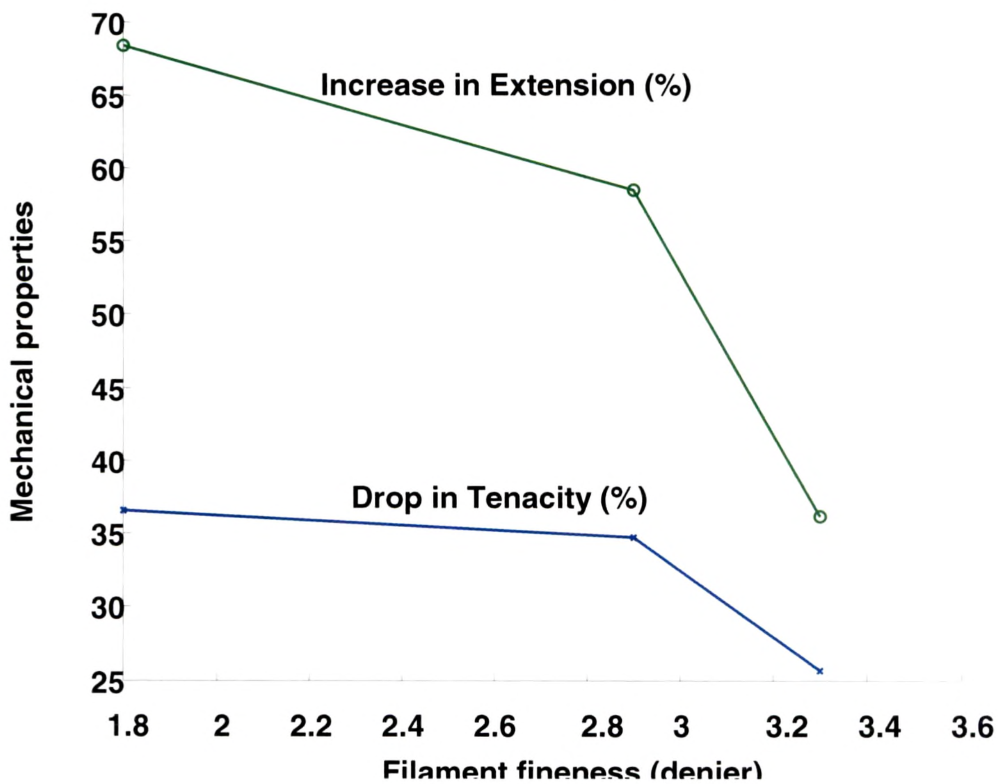
Property	Type of Yarn					
	Nylon			Polyester		
Sample code and Denier/fils.	N1 160/48	N2 70/24	N3 44/24	P1 150/72	P2 100/48	P3 70/36
1. Drop in Tenacity (%)	25.61	34.71	36.54	29.14	25.21	35.55
2.Increase in Extension (%)	36.11	58.43	68.33	52.48	49.58	55.75

- **N = Nylon, P = Polyester, tpm = twist per meter, gpd = gram per denier**

 # Tenacity of the feeder yarn gets increased as compared to parent yarn on under feeding due to drawing action depending on the improvement achieved in the orientation of filament segments[4, 15]. Change in degree of orientation purely depends upon the type of material, yarn fineness, cross sectional shape and filament fineness[2, 3, 28]. So, tenacity value for each feeder yarn has been reported in table 3.7 for reference.

It can be seen from table 4.11 (b) that on mechanical crimp texturising better textured finer filaments nylon as well as polyester yarns [sample N3 and sample P3 respectively] have executed poor strength realization and highest percent extension compared to others. This is due to their more obliquity inside the yarn structure. Effect of filament fineness on the mechanical properties of the nylon yarn has been illustrated graphically in figure 4.22. But filament fineness is almost identical for all selected polyester yarns, so such comparison is not possible.

Figure 4.22 Effect of Filament fineness on Mechanical properties of Textured yarn. (Nylon)



It is also observed from results [table 4.11(b)] that better textured 150d/72fils. polyester yarn has exhibited more reduction in tenacity value as compared to 100d/48fils. polyester yarn. Similarly more drop in tenacity value was gone on the account of equivalent size (70 denier) but with finer denier filaments polyester yarn in comparison to coarse denier nylon yarn.

It founds the support from Acar et al[29]. and Istavan[30] who reported that yarn with less tensile modulus finer trilobal cross section filaments, on texturising shows higher differences in path lengths among the constituent filaments due to increased bending deformation, results in more reduction in tenacity value.

Elongation of the textured yarn is the outcome of the extension caused due to the opening of the curls and the normal elastic extension of straight filaments[2, 4, 15]. Even the mutual cohesion between filaments due to entanglement in yarn also prevents a weak place in one filament which is being extended less than the neighboring filaments thus delays the occurrence of rupture and therefore increases the breaking extension of yarn after texturing [3]. Thus going in agreement to these findings textured yarn produced from the nylon feeder yarn with high extension (table 3.7), viz; 44denier/24filaments and achieved better degree of crimping and mingling on texturising [figure 4.17] has executed highest extension [table 4.11 (b)].

Percent spin finish value of all the samples under study is almost identical (table 3.7). So, no profound difference in the behaviour for negligible difference in spin finish has been noticed for either group of yarn under study.

4.11.2 Effect of Yarn Fineness.

In order to ascertain the effects of total yarn linear density (i.e. number of filaments), a 100denier 48filaments polyester yarn was folded to form 200, 300 denier yarns. The properties of such textured yarns [(1x 100d), (2 x 100d) and (3 x100d)] are given in table 4.12 (a-b). Photographs of the microscopical-views illustrating surface characteristics of the product yarn are given in figure 4.23.

Table 4.12 (a) Effect of Yarn Fineness on the Texturising Properties

(Pre twist factor of 24tex$^{1/2}$.turns/c.m., delivery speed = 100 m/min, 25 percent under feed.)

Sample-code and its description	Pre-twist (tpm) Theo. value	Pre-twist (tpm) Mea. value	False-twist (tpm)	Increase in denier (%)	Boiling water shrinkage (%)	Bulk-factor (Θ)	Instability (%)
C1, 1 x 100d/48fils.	720	688	3612	14.33	5.64	19.51	3.20
C2, 2 x 100d/48 fils.	509	480	2531	12.54	6.00	17.65	2.06
C3, 3 x 100d/48 fils.	416	354	2050	09.11	6.40	16.82	2.76

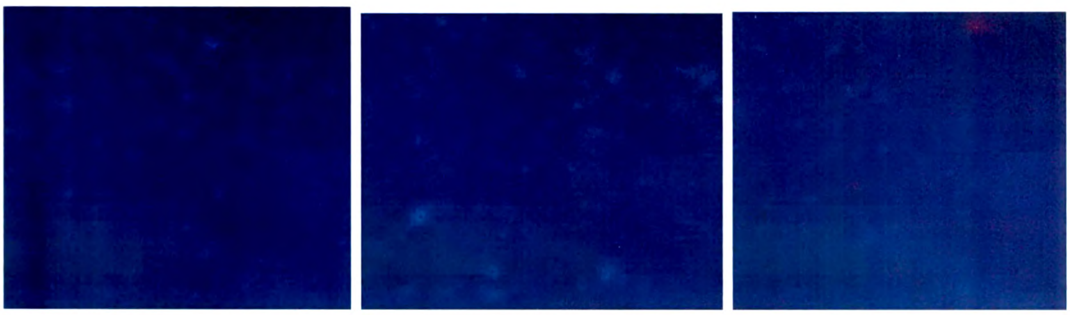
- **C = textured yarn, fils. =filaments, tpm =twist per meter**
- **1 =single end, 2 = two ends, 3 = three ends,**
- **Theo. = Theoretical, Mea. = Measured.**

Figure 4.23 (a) Photographs of Microscopical- Views

Sample C1 **Sample C2** **Sample C3**

(b) Photographic views of Tube Knitting and Dyeing Samples

Sample C1 Sample C2 Sample C3

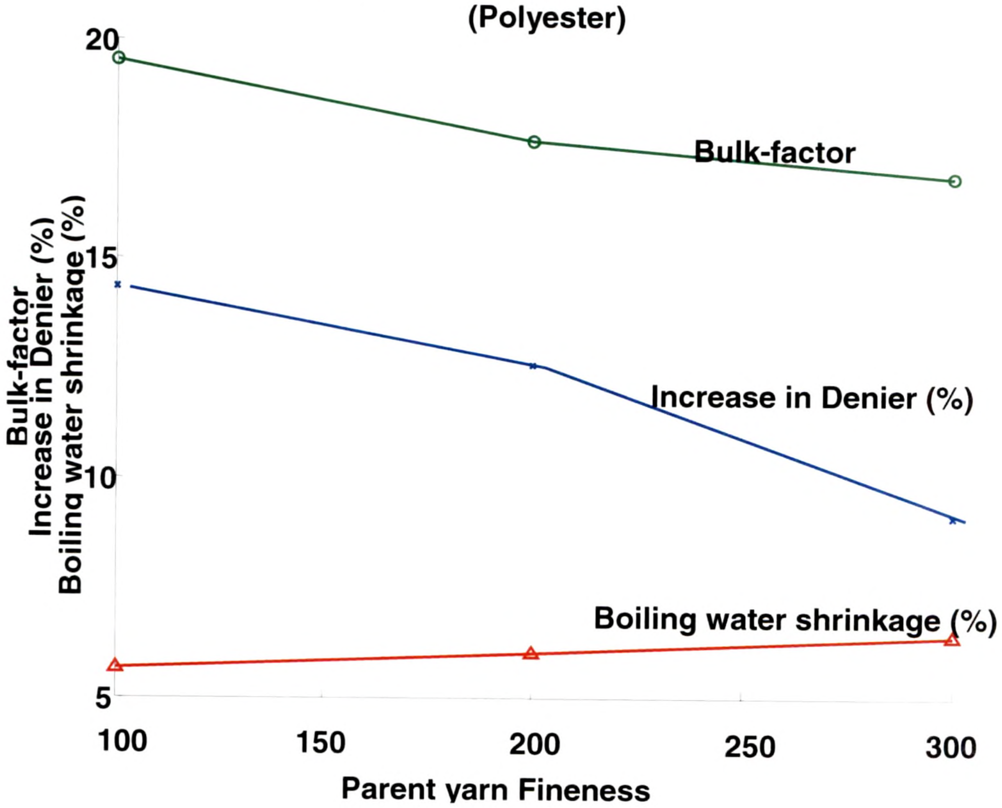


4.11.2.1 Increase in Linear density and Bulk

It can be observed from the results [table 4.12(a) and figure 4.24] that single-end yarn; sample C1 (100d/48fils.), has executed higher linear density and bulk values.

Figure 4.24 Effect of Yarn Fineness on Textured yarn Bulk, Denier and Boiling water shrinkage.

(Polyester)

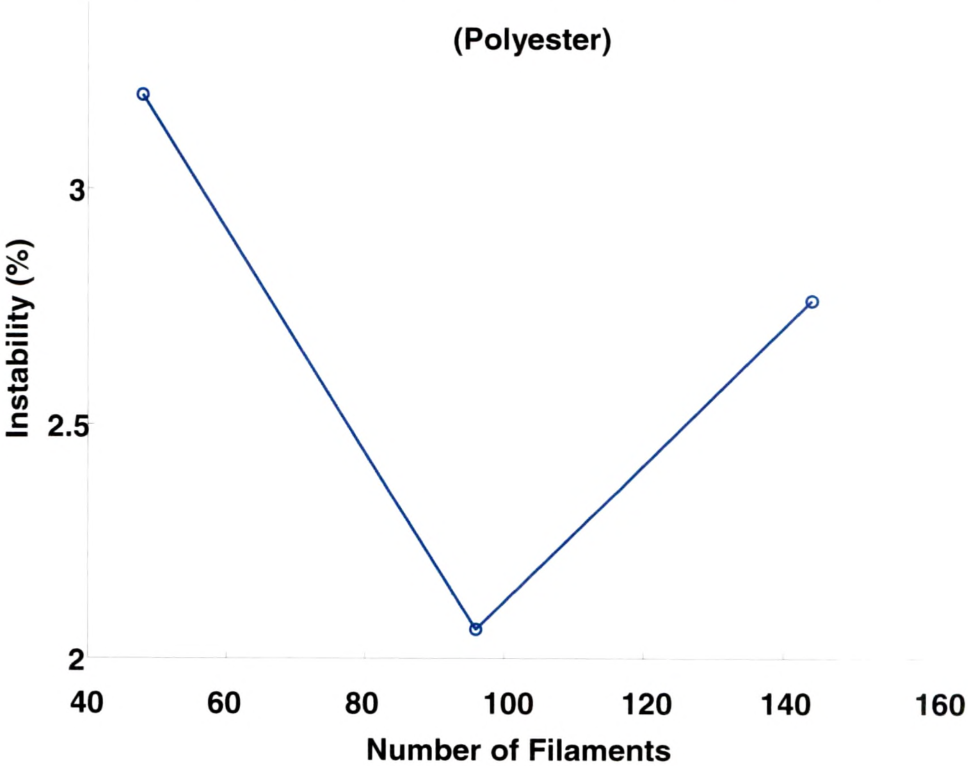


The possible explanation for this behaviour can be given with reference to false twist texturising. At optimum false-twist level finer yarn get twisted to a higher twist angle[2, 4, 47]. Thereby textured yarn made up of finer feeder yarn likely to exhibit smaller curls with a higher frequency as compared to the coarse one. Photographs of microscopical views [figure 4.23(a)] represents surface characteristics of all product yarns under consideration substantiate this presumption. Pre-twist factor being constant, increased shortening of the length of flat filaments are mainly due to higher degree of crimping attained. More the contraction in length more will be the increase in denier. Even for constant pre-twist factor compacting of textured yarn structure will be uniform irrespective of its fineness[61]. As a consequence of this finer yarn has shown higher bulk [table 4.12(a)].

4.11.2.2 Percent Instability

It is observed from the results [table 4.12(a) and figure 4.25] that single-end yarn is more unstable as compared to two-end or three-end yarns.

Figure 4.25 Effect of Number of Filaments on Textured yarn Instability (%).



This is mainly attributed to the lower degree of intermingling occurred due to less number of participating filaments. This goes in agreement to findings of Acar et al[29], Bock et al[33], Bose and Govindraju[34] , who reported that with the increase in the number of filaments (total yarn linear density), yarn quality gets enhanced due to increased potential for filament entanglement.

It can also be seen that two fold yarn is more stable than single yarn, but further increase in the number of ends to three-ends the instability value again increases [figure 4.25]. This has happened probably due to less intermingling occurred. As in the presence of more filaments in the texturising zone inter-filament frictional get increases, adversely affects its mobility to acquire new configuration[58, 59]. Moreover use of coarser yarn reduces area of contact per filament at false twist spindle (magnetic-pin) during texturising[19, 41]. Going by this finding reduced bending torque per filament during texturising has reduced filament migration during false-twisting and thereby reduced potential of intermingling for three-fold yarn. Reduced mingling along with constant lateral forces (pre-twist) must be resulted in reduced stability. Reduction in bulk and denier values of coarse denier product yarn substantiates deterioration in the level of texturising.

4.11.2.3 Pre-twist and Percent Boiling water shrinkage

Some difference in theoretical set and practically measured pre-twist values [table 4.12 (a)] is likely as found in earlier experiments also.

Percent boiling water shrinkage has shown rising trend along with increase in linear density of feeder yarn [figure 4.24]. However uniformity and dye uptake of tube knitted and dyed hoses remain unaltered for this slight difference in shrinkage value [figure 4.23].

4.11.2.4 Mechanical Properties

Although similar, difference in the number of filaments sharing the tensile load affects their tensile behaviour. So, results are evaluated in terms of change in mechanical properties instead of their absolute values [table 4.12 (b)].

Table 4.12 (b) Effect of Yarn Fineness on the Mechanical Properties

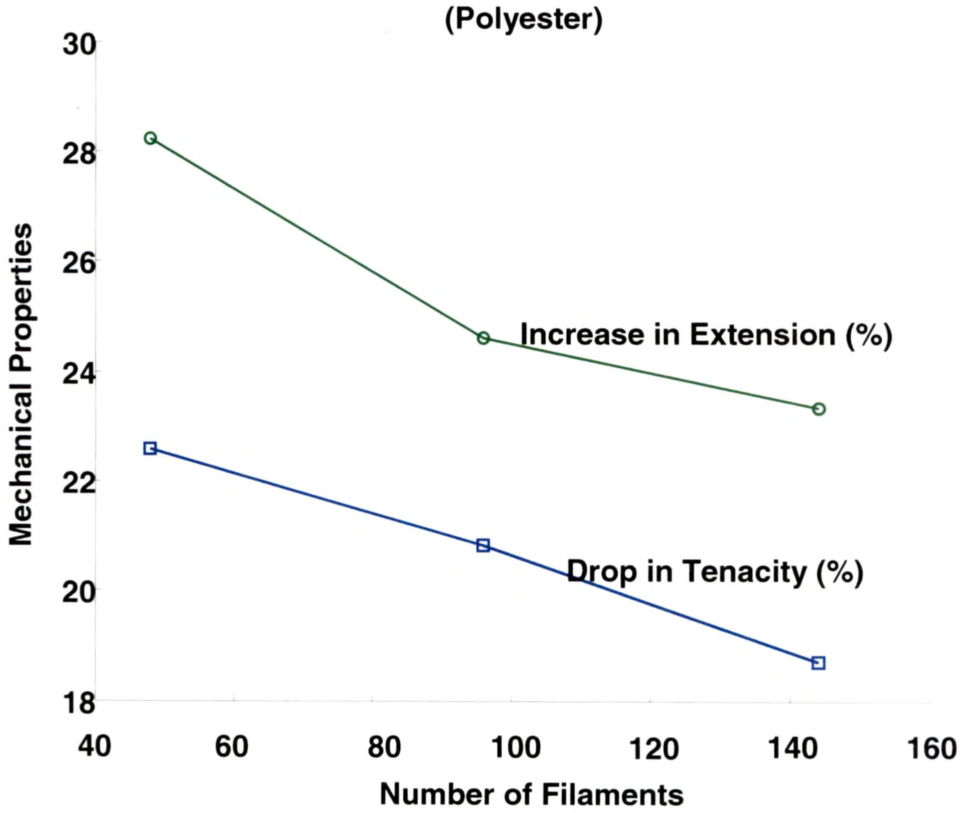
(Pre twist factor of 24tex$^{1/2}$.turns/c.m., delivery speed = 100 m/min, 25 percent under feed.)

Sample-code and its description	Drop in Tenacity (%)	Increase in Extension (%)
C1, 1 x 100d/48fils.	22.58	28.22
C2, 2 x 100d/48 fils.	20.83	24.61
C3, 3 x 100d/48 fils.	18.69	23.33

- **C = textured yarn, fils. =filaments, tpm =twist per meter**
- **1 =single end, 2 = two ends, 3 = three ends.**

From the results it is clear that better textured single end yarn has exhibited highest drop in tenacity and increase in percent extension as compared to other samples [figure 4.26]. Increased inter filament friction and deterioration in texturising quality as mentioned in section 4.11.2.1, in the presence of more number of constituents has stopped further drop in tenacity and reduced extension of two-fold as well as for three-fold yarns [figure 4.26].

Figure 4.26 Effect of Number of Filaments on Mechanical properties. (Polyester)



Performance- Evaluation

Of

Newly Engineered

Textured Yarn

In

Knitted and Woven

Structure.

4.12 Introduction

Fabrics were produced using the mechanical textured polyester filament yarns and its corresponding feeder (drawn flat parent yarn after underfeed) polyester yarns as wefts on the loom. Same warp yarn (50denier/24filaments, highly twisted with 3000 tpm and post heat-set at 90-95°C for 50minutes) and warp sett-values (40 per cm on the loom) were maintained for avoiding undue variations and identifying effect of weft yarn on fabric performance.

Table 4.13(a) Properties of Flat Feeder Weft- Yarns.

Sample code	Sample description	Denier	Tenacity (gpd)	Extension (%)	Boiling water shrinkage (%)
Ft	Feeder- yarn for false-twist texturising,100/48, white, C$	75	4.60	30.20	2.58
Fw1	Feeder yarn*, 100/48, white, C	79	4.21	24.60	2.54
Fg	Feeder yarn* 150/72, Green, T	130	2.56	17.30	3.89
Fw2	Feeder yarn* (2 x 100/48), white, C	162	3.98	24.66	2.60

$ Partially Oriented Yarn after drawing (before feeding to false-twist texturising), based on the data obtained from reputed industry.

*** Feeder yarn is the parent yarn after under feed. 25% Underfeed used for 100/48 yarn and 15% for 150/72 yarn.**

C = circular cross-section, T = Trilobal cross-section, gpd = gram per denier.

Denier and tensile properties of different feeder yarns, textured yarns and post heat-set textured yarn used as weft during study are given in table 4.13 (a-c).

Feeder yarns as well as textured yarns fabrics were woven and dyed under the identical condition as per mentioned in section 3.1.2.

Table 4.13(b) Properties of Mechanical Textured Weft- Yarns.

Sample code	Sample description	Denier	Tenacity (gpd)	Extension (%)	Boiling water shrinkage (%)
FT	100/48, white, C	90	4.21	20.98	9.87
F1	100/48, White, C, P.T.= 0.6	94.26	3.03	33.48	4.80
F2	100/48, White, C, P.T.= 24	95.18	3.26	29.13	5.64
F3	(2 x 100/48), White, C, P.T.= 0.6	189.10	2.69	30.12	5.95
F4	(2 x 100/48), White, C, P.T.= 24	190.60	3.31	27.78	7.00
F5	(3 x 100/48),White, C, P.T.= 24	267.99	3.25	26.67	6.40
F6	150/72, Green, T, P.T.= 24	149.60	3.06	27.50	6.61
F7	[100/48, White, C, + 50/36, Black, C] P.T.= 24	148.9	2.59	23.72	5.78

- C = circular cross-section, T = Trilobal cross-section, F.T. = False-Twist Textured yarn, F1-F7 are mechanical crimp textured yarns
- P.T.= Pre-Twist factor(in tex$^{1/2}$.tpcm), gpd = gram per denier.

Table 4.13 (c) Properties of Post Heat-set Textured Weft- yarns

Sample Code	Denier	Tenacity (gpd)	Extension (%)	Boiling water shrinkage (%)
HF2#	93.66	3.41	29.74	0.40
HF4	184.88	3.51	27.64	0.50
HF5	275.95	3.20	26.56	0.60
HF6	149.70	3.08	27.90	4.96

 # H indicates heat set yarn, F2, F4, F5 and F6 refers Mechanical Crimp Textured yarns as per described in table 4.13 (b).

C = circular cross-section, T = Trilobal cross-section, gpd = gram per denier.

Various tests carried out for the evaluation of fabric- quality are conveniently divided into four different groups for the analysis. Test results are therefore evaluated in terms of i)Constructional properties, ii) Mechanical properties, iii) Comfort related transmission properties and iv) Low stress mechanical properties and Aesthetic properties.

4.12.1 Constructional Properties

Constructional properties are considered for identifying different structural features of the fabrics. Test results obtained for all feeders and newly textured weft yarn fabrics are summarized into four groups [table 4.14(a-d)] as per the difference in their characteristics.

All the fabrics under consideration were plain woven. Even loom sett-parameters, viz; reed-count, warp-count, pick density etc. for all the fabric samples were kept almost same on the loom (section 3.1.2.4). Only variable introduced during fabric formation was type of weft. So, the performance of weft can be well judged for identical constructional parameters.

Table 4.14(a) Constructional Parameters of Woven fabrics

(Flat-Feeder yarn weft)

Property		Sample code			
		Ft	Fw1	Fw2	Fg
Linear density (denier)	Warp	62.5	59.1	61.8	66.8
	Weft	101.1	81.9	163.7	150.6
Fabric-sett	Ends/cm	43	42	42	47
	Picks/cm	29	30	25	30
Crimp (%)	Warp	19.35	12.87	18.41	18.12
	Weft	2.30	2.30	2.05	2.47
Thickness (mm)		0.2200	0.1998	0.2250	0.2351
Fabric weight per unit area (GSM)		71	59	87	90
Fabric width shrinkage (%)		1.52	1.20	1.15	5.30

- **Ft =feeder for false-twist texturising, GSM = gram per square meter.**
- **Fw1 = single end 100d/48filaments yarn, Fw2 = double end 100denier/48filaments yarn.**
- **Fg = Green dyed 150 denier/72filaments yarn.**

4.12.1.1 Fabric Sett and Fabric width shrinkage

It can be observed from the results [table 4.14(a-d)] that finished fabric sett values get altered from the sett-values used on the loom. Although they were kept constant on the loom depending on fineness of weft –yarn used (section 3.2.1.4). Difference in the value is purely due to width shrinkage occurs after wet-treatment[64, 65].

Table 4.14(b) Constructional Parameters of Woven fabrics

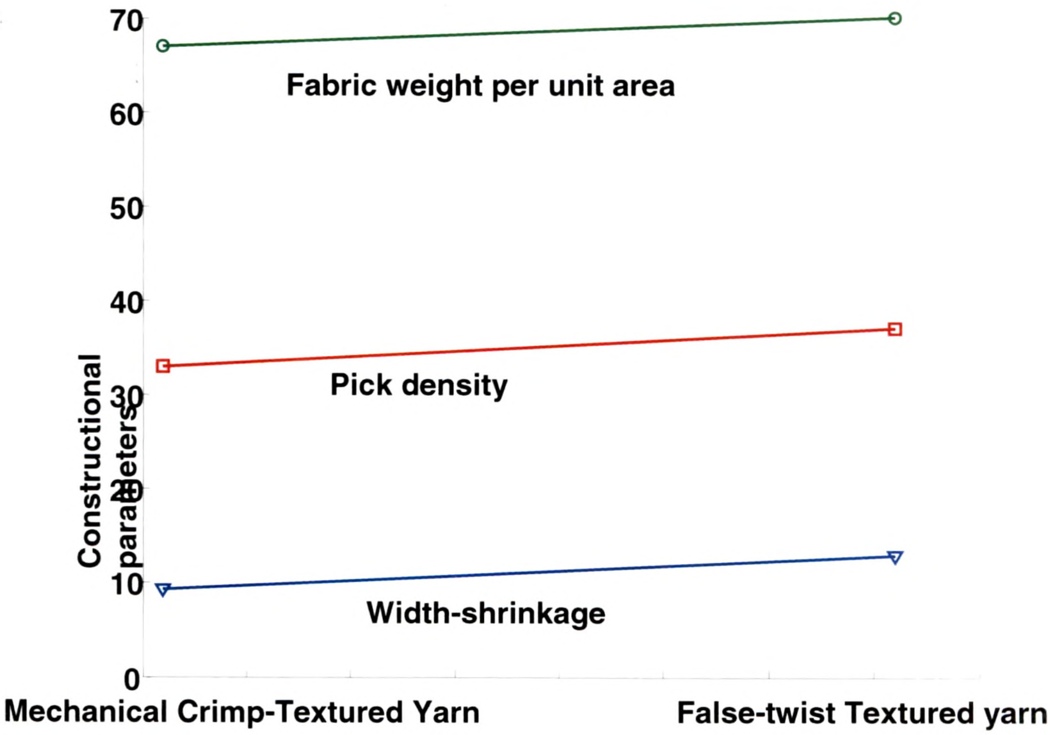
[Innovative Textured yarn weft (low pre-twist: 0.6 $tex^{1/2}$.tpcm)]

Property		Sample code		
		F.T.	F1	F3
Linear density (denier)	Warp	65.07	59.72	61.48
	Weft	136.4	101.4	198
Fabric-sett	Ends/cm	47	45	44
	Picks/cm	37	33	28
Crimp (%)	Warp	5.96	11.87	14.08
	Weft	6.98	2.88	3.93
Thickness (mm)		0.1540	0.2281	0.2640
Fabric weight per unit area (GSM)		70	67	98
Fabric width shrinkage (%)		12.82	9.33	5.33

- **F.T. = False-Twist textured, GSM = gram per square meter.**
- **F1 = Single end mechanical crimp textured.**
- **F3 = double end mechanical crimp textured.**

It is found that fabric woven with weft yarn having higher boiling water shrinkage [(table 4.13(a-c)] has exhibited higher width shrinkage [(table 4.14(a-d)]. False-twist textured weft-yarn fabric has exhibited higher width shrinkage as compared to mechanical crimp textured weft-yarn fabrics.

Figure 4.27 Comparison of Constructional parameters of False-twist textured filler fabric with equivalent Mechanical textured filler fabric.



This is mainly due to the crimp geometry created by the false twisting process, get converted into a latent status by a suitable heat treatment. Which on wet treatment in fabric get developed back, gives higher crimp contraction than mechanical textured yarn[50, 63]. Since width shrinkage of the fabric is in direct proportion to crimp contraction, higher width shrinkage value for false-twist textured weft yarn fabric as compared to other mechanical textured weft yarn fabrics is likely[44, 46]. Comparison of false-twist filler yarn fabric with equivalent size mechanical crimp textured weft yarn fabric is shown in figure 4.27. It supports the above mentioned phenomenon.

Table 4.14(c) Constructional Parameters of Woven fabrics
[Innovative-Textured yarn weft (higher pre-twist: 24 $tex^{1/2}$.tpcm)]

Property		Sample code				
		F2 1 x 100d/48fils.	*F4* 2x 100d/48fils.	F5 3 x 100d/48fils.	*F6* 150d/72fils.	F7 150d/84fils.
Linear density In denier	Warp	64.59	64.76	64.90	65.30	64.38
	Weft	102.8	202.1	288.2	163.0	160.9
Fabric-sett	Ends/cm	46	45	43	47	47
	Picks/cm	33	28	23	30	30
Crimp (%)	Warp	12.27	15.88	23.18	13.53	13.43
	Weft	3.52	2.42	2.03	3.87	3.05
Thickness (mm)		0.2593	0.2865	0.3210	0.2650	0.2665
Fabric weight per unit area (GSM)		72	99	133	91	91
Fabric width shrinkage (%)		7.2	4.55	3.85	9.85	8.33

- GSM = gram per square meter.

Following the same trend all the flat-feeder weft yarn fabrics have executed lower width shrinkage as compared to their textured weft-yarn fabrics [table 4.14(a-c) and figure 4.28]. Hence residual shrinkage of the heat set textured yarns is less[28, 46], there is a reduction in the width shrinkage of fabrics woven with post heat-set mechanical textured weft yarn as compared to mechanical textured weft yarn without heat setting [(table 4.14(d)].

Thus fabric shrinkage in the present study was not significantly affected by fabric structure (being identical). Figure 4.29 graphically represents the inter-relationship between mechanical crimp textured weft-yarn denier and fabric width shrinkage values observed for various samples under consideration.

Figure 4.28 Comparison of Width shrinkage of Feeder (flat) filler fabrics and Mechanical Textured filler fabrics.

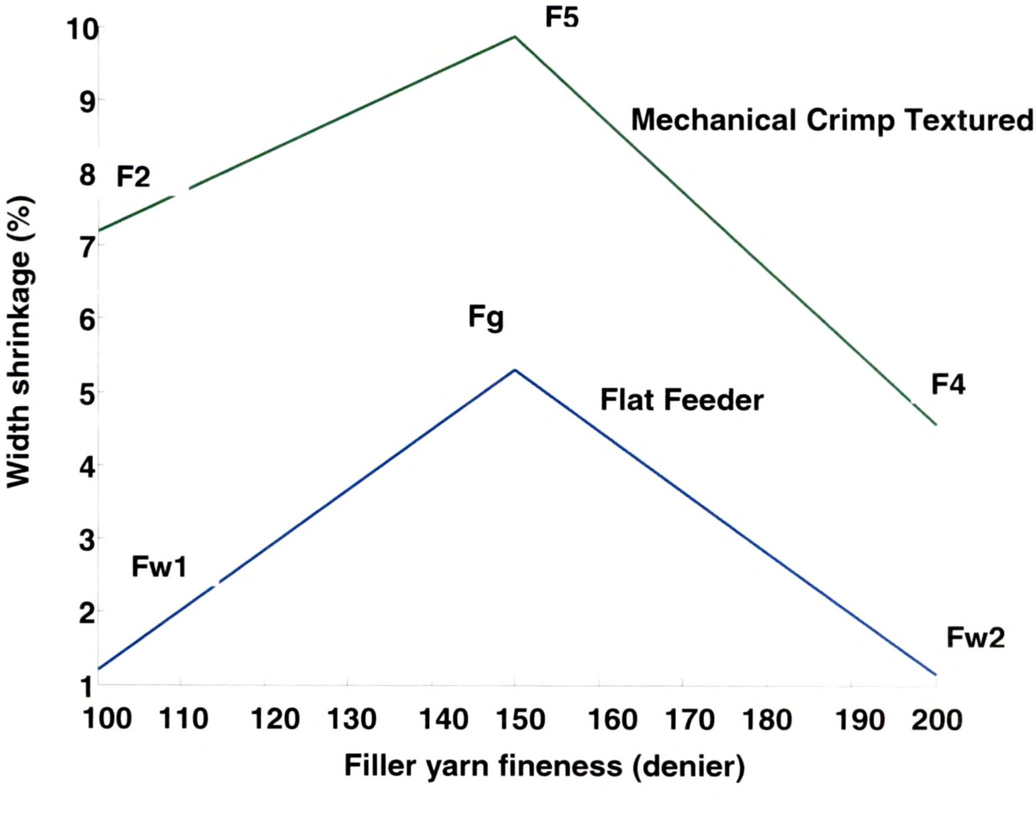


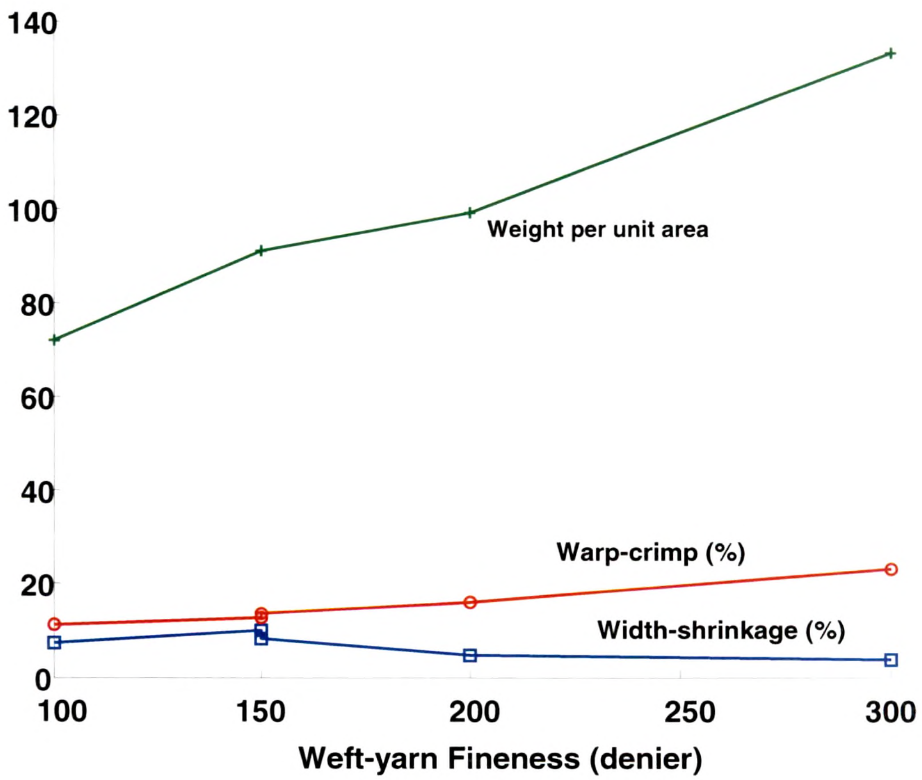
Table 4.14(d) Constructional Parameters of Woven fabrics

[Innovative Textured Yarn Weft (Post Heat-set)]

Property		Sample code				
		HF2	*HF4*	HF5	*HF6*	
Linear density (denier)	Warp	62.82	62.19	63.84	64.26	
	Weft	95.1	188.9	283.0	161.3	
Fabric-sett	Ends/cm	44	43	44	46	
	Picks/cm	33	33	30	28	
Crimp (%)	Warp	8.67	17.89	18.67	14.23	
	Weft	3.85	2.32	2.35	2.35	
Thickness (mm)		0.2409	0.2600	0.3140	0.2480	
Fabric weight per unit area (GSM)		69	100	131	88	
Fabric width shrinkage (%)		2.65	2.65	1.89	7.58	

- GSM = gram per square meter

Figure 4.29 Effect of weft-yarn Fineness on Constructional properties



It can be seen that width shrinkage get reduced with weft yarn denier except for 150d/72fils. yarn. This difference in behaviour may be due to trilobal cross-section of 150 denier yarn allowed it to undergo more interaction with water due to higher voluminisity. Thus results have shown good agreement with Butterworth et al[63]. according to them for identical weave, fabric width shrinkage much influenced by the denier of weft yarn and having inverse relation.

Figure 4.30 Effect of Boiling water shrinkage of Weft on Width shrinkage.

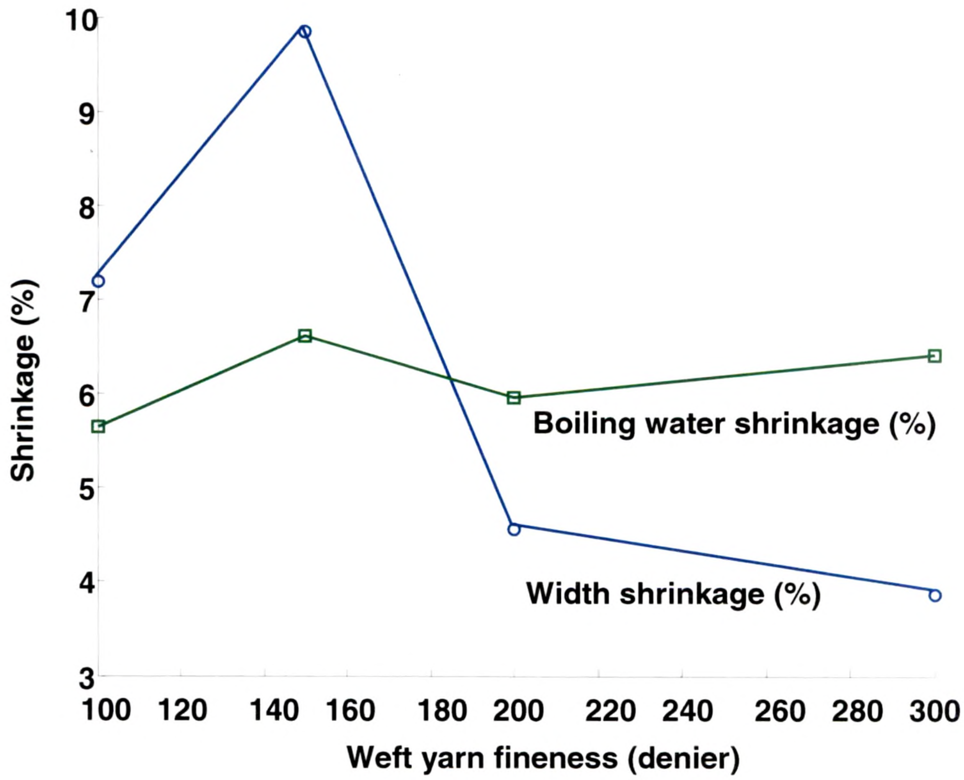
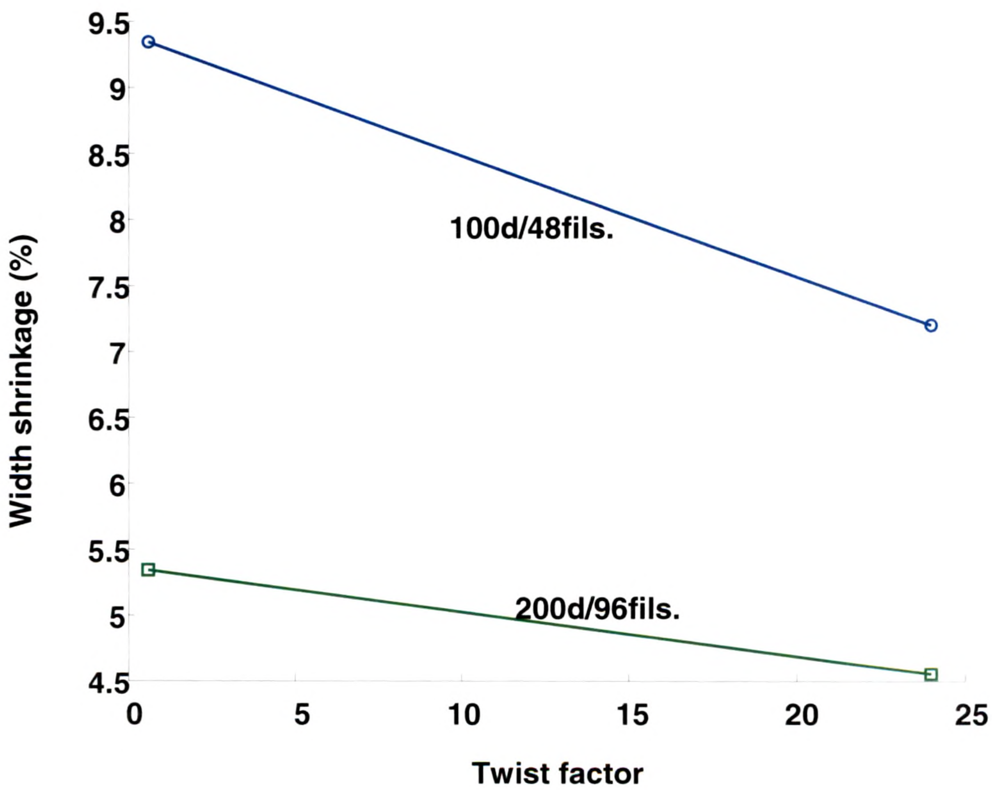


Figure 4.30 illustrate effect of weft yarn boiling water shrinkage on the width shrinkage of the fabric. It can be observed that width shrinkage has followed the similar trend of boiling water shrinkage except 300 denier weft yarn. This is due to presence of coarser weft

yarn for the identical fabric structure. Thus yarn fineness has played a dominating role over shrinkage of yarn.

It can be seen that width shrinkage of fabric gets reduced with the increase in pre-twist of the weft yarn [figure 4.31]. Although weft yarn boiling water shrinkage has increased with the increase in pre-twist [table 4.13(b)] for both the weft yarns under consideration, width shrinkage of the fabric get reduced. This is mainly attributed to the increased linear density of weft yarn on increased twist-contraction [table 4.13(b)]. So again weft yarn denier has played a decisive role for width shrinkage of fabric as compared to yarn shrinkage.

Figure 4.31 Effect of Pre-twist of Weft yarn on Width shrinkage

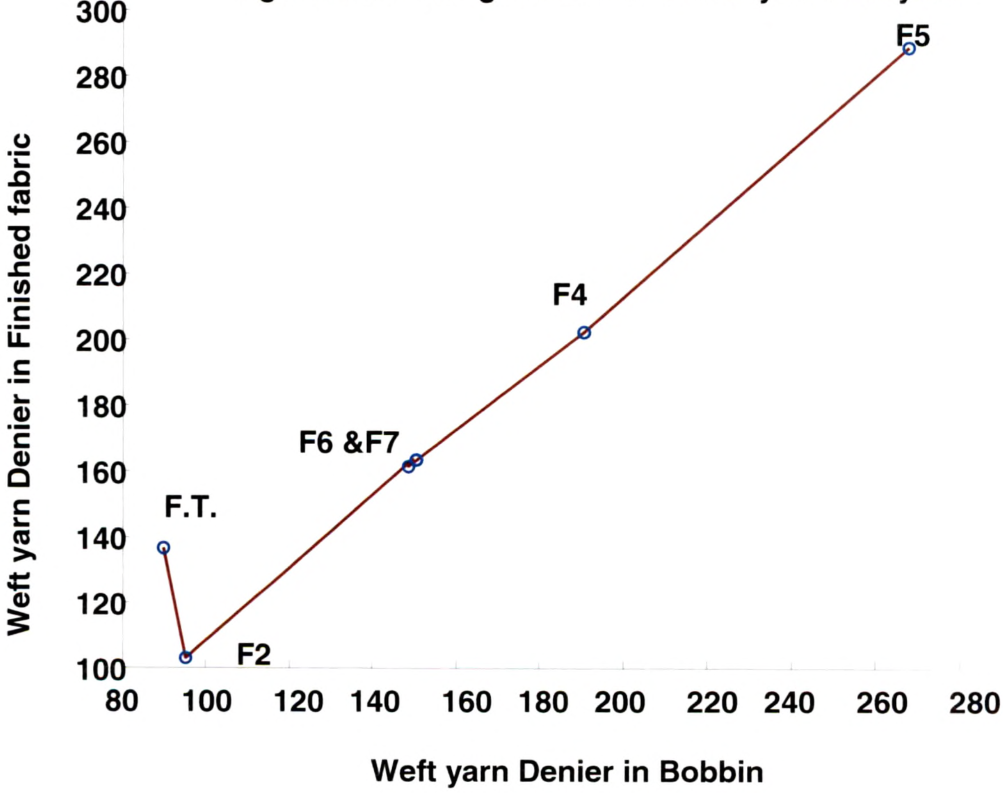


As a consequence of both the results it became apparent to conclude that in the present study weft yarn fineness has more influence on width shrinkage rather than its boiling water shrinkage. Results have shown good agreement with the findings reported for false-twist textured yarn. According to these findings the width shrinkage of the fabric is much influenced by the denier of weft yarn and little affected by residual or boiling water shrinkage of weft yarn[28, 67].

4.12.1.2 Linear density of Constituent Yarns

Results have shown that constituent yarn deniers have increased [table 4.14(a-d)] as compared to that measured from the bobbin [table 4.13 (a-b)]. For identical warp-yarn used effect is more pronounced for textured weft-yarns as compared to flat feeder weft-yarns [table 4.13 (a-b) and table 4.14(a-c)].

Figure 4.32 Change in Linear denisity of Weft yarn



It can be observed from the figure 4.32 that increase in the linear density (denier) is more for coarser weft yarn as compared to finer one. Equivalent size false-twist textured yarn has shown higher rise in denier as compared to mechanical crimped yarn. This is mainly attributed to its higher crimpiness. Thus results are showing good agreement with earlier findings[50, 64, 65, 74] , according to them denier get increased in direct relation to their crimping power and twist contraction apart from their shrinkage during wet processing.

4.12.1.3 Fabric Weight per Unit Area and Fabric Thickness

Results have shown that rise in fabric thickness and weight per unit area is more for newly textured weft-yarn fabrics as compared to their respective feeder weft-yarn fabrics [table 4.14(a-c)]. This is owing to closer thread setting and higher increase in constituent yarn deniers observed in finished textured weft-yarn fabric.

As a consequence of the same fabric with newly textured weft yarn carrying higher pre-twist has executed higher weight per unit area as well as thickness as compared to weft yarn with low pre-twist [table 4.14(b-c)].

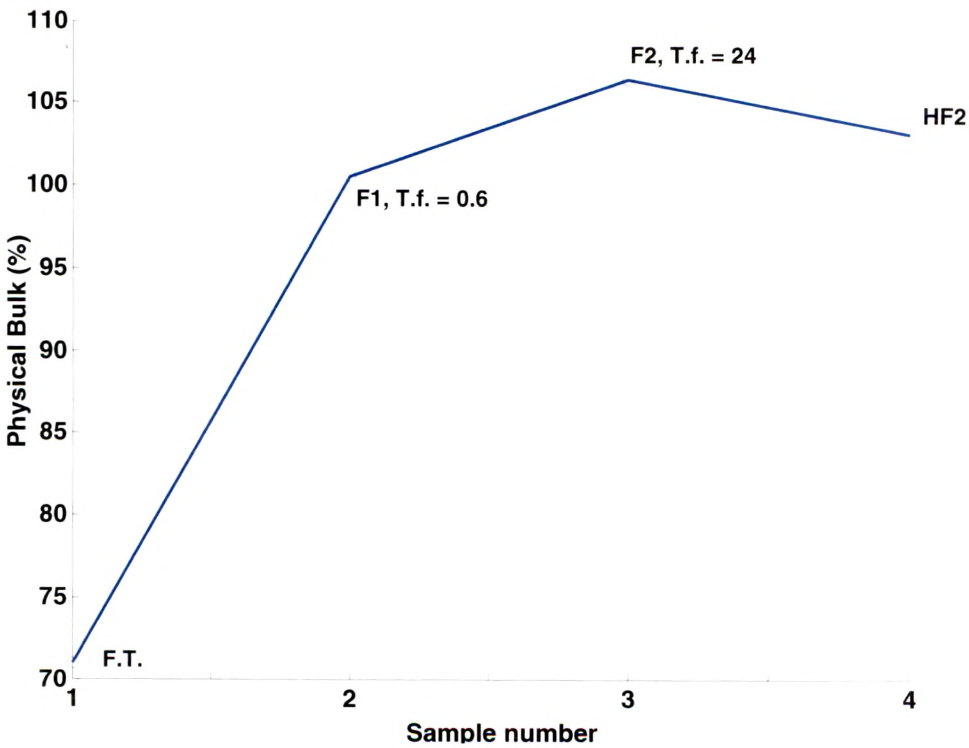
However false-twist textured yarn fabric [table 4.14(a-b)] has shown increase in weight per unit area but reduction in thickness as compared to equivalent size mechanical crimp textured yarn[figure 4.27]. This is mainly attributed to the greater mobility of the zero-twist textured yarn. It has not allowed it to remain stable against imposed stresses during weaving and finishing[4, 15]. Whereas presence of pre-twist in mechanical textured yarn structures has made them comparatively more stable.

More thickness and weight per unit area values were observed for finished fabric with coarser constituent yarns [table 4.14 (c) and figure 4.29]. Thus for identical fabric-sett, fabric thickness and weight per unit area have increased in a direct relationship to yarn count.

4.12.1.4 Physical Bulk

Improvement in the fabric cover or bulk is the outcome of increase in the thickness of textured yarn fabric as compared to flat feeder yarn fabric as per defined by Wray[52].

Figure 4.33 (a) Comparison of Physical Bulk of equivalent size (100denier/48fils.) False-twist and Mechanical crimp textured weft yarn fabrics



$$\textit{Physical Bulk}\ (\%) = \frac{\textit{Parent yarn fabric density}}{\textit{Textured yarn fabric density}} \times 100$$

Thus

$$\textbf{Physical Bulk (\%)} = \frac{Wp}{Tp} \times \frac{Tt}{Wt} \times 100 \text{ ....equation 2.37}$$

Using this relationship physical bulk of various fabrics under consideration has been calculated. These calculated values are presented graphically in figures 4.33 (a-b).

Bulkiness of fabrics produced by using equivalent false-twist textured (F.T.) weft-yarn and mechanical textured weft-yarns (F1,F2,HF2) is compared in figure 4.33 (a). It can be seen that independent of amount of pre-twist pertained by yarn and whether it is post heat set or not, mechanical textured weft yarn fabric has exhibited higher physical-bulk as compared to equivalent fineness false-twist textured weft yarn fabric. This is mainly attributed to the presence of real twist, which makes the mechanical textured yarn less mobile as compared to zero-twist false-twist textured yarn. This has allowed more rise in fabric thickness as compared to false-twist textured yarn fabric with respect to their flat feeder yarn fabrics.

It can be observed from figures 4.33(a-b) that irrespective of yarn fineness fabric bulk get increased with pre-twist of mechanical crimp textured weft yarn. This is due to compact weft yarn structure formed at higher pre-twist level. It has enforced constituent warp to follow longer bend length, and thereby resulted in increased warp linear density for constant finished fabric sett[64, 65]. This argument is found support from the increased warp crimp value for respective higher pre-twist weft-yarn fabrics [table 4.14(b-c)].

Figure 4.34 illustrate graphically effect of weft-yarn denier on physical bulk of the fabric.

Figure 4.33 (b) Comparison of Two fold 100d/48fils. Weft yarn Fabrics Bulk.

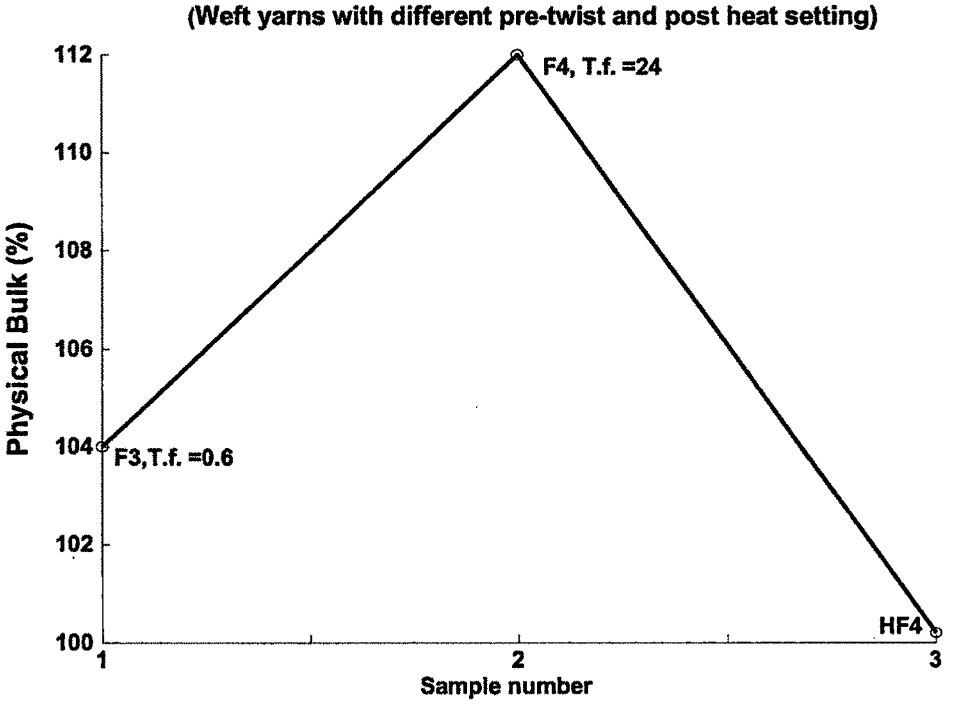
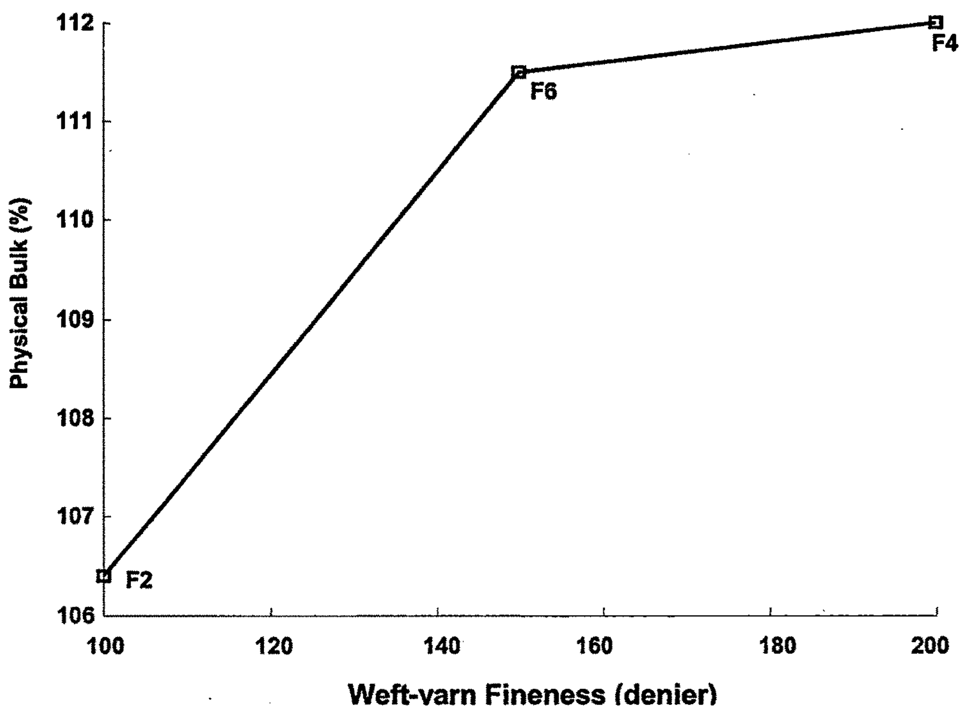


Figure 4.34 Effect of Weft-yarn Fineness on Fabric Bulk.



It can be observed from the figure 4.34 that physical bulk of the fabric has increased in direct proportion to weft-yarn denier. This is mainly attributed to reduced linear density of constituent yarns and low fabric sett values [table 4.14 (c-d)]. Going in the consequence bulk get diminishes with post heat set weft yarn [figure 4.33(a-b)].

Thus it becomes apparent to conclude that compared to false-twist texture yarn fabric mechanical crimp textured weft yarn fabric has shown higher bulk value irrespective of pre-twist value. Bulk of the fabric has increased with pre-twist value irrespective of yarn fineness. While on post heat setting bulk of mechanical crimp textured yarn fabric gets diminished.

4.12.2. Mechanical properties

Mechanical properties are considered for utility, performance and durability of fabric[62].

4.12.2.1 Tensile Properties

Many factors influence, directly or indirectly, the final values of the breaking force and elongation at break of a fabric in the warp and weft directions. It is the yarn used (warp and weft), i.e. its mechanical and physical properties (count, breaking force and breaking elongation, fineness, number of twists, raw material composition, after-treatments etc.), which has the most significant effect[61,64]. Slightly lower is the effect of the constructional properties of a fabric such as the weave, warp and weft thread density etc. There are also other factors which have an indirect influence on final values, such as the conditions in which weaving takes place: temperature, humidity, yarn tension during the weaving process etc[67,75].

In the present study except filler yarns all other variables like; type of warp yarn, plain weave, fabric sett and weaving conditions are kept constant. So the breaking force and elongation at break of a fabric are mainly influenced by the tensile properties of the weft-yarn used as well as Cloth Assistance Factor (CAF) [61]. Cloth Assistance Factor (CAF) can be evaluated by derived by Vernekar et al[76].

$$Cloth\ Assistance\ Factor\ (CAF) = \frac{Fabric\ strength\ per\ thread}{Yarn\ strength\ in\ bobbin}$$

Table 4.15 (a) Tensile Properties of Fabrics (Feeder weft-yarn).

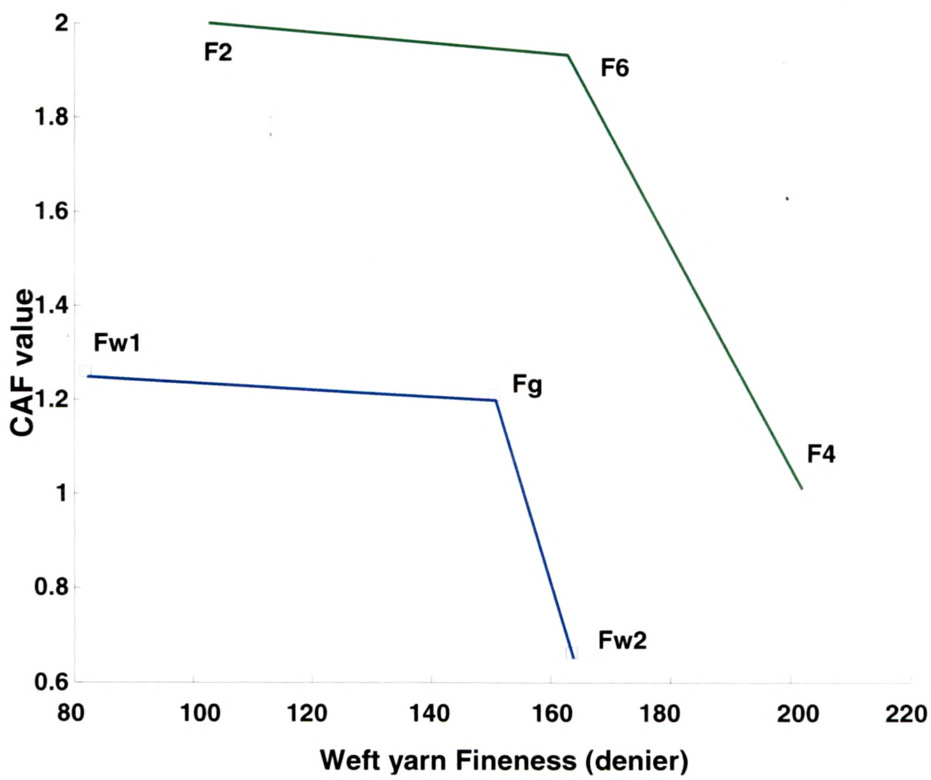
(Warp yarn tenacity = 2.56gpd and % Extension =23 in the bobbin)

Sample code	*Tensile strength (kg)*		*Single weft thread strength (gpd)*		*CAF*	*Extension (%)*	
	Warp	*Weft*	*Fabric*	*Bobbin*		*Weft-way in Fabric*	*Weft yarn in Bobbin*
Ft	14.78	20.33	*6.28*	*4.60*	*1.42*	*75.00*	*30.20*
Fw1	8.82	12.97	5.29	*4.21*	*1.26*	*69.90*	*24.60*
Fw2	8.82	12.97	2.64	*3.98*	*0.66*	*70.27*	*24.66*
Fg	9.27	14.80	3.27	*2.56*	*1.21*	*74.47*	*17.30*

- **Ft =feeder for false-twist texturising, gpd= gram per denier.**
- **Fw1 = single end 100d/48filaments yarn, Fw2 = double end 100denier/48filaments yarn.**
- **Fg = Green dyed 150 denier/72filaments yarn,CAF =Cloth Assistance Factor.**

Tables: 4.15 (a-c) present the measures of various tensile properties of fabrics under consideration. It can be seen from the results [tables 4.15 (a-c)], Cloth Assistance Factor (CAF) value is higher than one for all the filling yarns, except feeder Fw2. Higher values reported are the outcome of preferable increase in yarn to yarn friction for the selected plain weave. This positive fabric assistance has unanimously allowed the rise in tenacity value for weft-yarns in all fabrics [table 4.15(a-c)].

Figure 4.35 Comparison of CAF values of Flat Feeder Weft yarn Fabrics with respective Mechanical Textured Weft yarn Fabrics



It can be seen from the figure 4.35 that all the newly textured weft yarn fabrics have exhibited higher CAF values as compared to their flat feeder weft yarn fabrics. This is mainly due to increased linear density of yarn on texturising.

Table 4.15 (b) Tensile Properties of Fabrics (Textured weft-yarn).
(Warp yarn tenacity = 2.56gpd and % Extension =23 in the bobbin)

Sample code And Description	*Tensile strength (kg)*		*Single Weft-thread Tenacity (gpd)*		*CAF*	*Extension (%)*	
	Warp	*Weft*	*Fabric*	*Bobbin*		*Weft-way in Fabric*	*Weft yarn in Bobbin*
F1, 100d/48fils. P.T. = 0.6	10.2	15.13	5.29	3.03	*1.74*	41.80	33.48
F2, 100d/48fils. P.T. = 24	17.19	20.84	6.50	3.26	*2.00*	33.29	29.13
F3, 200d/96fils. P.T. = 0.6	10.13	15.13	2.72	2.69	*1.01*	38.23	30.12
F4, 200d/96fils. P.T. = 24	14.50	35.25	6.59	3.31	*1.99*	32.50	27.78
F5, 300d/144fils. P.T. = 24	14.19	57.68	6.25	3.25	*1.93*	30.50	26.67
F6, 150d/72fils. P.T. = 24	17.08	28.92	5.91	3.06	*1.93*	49.83	27.50
F7, 150d/84fils. P.T. = 24	17.08	26.58	5.51	2.59	*2.12*	37.48	23.72
F.T.	16.68	21.42	5.42	4.21	*1.28*	45.79	20.98

- **F.T. = False-Twist textured yarn, gpd =gram per denier.**

P.T. = Pre-Twist factor (in tex$^{1/2}$.tpcm), CAF =Cloth Assistance Factor

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Thus for the identical plain weave and sett values ends and picks get interlaced tightly and also with the increased tightness of weave static friction amongst the yarns get increased due to increase in arc of contact between the threads[63, 72].

High pre-twist textured weft yarn fabric, viz; F2 and F4, has exhibited more fabric-strength as compared to low pre-twist textured weft yarn fabric, viz; F1 and F3, irrespective of weft-yarn fineness. This is mainly due to preferable increase in Cloth Assistance Factor and filler yarn tenacity value [table 4.15(b)] at higher pre-twist, allowed to delay rupture.

Table 4.15 (c) Tensile Properties of Fabrics

(Post Heat-set textured weft-yarn).

(Warp yarn tenacity = 2.56gpd and % Extension =23 in the bobbin)

Sample code	*Tensile strength (kg)*		*Single Weft-thread Tenacity (gpd)*		*CAF*	*Extension (%)*	
	Warp	*Weft*	*Fabric*	*Bobbin*		*Weft-way in Fabric*	*Weft yarn in Bobbin*
HF2	14.50	19.00	6.05	3.41	*1.77*	32.10	29.74
HF4	14.58	39.75	6.37	3.51	*1.82*	30.45	27.64
HF5	14.58	52.16	6.04	3.20	*1.89*	28.53	26.56
HF6	16.66	22.35	4.94	*3.08*	*1.61*	35.10	27.90

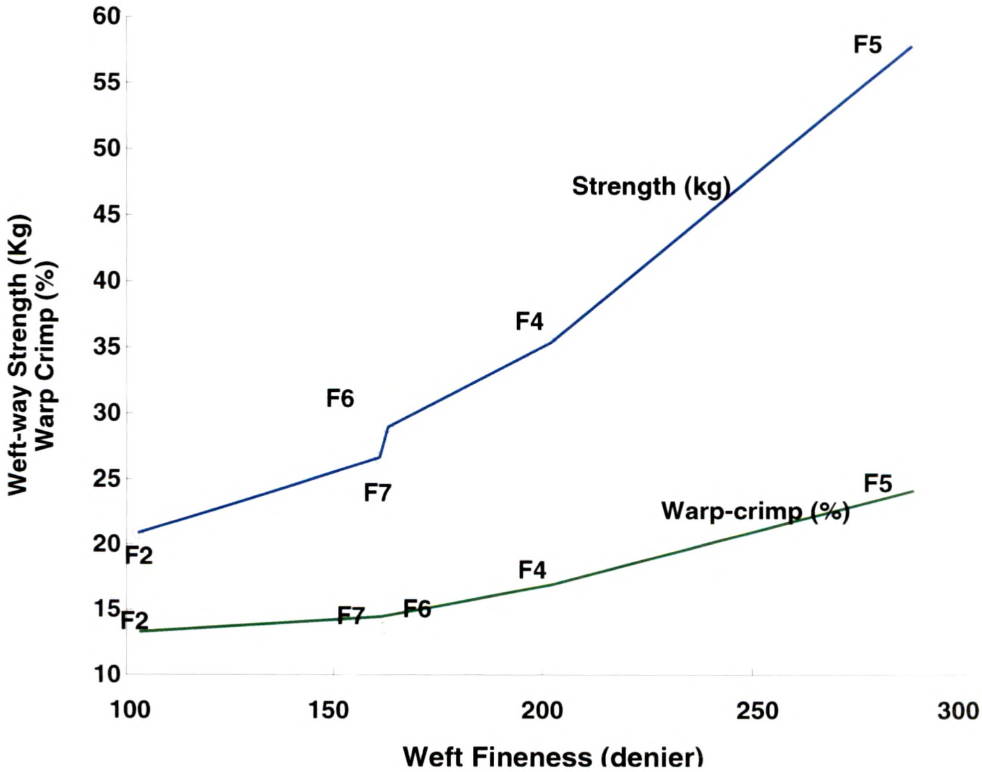
- **gpd = gram per denier, CAF =Cloth Assistance Factor**

It can be observed from the results that fabric strength get reduced for textured filler yarns with post heat setting, irrespective of their fineness [table 4.15(b-c)]. This is mainly due to the combined effect of the declination in constituent yarn strength as well as cloth assistance factor on the use of post heat set filler yarn.

Figure 4.36 illustrates effect of weft-yarn denier and warp crimp (%) on weft-way fabric tensile strength. It can be seen that fabric strength has increased in direct relation to filler yarn denier and warp-crimp (%), irrespective of weft yarn strength.

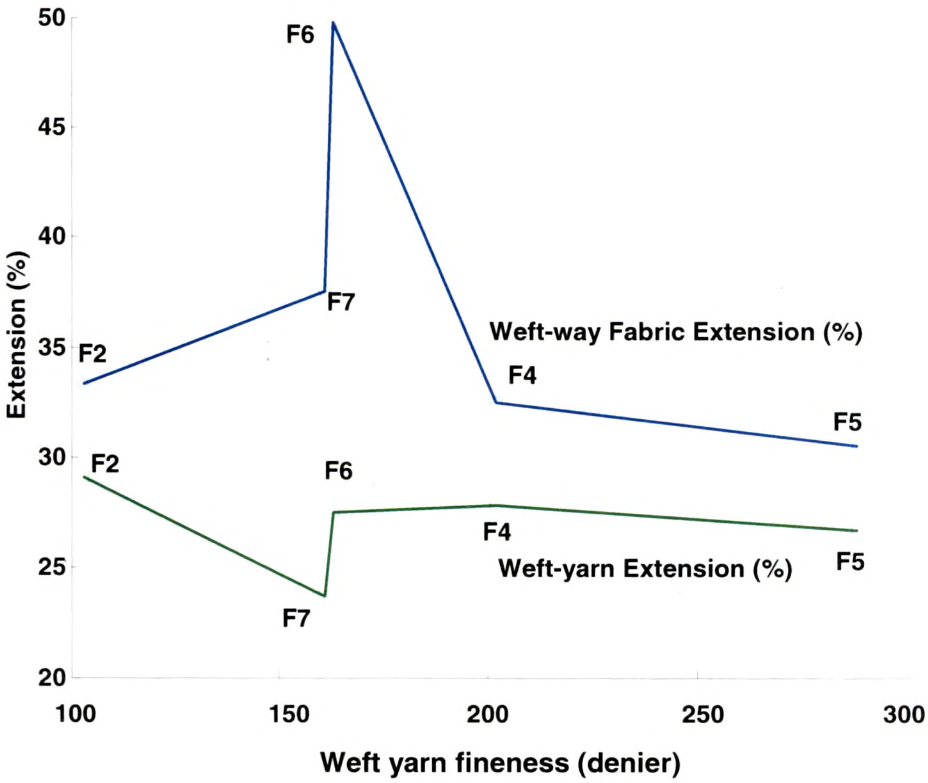
This is mainly attributed to the increased friction amongst yarn due to tight packing with coarser weft used as well as crimp-interchange took place between the threads of the two systems during tensile test. Higher bends followed by similar warp yarn for coarse denier weft has increased warp-crimp [table 4.14 (a-c)]. During tensile testing crimp decreases in the direction investigated, but increases in the perpendicular direction[61]. Fabric geometry being constant in the present study, fabric with higher warp crimp has executed higher weft-way strength.

Figure 4.36 Effect of Warp-crimp (%) and Weft fineness on Weft-way Tensile Strength



Hence type of warp was kept constant for all fabrics there is no pronounced difference found in the weft crimp value [table 4.14 (a-c)]. Thus variation found in warp-way tensile strength [table 4.15(b)] is mainly the outcome of difference in cloth assistance factor pertaining to different yarn fineness only.

Figure 4.37 Comparison of Weft-way Extension (%) of Fabric with respective Weft yarn Extension (%)



Higher weft-way extension value has been observed than weft yarn extension that measured in a bobbin form for all the categories of weft yarns used [figure 4.37]. This behaviour is going in close resemblance to the findings of P. Grosberg[75]. As per him any extension that takes place in warp and weft direction is usually of higher order of magnitude than the extension of constituent yarns. By and large, the first part of extension is due mainly to crimp redistribution while the latter part of the extension is due to fiber or filament extension and to a certain extent, to thread compression.

4.12.2.2 Tearing Strength

Harrison[77] has identified tearing strength as a fabric characteristic that allows the threads to group closer together under the force of the tearing agency and so, instead of the successive breakage of individual threads; the action becomes more of strength on group of yarns. Thus grouping efficiency and single thread strength in the direction of test play a detrimental role for tearing.

Test results for tear strength tests have been given in table 4.16. It can be observed from the results [figure 4.38 (a-b) and table 4.16] that three-fold 100denier/48fils. (Sample F5 and HF5) has invariably shown higher tear strength value as compared to other samples in a group.

This is mainly attributed to the presence of higher number of similar filaments with a slight difference in weft-shrinkage and almost identical tenacity of the weft-yarns [table 4.15(b) and figure 4.38 (b)]. The same trend has been continued for post heat set textured filler fabrics also [table 4.16], substantiate the argument.

Even for flat feeder weft yarn group flat feeder of false-twist textured yarn (sample Ft) with higher tenacity has exhibited highest weft-way tear strength [figure 4.38(a)], although it has less width shrinkage than sample Fg in that group.

Thus yarn with higher resistance against the tearing agency was able to execute better tear strength value.

Figure 4.38 (a) Effect of Width shrinkage (%) and Weft yarn Tenacity on Weft-way Tear strength.
(Flat-Feeder Weft Yarns)

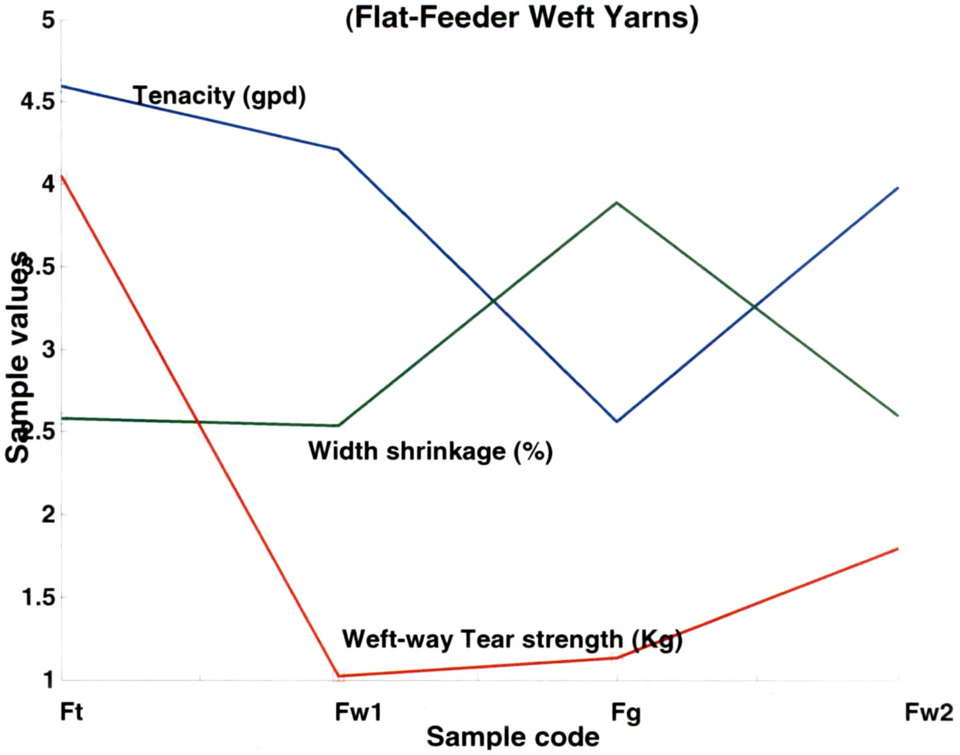


Figure 4.38 (b) Effect of Width shrinkage and Weft yarn Tenacity on Tear-strength (Textured weft yarn)

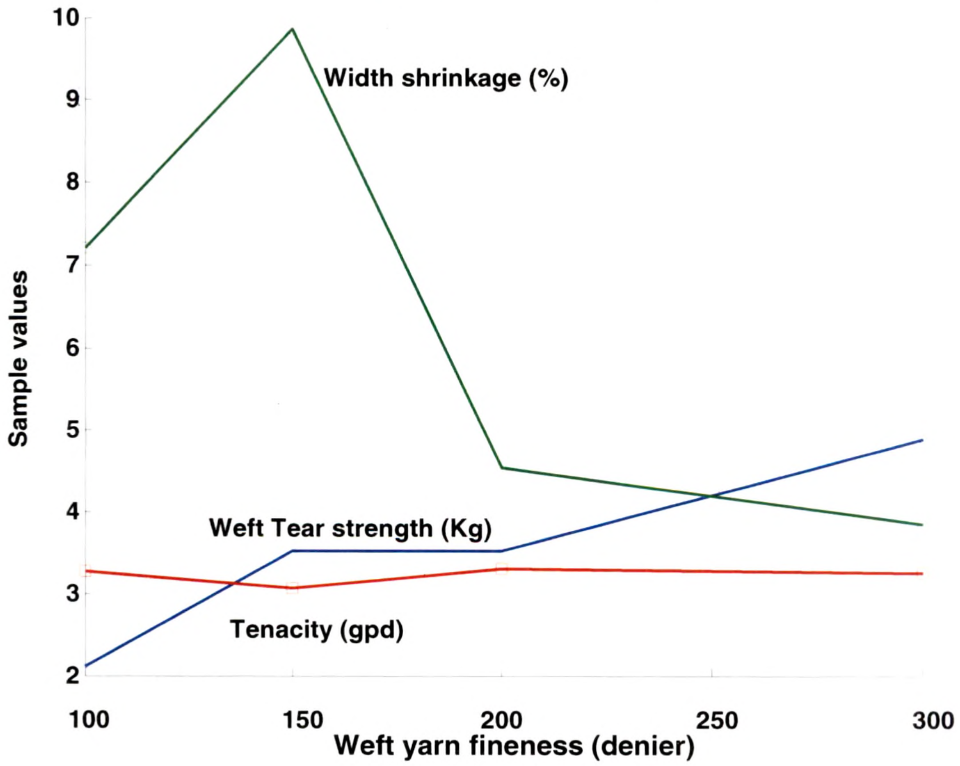


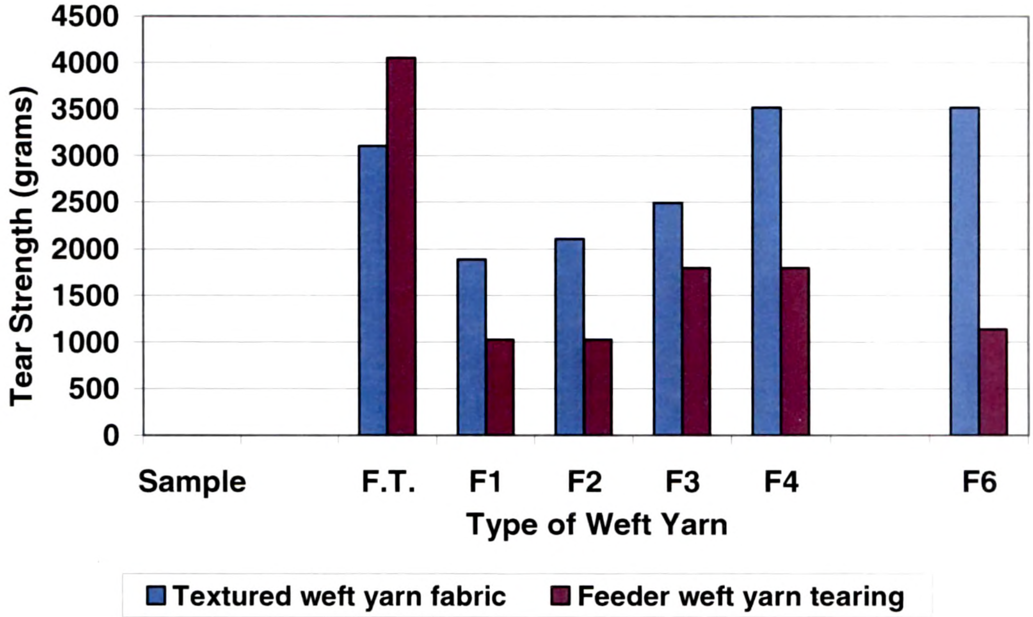
Table 4.16 Tearing and Abrasion Properties

Sample code	Tear-strength (grams)		Abrasion Resistance (Cycles)
	Warp	Weft	
Feeder-Yarn			
Ft	3563	4053	94
Fw1.	2368	1024	43
Fw2	2560	1792	89
Fg	3264	1134	59
Textured-Yarn			
F1	2773	1888	40
F2	2859	2112	36
F3	2325	2496	69
F4	3179	3520	26
F5	3200	4885	48
F6	3193	3520	64
F7	3151	2703	34
F.T.	3032	3109	75
Post Heat-set Textured Yarn			
HF2	2624	1600	53
HF4	2880	3072	59
HF5	3136	4416	75
HF6	3151	2689	37

Type of weave, sett value as well as type of warp yarn used for study was kept identical for all samples. So, warp way tear strength behaviour has not been considered for discussion.

Figure 4.39 executes comparison of flat feeder weft yarn fabric tear strength with respective textured weft yarn fabric.

Fig.4.39 Comparision of Tear strength of Feeder yarn and Textured yarn Fabrics



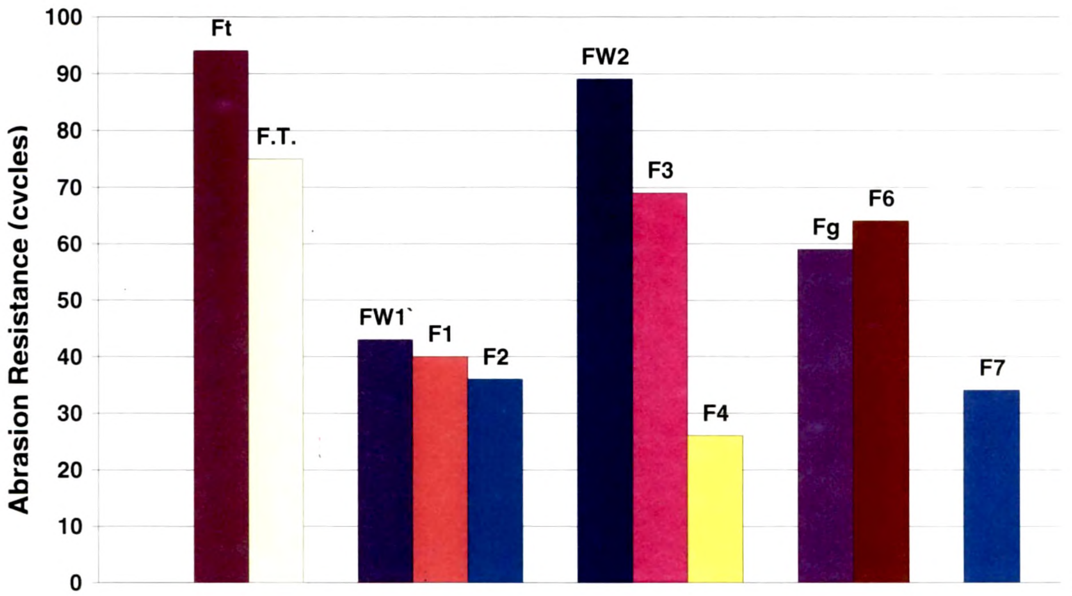
It is also been seen from figure 4.39 that textured filler yarn fabrics have shown higher tear strength value as compared to respective flat feeder filler yarn fabrics, except for false twist textured yarn. Difference in the behaviour is mainly attributed to presence of pre-twist. Pre-twist level has influenced textured yarn strength positively. Thereby low pre-twist textured yarns (F1 and F3) have exhibited comparatively lower rise in tear strength as compared to high pre-twist mechanical textured yarns (F3 and F4).

4.12.2.3 Abrasion Resistance

Ability of constituent filaments to withstand repeated distortion is the key to its abrasion resistance. Therefore higher abrasion resistance for the fabric with feeder yarn (sample Ft) filler as compared to fabric with false-twist textured filler (F.T.) is likely [figure 4.40].

As a consequence of the same higher abrasion resistance value is accounted for flat feeder filler yarn fabrics as compared to newly textured filler yarn fabrics [figure 4.40]. This is due to the flat surface offers larger cover area at the point of abrasion.

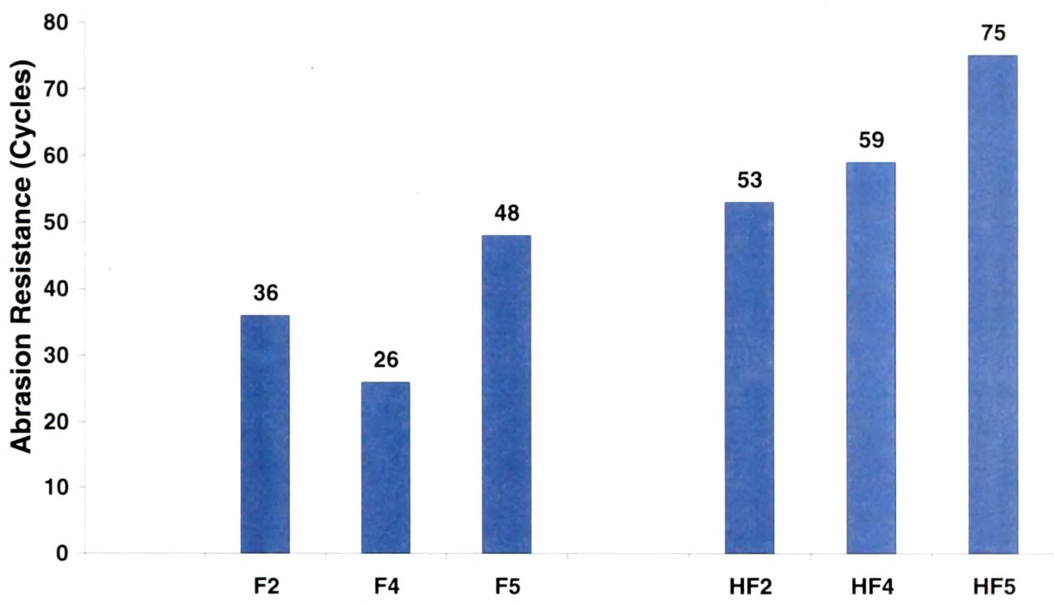
Figure 4.40 Abrasion Resistance (cycles) for Different Type of Weft- yarns.



Highest abrasion resistance has been shown by false-twist textured weft yarn fabric as compared to all other mechanical crimp textured weft yarn fabrics [figure 4.40]. More flattening of false twist textured yarn on weaving due to its higher mobility has probably allowed it to undergo for more number of abrasion cycles for complete abrasion as compared to compact mechanical textured yarns. Reduction in abrasion cycles observed for fabrics having newly textured weft yarn with high pre-twist substantiate the argument. As with the increase in pre-twist level, yarn becomes more compact and held more tightly against abrader, results in reduced number of abrasion cycles for the identical load[65].

Abrasion value of fabrics under consideration has increased in direct relation to number of filaments in yarn cross-section for constant pre-twist level [figure 4.41]. Presence of higher number of similar filaments incorporated for coarser three fold filler yarn (sample F5) into a fabric has conferred better abrasion resistance as compared to single and double fold filler yarns[78]. The same trend is also observed for post heat-set filler fabrics as well as feeder filler yarn fabrics [table 4.16]. However there is some declination in abrasion resistance value for sample F4 as compared to sample F2. This may be due to the ability of sample to abrade under identical condition of abrasion.

Figure 4.41 Abrasion Resistance (cycles) for Different Weft-YarnFineness.

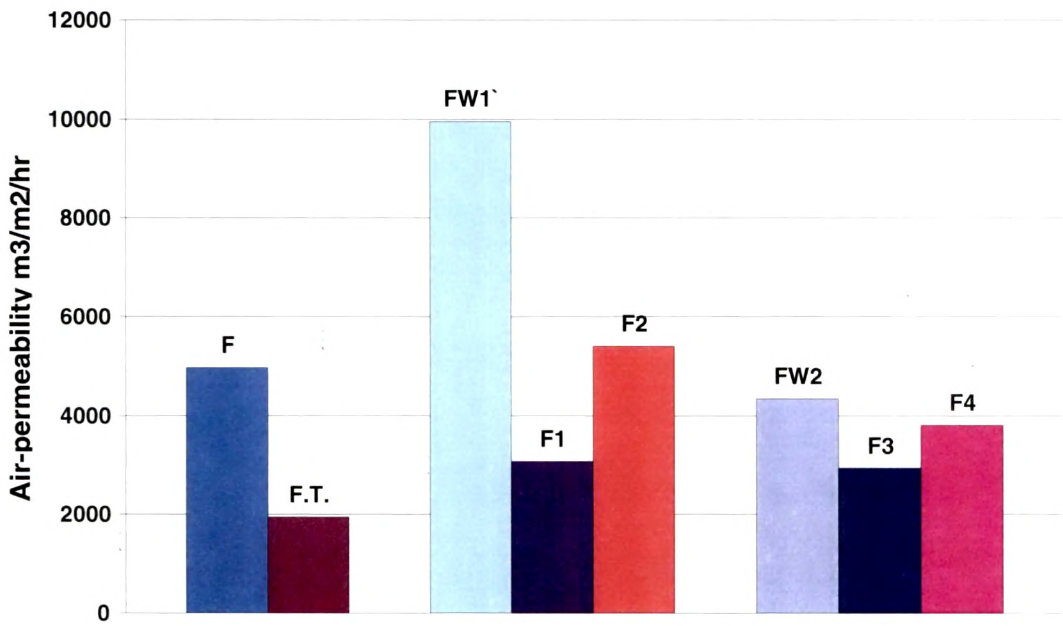


4.12.3. Comfort Properties

4.12.3.1 Air-permeability

Air-permeability is mainly attributed to the porosity of the fabric. Porosity of the fabric is purely dependent on the porosity of the constituent yarns and air gaps between the constituent yarns after interlacement[46]. In the present study type of weave, warp yarn as well as fabric sett values were kept constant during weaving and similar finishing treatment has been given. So the porosity of the fabrics under study is straight way the reflection of weft yarn porosity.

Figure 4.42 Effect of Type of Weft-yarn on Air permeability



Reduction in the air permeability values are found for all the fabrics, woven with textured yarn weft in comparison with respective feeder yarn weft fabrics [figure 4.42]. This is mainly due to the better cover of fabric woven with textured filler yarns. As on crimping flat feeder yarn shows greater amount of air trapped in the structure (increased bulk). Even increased weft-yarn linear density on texturising, along with slight rise in sett value [table 4.14 (a-c)] provide better cover to fabric for identical warp used in fabric formation. Air resistance of such fabrics get increased, reduces air permeability[61, 78]. Reduced air permeability of false-twist textured filler yarn fabric as compared to its respective feeder weft-yarn fabric substantiates this presumption.

It can also be noticed that fabric woven with higher pre-twist textured weft-yarn (sample F2 and sample F4) has exhibited higher air permeability than the fabric woven with respective low pre-twist textured weft-yarn [sample F1 and sample F3]. This is mainly attributed to higher packing coefficient of yarn attained at higher twist level[4]. This reduces air trapped in the structure and increases air gaps between constituent yarns.

This is also going in agreement to Clayton's[47] work. He has shown that the twist factor in the yarns has a great influence on air permeability. He found that for constant cover factor of warp and weft, only by changing twist factor of weft, air permeability increases linearly.

Figures 4.42 (a-b) illustrate that with the use of coarser weft with higher number of filament air permeability get reduced. This is due to increased compactness of woven structure in the presence of higher number of filaments, reduces air-gaps, and thereby air permeability. Same trend is also observed by post heat-set yarns.

Textured weft yarn on post heat setting has shown reduction in air permeability as compared to respective non-heat set textured weft yarn fabric [figure 4.42(a-b)]. This is mainly due to reduced porosity of textured yarn on heat relaxation.

Figure 4.42 (a) Effect of Weft-yarn Fineness on Air permeability

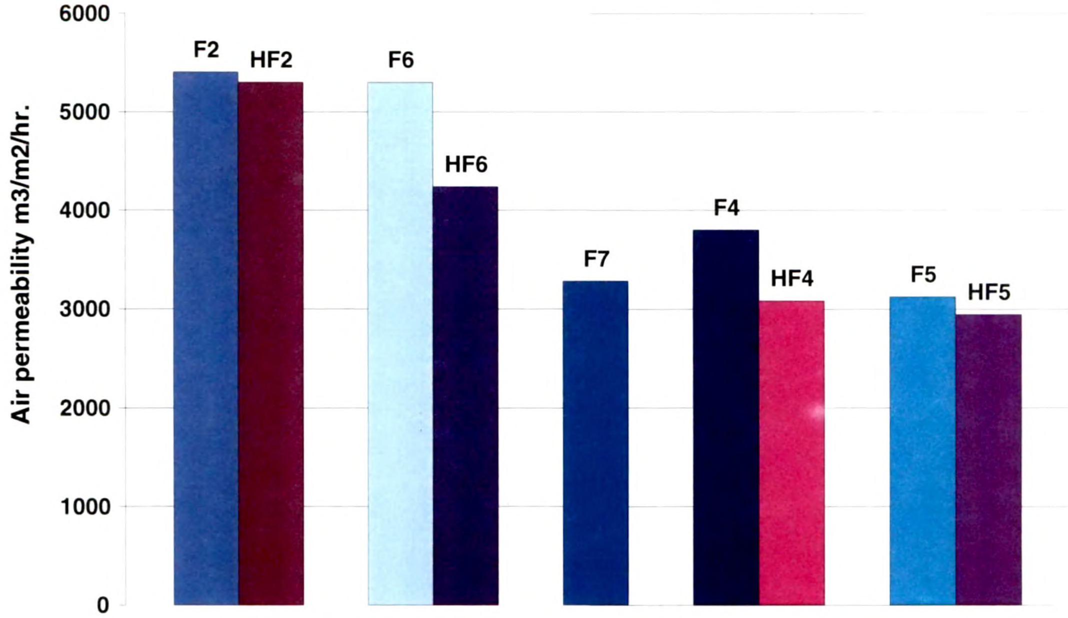
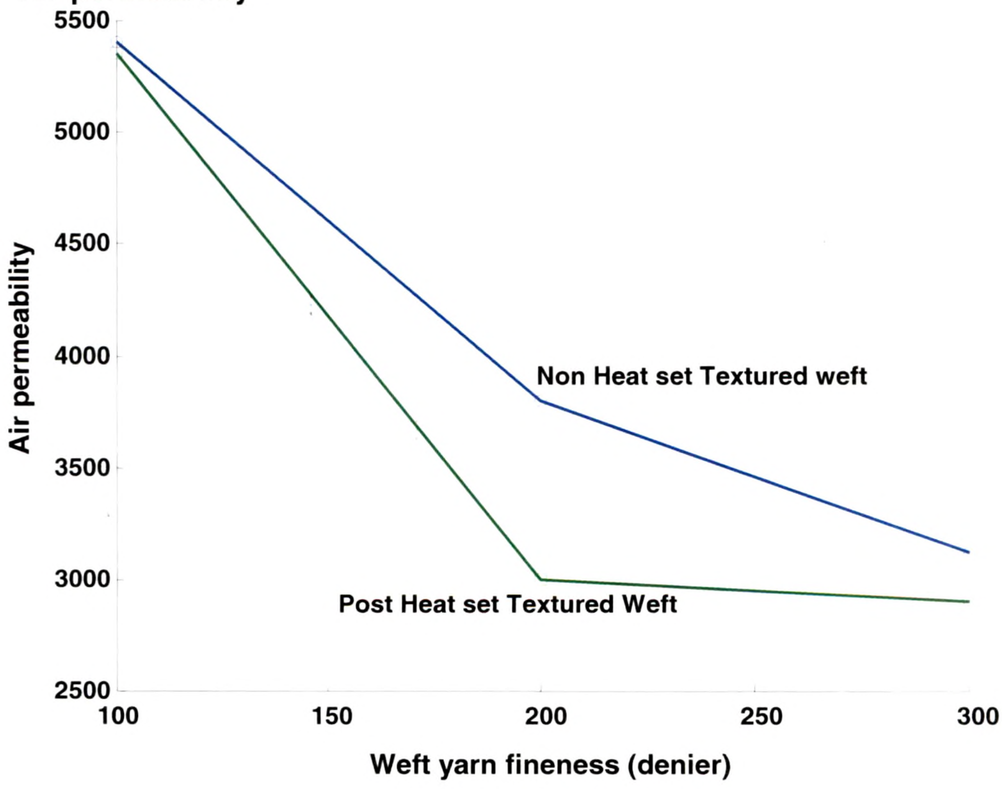


Figure 4.42 (b) Effect of Number of Filaments per yarn cross-section on Air-permeability



4.12.4. Low Mechanical Stress and Aesthetical Properties

Low stress mechanical properties like stiffness relates to handle and tailorability of the fabric. In addition to these, specific end-use and aesthetic properties like drape, crease recovery of the fabric also need to be defined. Results of these tests are given in table 4.17

4.12.4.1 Stiffness and Drape

Reduction in bending rigidity and drape values for limpy and lighter weight structure of false-twist textured yarn fabric (sample F.T.) as compared to respective flat yarn fabric is seen more pronouncedly from the results [table 4.17].

Figure 4.43 Effect of Weft yarn Fineness on Stiffness.

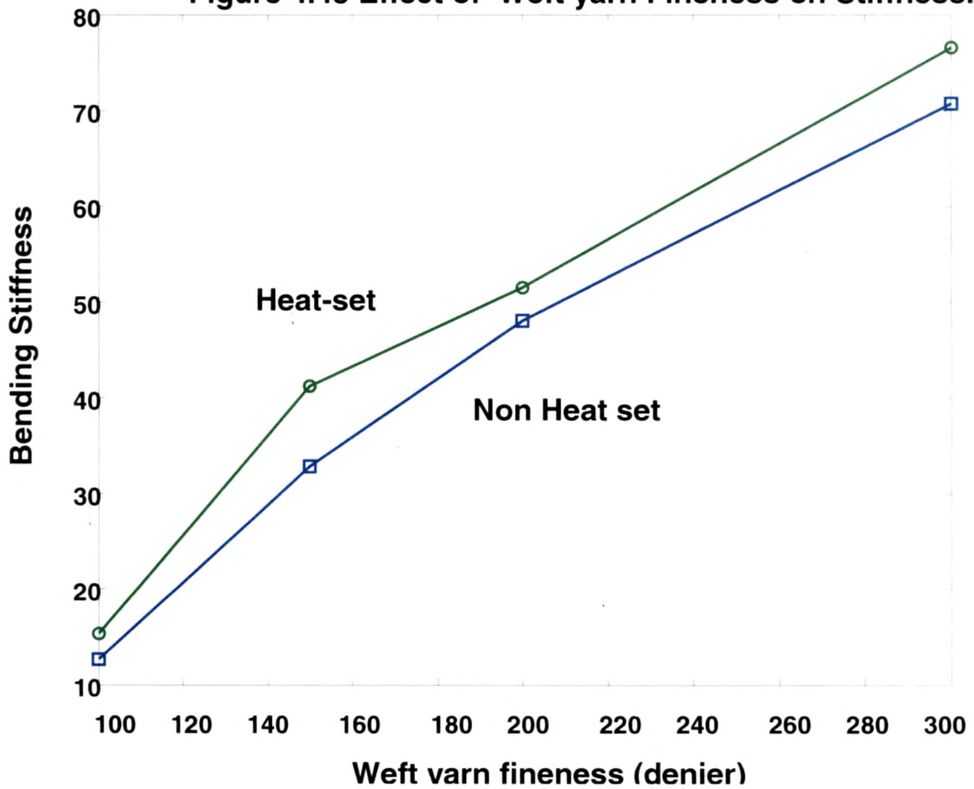


Table 4.17 Aesthetical and Low Stress Mechanical Properties

Sample Code	Bending Rigidity (mg.cm2/cm)		Drape (%)	Crease Recovery Angle	
	Warp	Weft		Warp	Weft
Feeder yarn					
Ft	10.01	47.09	36.71	123	135
Fw1	7.74	10.44	26.76	123	132
Fw2	15.82	42.63	33.27	123	134
Textured yarn					
F.T.	15.51	19.53	36.33	128	137
F1	10.17	11.84	31.87	129	132
F2	11.62	12.55	32.74	128	138
F3	16.82	45.09	34.39	128	135
F4	16.69	48.82	35.27	128	139
F5	10.59	70.62	33.65	128	143
F6	12.38	32.89	31.74	127	128
F7	10.75	12.86	27.91	128	129
Post heat-set yarn					
HF2	14.51	15.26	33.27	126	131
HF4	27.17	51.47	33.27	126	133
HF5	11.09	76.48	30.97	127	135
HF6	18.41	41.21	29.82	128	129

Fabric woven with mechanical textured weft-yarn with higher pre-twist has exhibited higher stiffness and drape. Higher the pre-twist level compact the product-yarn, and thereby stiffer the fabric with higher weight per unit area [table 4.14 (a-c)]. So, proportionately more rise in both the values is expected. This also found support from the basic theory of stiffness described by Booth[61] and Savile[64].

According to them thicker fabric with higher weight per unit area results in increased stiffness thereby executes higher bending length and as a result of this higher bending rigidity value. Stiffer the fabric more will be the drape[61, 64, 78].

However textured yarn on heat setting has exhibited more stiffness values in contradiction to less drape values reported as compared to equivalent non heat-set textured filler yarn fabric (table 4.17 and figure 4.43).

4.12.4.2 Crease-recovery

The type of woven structure and characteristics of constituents largely affect crease recovery. Warp yarn used throughout this study is kept constant, viz; 50 denier 24 filaments/ c.s. highly twisted yarn with 3000 tpm and heat set at 90-95°C for 50 minutes. Even plain weave (1/1) is used for all flat feeders as well as textured yarn fabrics. Under such condition the uniform behavior for warp direction crease recovery is expected for all the samples irrespective of type of weft used. Almost uniform rise in warp-way crease recovery from 123 to 128 observed for all samples under consideration goes in line with the expectation [table 4.17].

Crease recovery value in the weft direction has increased with the increased thickness, drape and bending rigidity of the fabric. Thus highest crease-recovery value observed by sample F5 woven with weft yarn with highest 144 filaments of same 2.08 denier is likely.

4.13 Knitted Fabrics

Tube Knitting and Dyed samples prepared for confirmation trial (sample G1 – sample HG6) were checked for their physical properties like courses/cm, wales/cm and thickness of knitted hoses. Test results are reported in table 4.18. Knitted hose bulk has been calculated by using the following relationship[50].

$$Fabric\,Bulk\,(B) = \frac{Fabric\ thickness\ (cm)}{Fabric\ area\ density\ (g|cm^2)}$$

Table 4.18 Properties of Knitted Fabrics – (Confirmation Trial)

Sample Code	Pre-twist (tpm)	Courses/cm	Wales/cm	Thickness (mm)	Weight per unit area (GSM)	Bulk (cm^3/g)
Parent Green 150/72	Zero	11	10	0.2033	97.75	2.08
G1	118	14	12	0.4800	97.41	4.93
G2	197	13	12	0.4233	92.29	4.59
G3	276	13	12	0.4166	101.10	4.12
G4	354	13	12	0.3966	90.10	4.40
G5	472	13	12	0.3800	88.30	4.31
G6	591	13	12	0.3633	88.60	4.11
HG6	591	13	12	0.3400	91.90	3.70

- *tpm =twist per meter, GSM = Gram per Square Meter.*

It can be seen on texturising thickness of the hoses get increased as compared to parent yarn hose. Higher bulk is reported for low pre-twist textured yarn but gets reduced with the increase in pre-twist level. This is due to increased yarn compactness. For equivalent process and material parameters post heat setting has reduced bulk further.

All these observations are going well in agreement to respective measures obtained in yarn stage as well as for woven fabric.

Cost Effectiveness Study of Mechanical Textured Yarn

with respect to

Commercial Texturising Systems.

4.14 Cost Effectiveness of Mechanical Textured Yarn with respect to Commercial Texturising Systems.

Unlike the commercial texturising systems theme of new concept of texturising is worked out purely on the laboratory module only. Thereby absolute figures for the production rate, respective labour allocation utilized in the process and the power consumption for the full-flange shop-floor machine production for innovative texturising system are not available. So a relative comparison is only possible to identify economy of new system with respect to commercial systems. Comparative statement for almost equivalent fineness air-jet textured and false-twist crimp textured yarn has been prepared based on the figures obtained from one of the reputed industry in this field located nearby Surat (table 4.19).

4.14.1 Important Points to be considered for Cost-Evaluation

1. This industry has its own power generation plant. So, unit cost per kilo-watt of power is very low, only Rs.2.65. Since this section deals with the comparison so to maintain uniformity the respective power cost per unit has been translated to Rs.8 per kilo-watt, rate adopted for industry.
2. Raw material used for both the commercial texturising processes is Partially Oriented Multifilament Yarn (POY), have a price value of Rs.68.30 per Kg., with the addition of 5% Vat it becomes Rs.71.80/Kg.
3. Compressor consumes a considerable power in case of air jet texturising, so as per reference industries' specification 20

Horse Power per 10Kg. Of production has been added to the machine-power. This has made power cost per Kg., for air jet textured yarn higher than false-twist textured yarn.

4. Other cost includes transport cost, oil cost, repairs and maintenance cost, salary and wages cost etc. have been as per furnished by the industry only. As less quantity has been packed in the fancy boxes for air jet textured yarn its packing cost is higher than false-twist textured yarn.
5. Total product cost per Kg. is the inclusive of raw-material cost/kg, machine power cost/kg and others cost/kg.

4.14.2 Cost Evaluation of Innovative Textured Yarn. (For single head Lab Apparatus)

Steps followed for this evaluation are given in sequence.

4.14.2.1 Cost per unit weight for the newly engineered product

It has been calculated by using production data and power consumption values measured from the lab module at the highest possible delivery speed of 250m/min at 95% efficiency as follows.

Production/Day/single head (kg) =

$$\frac{\underset{(m/min)}{\text{Delivery speed}} \times 60 \times 24 \times \%\text{Efficiency} \times \text{Product yarn denier}}{9000 \times 100 \times 1000}$$

$= 3.8$ **kg.**

4.14.2.2 Machine power cost per Kg.

Machine power cost in Kilo watt per hour has been calculated by using load V (volts) and power values I (Amp.) measured practically at the delivery speed of 250 m/min with the help of Clamp Meter with 261option (500V) Insulation Tester by using following relationship.

Machine Power Consumed / Hr. (Kw./Hr) P = V I

= 1.26 HP /hr.

Where V = 275 volts (= 275/746 HP), I = 3.4 Ampier

Using machine power consumed value, unit power cost and Production per day machine power cost per Kg. of material produced has been calculated as follows.

Machine Power cost (Rs./kg) =

$$\frac{\text{1.0027 HP /hr. x 8 Rs./HP x24}}{\text{3.8 kg./Day}}$$

= 63.32 Rs./kg. ....(A)

4.14.2.3 Raw-material Cost per Kg.

Fully Drawn Multifilament Polyester Yarn (FDY) of 100d/ 48fils.of has been used for evaluation. It has a cost of Rs.88.00 per kg. And 5% vat to be added to it. So, it becomes

Rs. 88.00 x 1.05 = 92.4 Rs./Kg. ....(B)

4.14.2.4 Cost per Kg.

Ignoring other expenses cost/kg of the new product for lab model was calculated as

Cost/kg of new yarn **= A + B**

(Excluding other expenses)

= Rs. 155.13/ Kg. ....(C)

Table 4.19 Comparative Cost-sheet of Textured Yarns.

No.		Type of Texturising System		
	Variable	Air-jet Textured yarn	False-twist Textured yarn	Mechanical-Crimp Textured yarn
1.	Production /spindle/Day (Kg)	8.65	13.68	3.8
2.	Power/spindle/Hr. (Kw/Hr.)	1.71	0.27	1.26
3.	Compressor power /spindle/Hr. (Kw/Hr.)	17.3	-	-
4.	Heater power cost/spindle/day (Kw/Hr.)	-	1.66	-
5.	Total Power /spindle/Hr.	19.01	1.93	1.26
6.	M/c Power (Rs./Kg)	421.9	27.08	63.32
7.	Raw material cost (Rs./Kg)	71.80	71.80	92.40
8.	Other cost inclusive of Maintenance and Repairs (Rs./Kg)	15.40	6.55	Still not available as Lab apparatus.
	Total Cost =(6+7) (Rs./Kg) (excluding Other cost)	549.37	98.88	155.13

It is clear from this calculated data and table 4.19 that cost/kg of the new yarn is higher than False-twist texturising system but less than Mechanical air-jet texturising. The following major points should be considered while deciding its cost effectiveness.

1. Single head Lab model has been used for the production of innovative yarn, likely to be suffering from the limitations like; low production rate and higher power consumption in the absence of sophistication in driving system and house keeping. Both the values have greater influence on cost/kg of the product yarn.
2. Majority machine parts are fabricated one and not optimized in terms of size and weight as true for other systems add up to power-cost.
3. Bigger capacity motors are installed for driving parts at comparatively slower speed due to limitations of lab model increases resistance and thereby exhibits higher power load, results in higher power cost.
4. Number of machine variables involved are less requires less maintenance and spares, even no pre-production processes (heat-setting) and post-production processes (doubling/ plying) are required reduces cost as well as product delay.

If all above mentioned points are taken care off on actual shop-floor this newly engineered system has a potential to survive in the competition with other systems on the economical ground.

…………x……………..x……………..x……………x:……………x………..