

## EFFECT OF POST-TEXTURED HEAT SETTING ON TEXTURED YARN PROPERTIES: COMPARISON BETWEEN AIR-JET AND STEAM-JET TEXTURED YARNS

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### ABSTRACT

*Dimensionally stable textured filament yarns are recognized as having important attributes, which are suitable for fabric production and sewing threads. The most successful method of texturing to achieve the above yarn qualities is spun-like textured yarn produced from Air-jet texturing with post textured heat setting. Even though high pressure air has been used and established for manufacturing spun like textured yarns, there are no evidence on research work to investigations the suitability of other high pressure fluids such as steam and water. The objective of this research work was to use high-pressure steam in order to replace air in air-jets in the production of spun-like textured yarns and investigate the effect of post textured heat setting on textured yarn properties. An existing air-jet texturing machine was modified to supply and control both compressed air and high pressure steam to the texturing nozzle. Effect of post textured heat setting on loop instability, shrinkage, strength, tenacity, elongation and linear density of the steam-jet textured yarn was studied and compared with air-jet textured yarns. Results show that the instability, loop density and shrinkage of both air-jet and steam-jet textured yarns decrease when the temperature is increased. Further, it was observed that the instability, loop density and the boiling water shrinkage of steam-jet textured yarns are lower than that of comparable air-jet textured yarns before the textured yarn is heat set.*

**Keywords:** Air-jet texturing, Steam-jet texturing, heat setting, loop instability, shrinkage,

### 1. INTRODUCTION

Aim of this research was to analyze and compare the properties of steam-jet textured yarns with air-jet textured yarns made under similar process conditions with different post textured heat setting temperatures. One of the significant texturing processes in current use, air-jet texturing, operates by mechanical interlocking and not by heat setting in the case of the other texturing techniques such as false-twist. It is a cold fluid texturing process that converts flat, continuous synthetic filament yarns into an entangled, convoluted, bulky, spun-like yarn. The air-jet texturing process is a versatile texturing method in that it can blend different filament yarns together during processing, and it can thereby simulate the desirable attributes of staple spun yarns. This greater versatility offers the texturiser substantial scope for product developments. It can therefore be applied to any continuous filament yarn, including viscose rayon, glass and other new high performance fibres, as well as nylon, polyester and polypropylene. The

basis of the method is that a filament yarn is overfed through a specially designed jet that creates a supersonic, highly turbulent airflow, so that loops are forced out of the yarn. The extra lengths of the filaments provided by overfeed are taken up by entanglement of the filaments, thus creating loops that are locked into the yarn.

After leaving the texturing zone, the textured yarn is generally drawn for the purpose of stabilizing the loosely textured protruded filament loops. Even after the stabilizing, textured yarn has relatively large filament loops which are undesirable, especially for applications such as sewing threads. Stabilising after texturing alone not sufficient to achieve required surface characteristics and shrinkage of the textured yarn. Therefore, post-textured heat setting is conducted to reduce the loops size and also to reduce the boiling water shrinkage (Fisher, 1982; Krenzer, 1988).

In the case of air-jet textured sewing threads it is important to shrink larger protruded loops after the texturing process. It is believed that the larger

protruded loops adversely affect the sewing process. Sewing thread based on air-jet textured yarns present a different problem. Although these yarns are dyed, there is no opportunity during the texturing process to build a softly wound package suitable for autoclaving, because of the need to twist the yarn. Therefore, it is desirable to reduce the shrinkage of the yarn to about 1% by some other means, preferably during the process. Heated roller or godet heating has been applied successfully, in conjunction with the use of hot pins and sometimes also hotplates before and after texturing. The residual shrinkage of polyester yarns can in fact be reduced step by step, in other words the effect is cumulative.

In many air-jet textured yarn applications, polyester is package dyed. To ensure even dye penetration, it is important that no further yarn shrinkage takes place during dyeing. This is achieved by steaming the textured yarn in an autoclave for approximately 20 minutes at approximately 130°C. However, modern air-jet texturing machines are being fitted with heated rolls before and after the texturing-jet. These reduce the residual shrinkage of polyester yarns significantly and avoid the need for autoclaving (Hearle, Hollick & Wilson, 2001).

Research on air-jet texturing, in particular effect of post-textured heat setting on textured yarn properties is rare. According to Denton (1989), early investigation had showed that the tubular heater usually used on air-jet texturing machines were inadequate to do more than shrink the surface loops of the yarn. Investigation of new thermo contact heaters shown that at least 3 meter of heating at temperature above 220°C was necessary to reduce yarn shrinkage below 2% (Denton, 1989). Bock (1982) researched on post textured heat setting and concluded that at 0% overfeeds during heat setting gives a considerable improvement of yarn stability. He reported that at 8% overfeed; the yarn stability diminishes even though there was a reduction of loop size.

## 2. METHODOLOGY:

A single position industrial air-jet texturing machine was modified to make both air-jet and steam-jet textured yarns under similar processing parameters. The machine was originally designed to make air-jet core-effect textured yarns, especially for sewing threads. At the start of the present work the machine was modified to supply both

compressed air and high-pressure steam for air-jet and steam-jet texturing. Using the identical jets, the relationships between steam-jet and air-jet textured yarns have been studied. Only one type of each core-yarn and effect-yarn have been used in the study in order to eliminate the effects of supply yarn properties. Following process conditions, which was used for commercial air-jet textured sewing threads have been used and maintained constant in the study.

Jet type: Commercial jet

Fluid pressure: 8 bar (air and steam)

Production speed: 275 m/min

Core yarn: Polyester 415dtex/ f48 POY

Core yarn draw ratio: 2.19 at 110°C draw pin temperature

Core yarn pre-heating temperature: 180°C / 10 wraps at godet roller

Core yarn overfeed: 5.5%

Effect yarn: Polyester 86dtex/ f36 POY

Effect yarn draw ratio: 1.75 at 70°C draw pin temperature

Effect yarn overfeed: 37.9%

Baffle ball setting: 1.5 mm

Core yarn wetting: ON

Godet roller has been used to apply heat to the yarns during the post textured heat setting. The core draw-pin temperature, the effect draw-pin temperature and the core-yarn pre-heat setting temperature have been maintained constant as explain above. The post-textured heat setting temperature has been changed from 180°C to 220°C and also compared with the non post-textured heat set yarns. The textured yarns have been wrapped 40 times on the heated godet roller.

Acar's loop instability test method (Acar & Wray, 1986) was used to measure loop instability. Acar's test method is based on load elongation curves of the textured yarn. The loads used are 0.01 cN/dtex (lower limit) and 0.5 cN/dtex (upper limit). The difference in elongations, which corresponds to the loads, provides a measurement of the instability of the textured yarn.

Loop density is defined as the number of loops available on the surface of the textured yarn per unit length. SDL friction and hairiness tester was used to measure the number of loops available on the surface. A yarn length of 10 m with the yarn moving at a speed of 30 m/min was chosen. Ten

yarn samples have been tested and the average number of loops per 10 cm was calculated.

Shrinkage of yarns in boiling water was carried out according to the ASTM D2259-91 test method.

Tensile properties of textured yarns were measured with an Uster-Tensorapid automatic yarn-testing instrument. The instrument is a single yarn strength tester and operates at a constant rate of extension. Following BS EN ISO 2062:1995, with a sample length of 50 cm, the cross head moving speed has been adjusted to give a yarn failure time of 20±3 seconds. Twenty tests have been carried out for each package and the average strength, tenacity and elongation results have been obtained from five packages where possible.

**3. RESULTS:**

**3.1 Loop Instability**

Insert figure 1 here

Figure 1 shows that loop instability of both air-jet and steam-jet textured yarns reduces when the post-texturing heat setting temperature is increased. When heat is applied to the textured yarn, it reduces the amount of shrinkage left in the individual core and effect filaments. Therefore, it can be concluded that post-texturing heat setting effectively reduces the loop instability of the textured yarn.

It can also be seen that loop instability of steam-jet textured yarns are lower than air-jet textured yarns. This may be due to shrinkage of the filaments during the steam-jet process. Since the steam-jet textured yarns have shrunk further during the post-textured heat setting, it can be concluded that the lower loop instability of the steam-jet textured yarns are due to better loop entanglements. Temperatures above 220°C could not be used to heat set the textured yarns, as it was found that the effect-yarn filaments stick to the godet rollers at that temperature. Therefore, godet roller temperature and number of wraps to be established for the relevant production speed. This study was done only at constant production speed of 275 m/min.

**3.2 Loop Density**

Insert figure 2 here

In texturing, the effect filaments generally provide the protruding loops. Since the effect-yarn is not heat-set before texturing, the shrinkage of the effect-yarn is relatively high compared to the pre-heat set core-yarn. Therefore, when the textured

yarn is heat set, the effect filaments shrink more than the core filaments. Microscopic observations revealed that the size of the loops after post-textured heat setting is very small. The minimum setting that could be used in the hairiness tester was 1mm. Hence, the loop density results of the post-textured heat set yarns do not reflect the actual tiny surface loops that are less than 1mm. Visual inspections shows that there are substantial numbers of tiny loops. Therefore, the loop density of the air-jet and steam-jet textured yarns cannot be properly compared after post-textured heat setting. In both air-jet and steam-jet textured yarns, it can be seen that post-textured heat setting reduces the protruding loop size significantly.

**3.3 Boiling water shrinkage**

Insert figure 3 here

One of the main objectives of post-textured heat setting is to reduce the boiling water shrinkage of the textured yarn. As expected, Figure 3 shows that the boiling water shrinkage reduces when the post-textured heat setting temperature is increased. The results show that the boiling water shrinkage of the steam-jet textured yarns (2.4%) is lower than the air-jet textured yarns (4.7%) before post textured heat setting. The steam-jet textured yarns required godet roller temperatures of approximately 190°C to reduce the shrinkage level to about 1%, whereas the air-jet textured yarns required a temperature of approximately 210°C. Although the 2.4% boiling water shrinkage is not sufficiently low for use in sewing threads, steam-jet textured yarns could be produced without heat setting for other application such as weaving and knitting without using expensive godet or autoclaves.

**3.4 Effect on Yarn Strength, Tenacity, Elongation and Linear Density**

Insert figure 4 here

Insert figure 5 here

Insert figure 6 here

Insert figure 7 here

Figures 4, 5, 6 and 7 show that strength, tenacity and elongation increase when heater temperature is increased to about 210°C and then reduce when the temperature is further increased. During the process it was observed that filaments start melting at temperatures of 220°C. This could be the reason for the reduced textured yarn strength above temperatures of 210°C. The increase in strength, tenacity and elongation could be due to the effect of shrinkage that straightens the core filaments and provides more load bearing straight filaments to the textured yarn structure. The post-texturing heat setting does not have a significant effect on the linear density of the textured yarns as the heat setting has been performed under tension and the textured yarn has not been allowed to shrink.

### 3.5. Microscopic Observations

Insert figure 8 here

As expected, Microscopic observations show that heat setting reduces the effect filament loop size. Figures 8 show the steam-jet and air-jet textured yarn before and after heat-setting at different godet roller temperatures.

## 4. DISCUSSION

The effect on textured yarn caused by post texturing heat setting can be summarized as follows.

- The instability, loop density and boiling water shrinkage of both air-jet and steam-jet textured yarns reduce when the temperature is increased. The instability, loop density and the boiling water shrinkage of steam-jet textured yarns are lower than air-jet textured yarns before the textured yarn is heat set. The difference between the steam-jet and air-jet textured yarns reduces when the temperature is increased and eventually becomes the same when the temperature is about 210°C.
- The strength, elongation and tenacity of both air-jet and steam-jet yarns increase when temperature is increased to about 210°C and then decrease. The strength, elongation and tenacity of steam-jet textured yarns are higher than air-jet textured yarns before the textured yarn is heat set. The difference between the steam-jet and air-jet textured yarns reduces when the temperature is increased.

However, strength, tenacity and elongation of the steam-jet textured yarn remain significantly higher than the air-jet textured yarns even at the optimum temperature of 210°C.

From the above results it can be concluded that post-texturing heat setting is important in both air-jet and steam-jet processes for reducing protruded loop size and the boiling water shrinkage. However, steam-jet textured yarns require lower temperatures to reach the required levels. Therefore, the energy required for heat setting is lower in the case of steam-jet texturing. It can be also seen that steam from the jet can be re-used to heat set the textured yarns and the energy cost for heat setting can be further reduced.

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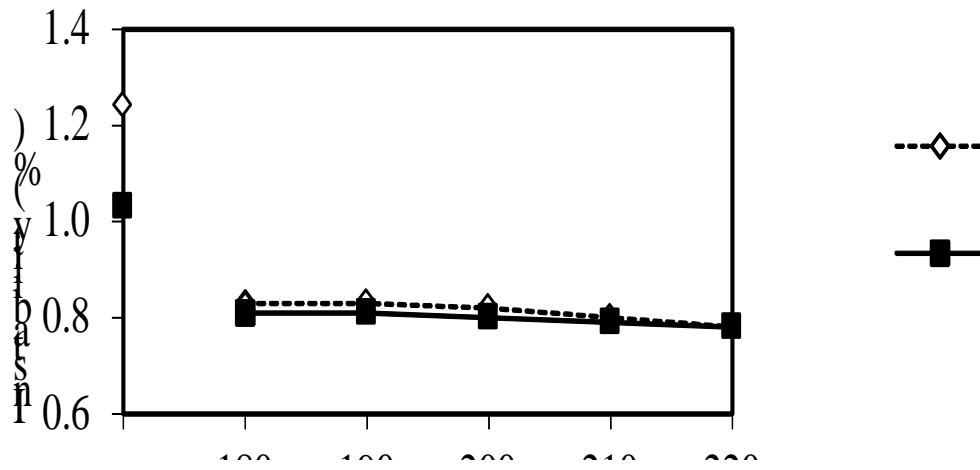


Figure 1. Effect of Post-Textured Heat-Setting on Textured Yarn Instability

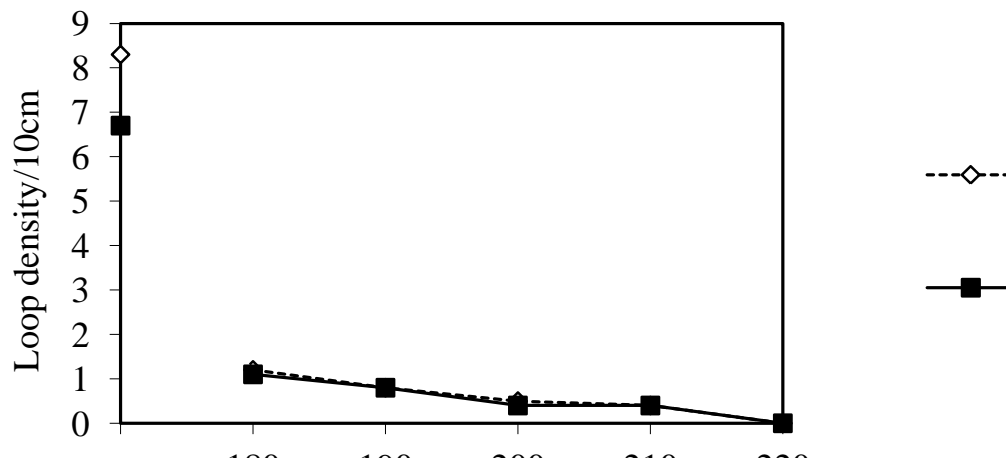


Figure 2. Effect of Post-Textured Heat-Setting Temperature on Loop Density of Textured Yarns

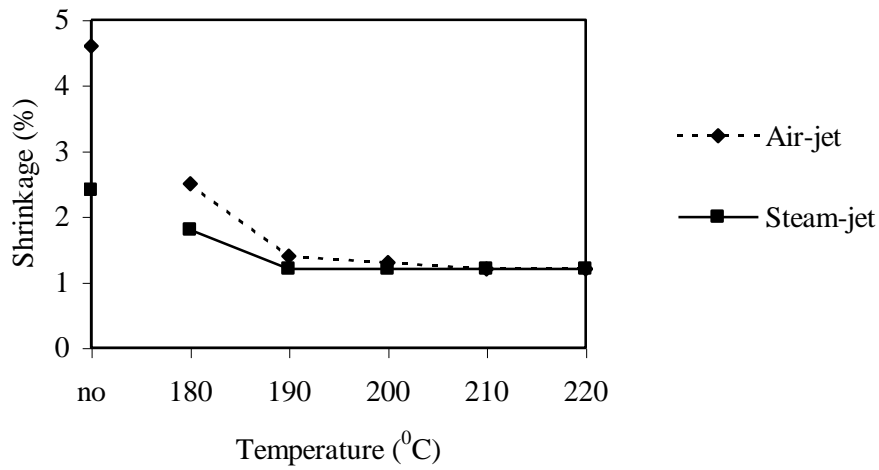


Figure 3. Effect of Post Textured Heat-Setting Temperature on Shrinkage of Textured Yarns

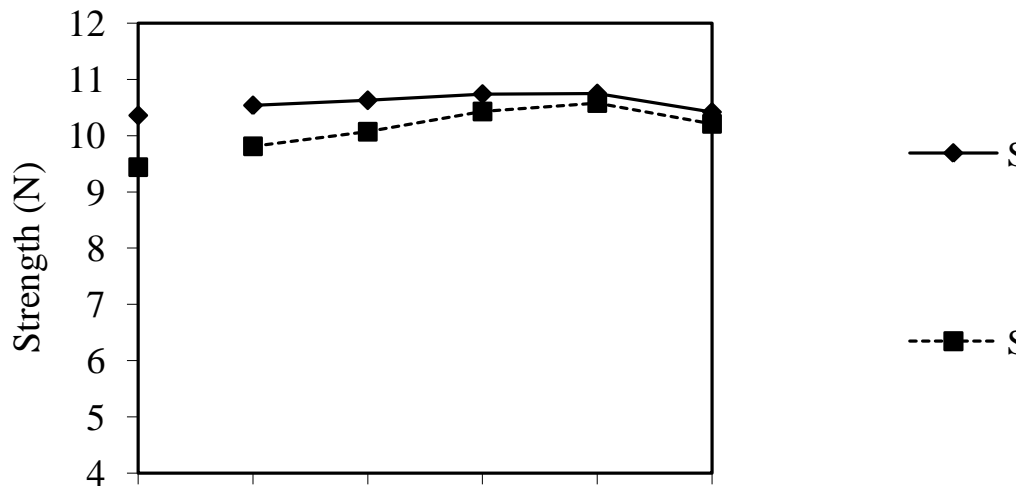


Figure 4. Effect of Post-Texturing Heat Setting on Strength

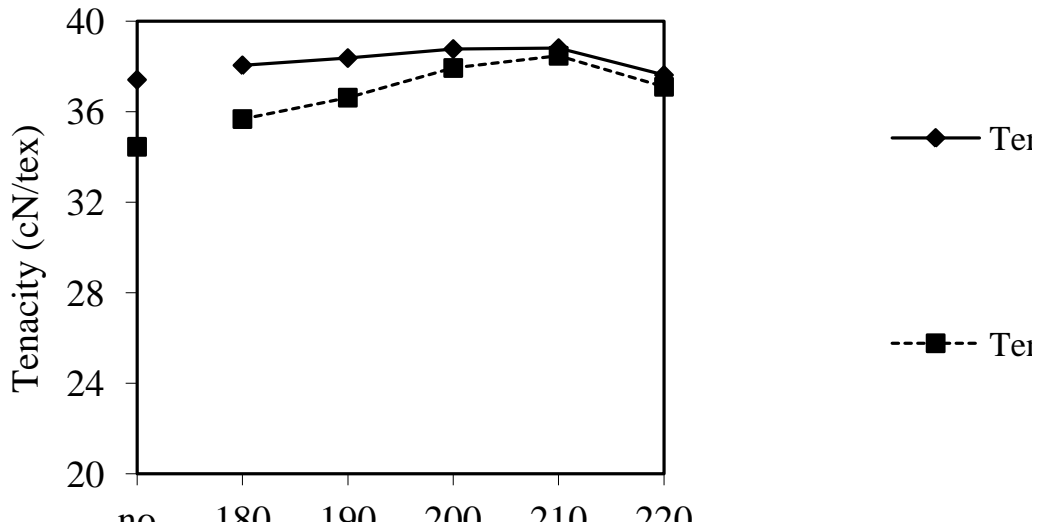


Figure 5. Effect of Post-Texturing Heat Setting on Tenacity

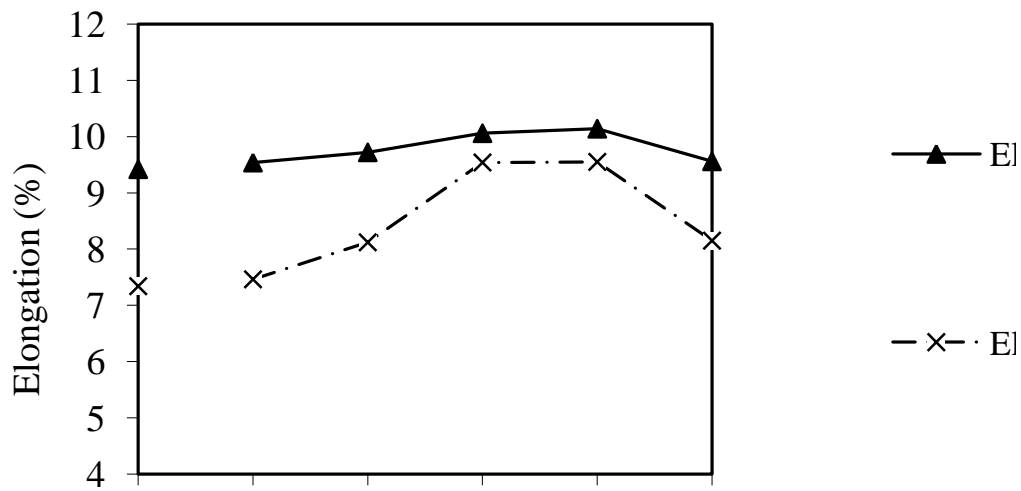


Figure 6. Effect of Post-textured Heat Setting on Elongation

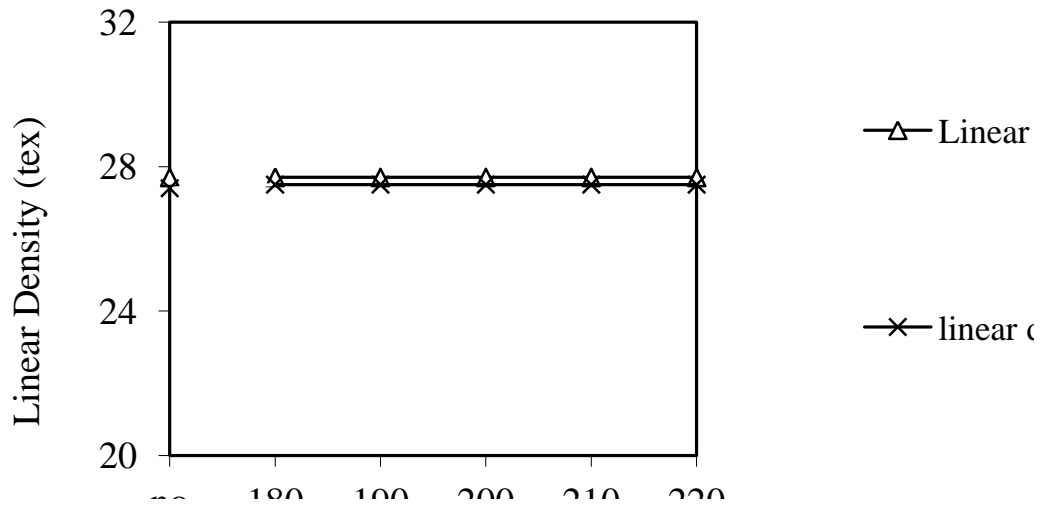


Figure 7. Effect of Post-Texturing Heat-Setting on Linear Density

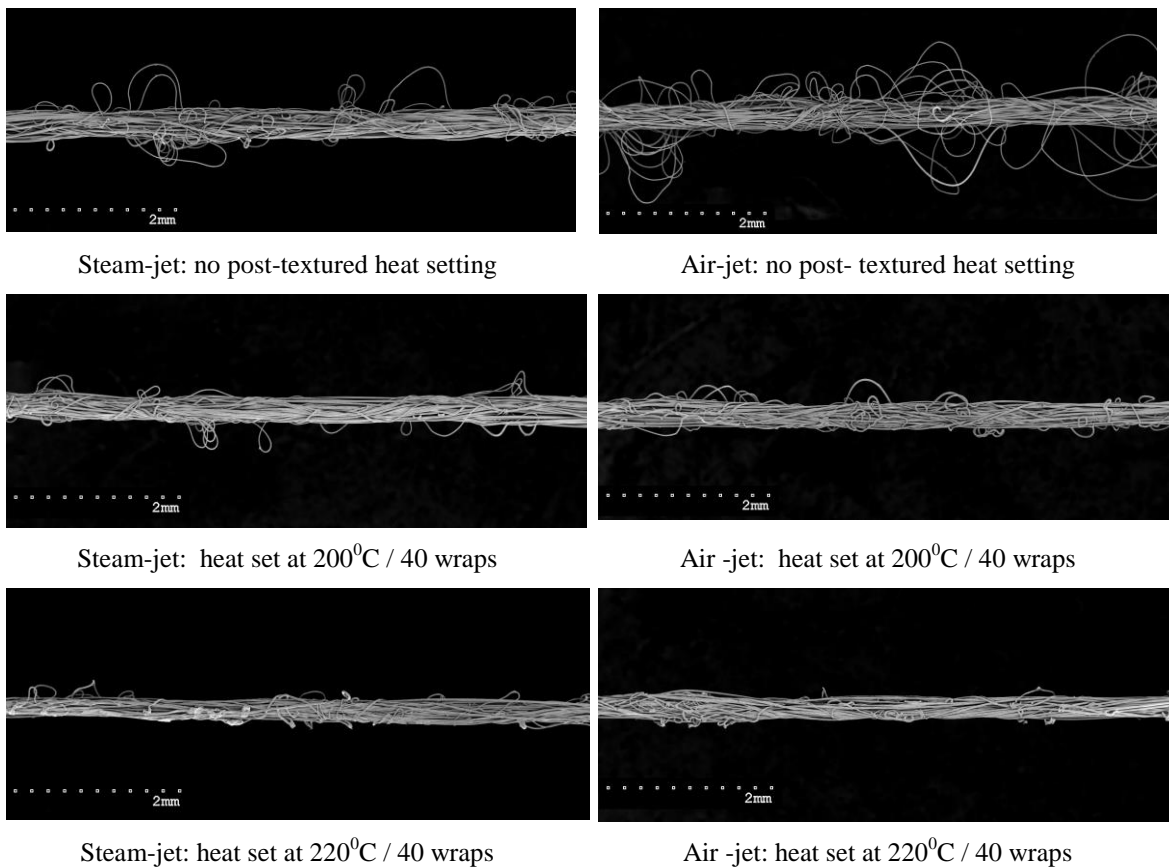


Figure 8. SEM Images of Steam-Jet and Air-Jet Textured Yarns