Investigation of Self Crimp Method as Applied to Polypropylene Fibers

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ABSTRACT

INVESTIGATION OF SELF CRIMP METHOD AS APPLIED TO POLYPROPYLENE FIBERS

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Use of man-made fibers supersedes that of natural fibers by the development of technology in textile field. Moreover, man-made fibers have been reached a widely used. Especially, they are needed to have crimps, curls, loops and bulk appearance in order to be used in manufacturing hosiery goods, upholstery, drapery, carpet and industrial fabrics. These properties can be obtained by using different texturing processes according to the type of the man-made fibers. But, texturing process is required for using high levels of air, power and heat. This condition causes increase in production cost. To be a competitive in the world, high speed production rates are required at the low production costs.

This study includes the investigation of self crimp method on applied polypropylene (PP) fibers used in producing man-made carpet as a pile yarn. Self crimping filament yarn spinning (FYS) process is used to deform the molecular structure of melted yarn by using intensive-local cooling having low temperature. This changed molecular orientation causes the crimp effect in filaments. For investigation, spinnerets are designed, local cooling unit is invented. Both of them are mounted on bulk continuous filament (BCF) spinning machine. In the experimental studies, 48 sample yarns are obtained by changing BCF spinning machine parameters with designed units. The physical properties of them tested in laboratory are compared with both BCF yarn and continuous filament (CF) yarn. In conclusion, according to test results and visible outcomes, it is proved that the self-crimp FYS has crimp effect on the yarn.

Key words: Self Crimp, texturing, polypropylene, bulk continuous filament (BCF)

ÖZET

KENDİLİĞİNDEN KIVRILMA METODUNUN POLİPROPİLEN ELYAFINA UYGULANMASININ ÜZERİNE ARAŞTIRMASI

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Tekstil alanındaki teknolojik gelişmelerle beraber yapay elyaflar doğal elyafların yerini almaya başlamış ve daha geniş bir kullanım alanına ulaşmıştır. Özellikle yapay elyafların iç giyim, döşemelik, perde ve halı gibi tekstil ürünlerinde yaygın bir kullanımı sağlamak için daha dolgun, kıvrışık, şişkin ve hacimli özelliklerine sahip olması gerekmektedir. Bu özellikler sentetik filament ipliğin türüne göre farklı tekstüre işlemeleri kullanarak elde edilebilir. Fakat, tekstüre işlemini gerçekleştirmek için yüksek miktarda hava, enerji ve ısı kullanımı gerekmektedir. Bu durum ise üretim maliyetlerinin artmasına neden olmaktadır. Halbuki, dünya üzerinde rekabet edebilmek için çok ürünü daha düşük maliyetlerde üretmek gerekir.

Bu çalışma kendiliğinden kıvrılma (self crimping) metodunun makine halılarında hav ipliği olarak kullanılan BCF polipropilen elyafına uygulanması üzerine bir araştırmayı içermektedir. Kendiliğinden kıvrılmada, eriyik halde akan filamentlerin dış yüzeyin bir tarafı düşük derecede bir soğutma sistemine temas ettirilmektedir. Bu temas sonucu sıcak haldeki polimerlerin bir yüzeyi aniden soğuması ile moleküler değişim oluşacaktır. Moleküllerdeki değişim, filamentlerin kıvrılmasına neden olacaktır. Araştırma için yeni düze ve yerel soğutma ünitesi tasarlanarak BCF iplik makinesi üzerine uyarlanmıştır. Deneysel çalışmalarda, tasarlanan ünitelerle beraber BCF iplik makinesinin parametreleri değiştirilerek yaklaşık 48 numune elde edilmiştir. Numunelerin fiziksel özellikleri laboratuar ortamında test edilerek hem BCF ipliği hem de CF ipliği ile karşılaştırılmıştır. Deney sonuçları kendiliğinden kıvrılma tekstüre metodun polipropilen ipliğine uygulanabileceğini ve istenilen kıvrımın gerçekleştiğini göstermiştir .

Anahtar Kelimeler: Kendiliğinden kıvrılma, sentetik iplik teksturize, polipropilen, BCF

ACKNOWLEDGEMENTS

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LIST OF SYMBOLS

A Current Amper
a-PP Atactic
BCF Bulk Continuous Filament
CD Cation Dyeable PET terephtalate
CFL Polyvinylchloride
cN Zenti Newton
cm Centimeter
FYS Filament Yarn Spinning
i-PP Isotactic
m/min meter/minute
m/s meter/second
MFR Melt flow rate
PA6 Polyamide 6
PAN Acrylic
PBT Polybutylene terephtalate
PET Polyethylene terephtalate
POY Partially Oriented Yarns
PP Polyproylene
PTT Polytrimethylene terephtalate
RPM Revolution per minute
SML Starlinger Machine Lenzing
US United States

CHAPTER 1

INTRODUCTION

1.1. Introduction

Early humans used natural fibers, as cotton, silk and wool, in producing yarn. Yet, due to demands of contemporary humans and technological developments new types of fiber are needed to create. Therefore, people discovered man-made fibers, which are classified in to two groups as natural man-made fibers as viscose and synthetic man-made fibers as polypropylene, acrylic and polyester.

At the end of the 1930s, a new field on the production of man-made fibers is started to be researched. In 1939, investigations on the production of a synthetic polyamide fiber were carried-out in the USA. In the following years, the development of manufacturing processes for the other kinds of synthetic fibers, as polyester, polyacrylonitrile and polypropylene, etc., are started. The Polypropylene material is produced in the years of 1955 - 1958 [1, 2].

By the technological developments, man-made fibers are started to be produced in three different systems as melt spinning, dry spinning and wet spinning [3]. The most used system on production of man-made fibers is melt spinning system. Thus, Bulk Continuous Filament (BCF) spinning system is widely used.

The BCF polypropylene yarns are generally used in carpets (Figure 1.1). Carpet, one of the oldest and the most important textile products in the world is a traditional Turkish textile product. Firstly, carpets are produced by hand from natural fibers. Today, carpets are produced by machines. In machine production, more stable and strength yarns are needed to run machines faster and get more efficiency. As a result, people are started to use synthetic man-made fibers in the production of carpets. However, the synthetic fibers must be produced soft, bulky, and handy to give the appearance and the feeling of natural fibers.

Figure 1.1 The BCF Carpet Yarn Bobbins

The continuous synthetic filament yarns are needed to have bulk appearance for usage areas as hosiery goods, knitted outerwear, upholstery, drapery, carpet and industrial fabrics. Such yarns with a modified structure are called textured and the process of their manufacture is called texturing. So, texturing process applied to impart additional value and quality to synthetic filament yarns creates crimps, curls, loops and bulk formation.

The majority of texturing processes filament yarns is subjected to a mechanical action (twisting, crimping, stretching on a sharp edge, etc.) with simultaneous heating for setting the modified structure [1].

There exist different methods and technologies are available in use for the purpose of texturing, and the major ones are;

- False-twist texturing
- Air-jet texturing technology
- Stuffer box technology
- Bi-component technology

As a new method “Self Crimped Filament Yarn Spinning (self crimped FYS)” process is currently developed.

Most of the synthetic filament yarns are textured after spinning in order to give basic textile qualities such as; bulk, natural, appearance, warm hand, softness and flexibility.

In texturing process, air-power, heat and energy are highly demanded. Mechanical processes have very low production rates and high power demands. However, high speed production rates and low production costs are required in the development of the production of filament yarns. Therefore, new development texture systems for the production of filament yarns are necessitated.

1.2. Objective of the thesis

The aim of this study is to apply self crimped FYS on polypropylene fibers. In the traditional texturing methods, too much air is used. Heat consumption and energy costs are in high levels.

But in the self crimping FYS, there are no or very less air consumption, no heat loose, less energy usage and low or no noise emissions. The future developments will be focused on creating texturing effects by means of self-crimping. Self-Crimping system is more economical, speedier and has fancy texturing effects. This system produces better quality yarns.

The fields of application of crimped textures yarn are considerably wider than those of high or low stretch yarns. Crimped textured yarns are the most successfully used for making carpets. The main characteristics of such yarns are high crimp, bulkiness and some of these yarns have elastic stretch.

Self crimping is the molecular structure deformation by intensive-local cooling and molecular orientation difference in fiber cross section [4]. In this system, the production performance and quality of the yarn are increased, the energy consumption of air-heat is decreased and much more economical production can be done.

In the self crimped FYS, the polypropylene (PP) filament yarns affected by local-cooling to the cross section of the fibers gets molecular orientation and this situation causes the crimp effect on the yarn in theoretically.

The main objective of this thesis is to make self crimping method practically in order to investigate the crimp level and physical properties of the textured yarn.

1.3. Literature Survey

Many textured studies on the BCF carpet yarn can be found in search of the literature survey. Most of them are dealt with false-twist texturing [5-8], air-jet texturing technology [9-13] and stuffer box technology [14-16].

A few studies are found on bi-component technology and the self crimped FYS process [17,18,20-25] in the available literature.

Tatsuki Matsuo [17], has studied Polypropylene Fibers Crimped by Asymmetrical Quenching (Japan, 1974). The methods for producing crimped fibers can be classified as follows: One is mechanical crimping such as false twisting or stuffing box crimping. Another is to utilize the latent crimpability grown in spinning. As to the latter, there are two crimping method: bi-component and asymmetrical condensating. For bi-component spinning, a certain special apparatus is required to conjugate two components of dopes. On the contrary, no special apparatus is necessary for asymmetrical quenching. Therefore asymmetrical quenching has a great advantage over bi-component spinning from the view point of investment cost. Because threads are generally cooled by cross air flow in melt spinning, they are more or less asymmetrically quenched as to their fiber axes. But as is well known, most undrawn fibers so far obtained by melt spinning have never latent crimpability. It is thought that, in addition to asymmetrical quenching, some other special conditions are necessary for providing undrawn fibers with latent crimpability. In the study the Polypropylene PP material is used. The test machine capacity is 1kg/hour, take up speed is 600 m/min, Quenching conditions is 0,8 m/sec across thread lines at 20 mm below the spinneret, Spinneret diameter of 0.8 mm and 10 or 0 holes, Yarns are drawn at 25ºC between two rolls with the drawing ratio of 3. Experimentally the Figure 1.2 shows the intrinsic viscosity versus and the crimp percentage. The crimp percentage takes fairly sharp peaks at an optimum spinneret temperature at each distance between the spinneret and the upper end of quenching air. The shapes of helical crimps obtained by drawing and then heat-treating these fibers in a relaxed state, this is shown in Figure 1.3. It is experimentally and theoretically proved that the effect of the linear density on the helical crimp diameter is smaller in asymmetrical quenching than in bi-component spinning. So, the optimum undrawn fiber density increases with the increase in single filament linear density. Crimpability can then be intensified with an increase of quenching air velocity or by spinning hollow fibers.

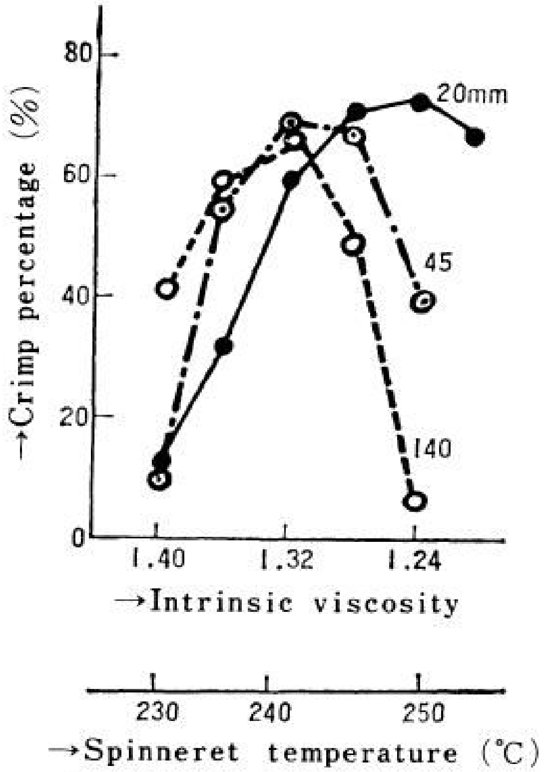


Figure 1.2 Changes in crimpability with spinneret temperature (Figure on the curves show the distance between the spinneret and the upper end of quenching air) [17]

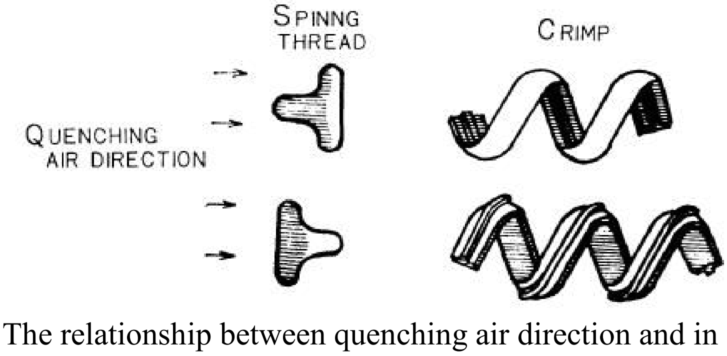


Figure 1.3 The relationship between quenching air direction and in or outside of a helical crimp [17]

Rweis. P., Lin Y. T., Su Y. Y. [18], have studied self-crimp polyester fibers (2005). Self-crimp polyester yarns were manufactured using a conjugated spinning process involving two parallel but attached fibers with different shrinkage properties. Maintaining identical or very similar melt viscosities of the two components was demonstrated to be very critical for obtaining a straight interface and eliminating the dog-legging problem. This study has found that the combination of PET/PTT (Polyethylene terephtalate/Polytrimethylene terephtalate) outperformed that of PET/PBT (Polyethylene terephtalate/Polybutylene terephtalate) and PET/CD (Polyethylene terephtalate/Cation Dyeable PET terephtalate) in terms of crimp potential, crimp stability, and elastic recovery. Figure 1.4 shows the effect of the cross-sectional shape on crimp potential. Two polyester resins, comprising PET as fixed ingredient and another conjugated part selected from PBT, CD and PTT, were spun simultaneously using a bicomponent spinning set. The melt-viscosity was measured via a continuous rheometry to determine the optimal spinning temperature. In this study, two individual single-screw extruders extruded PET and its conjugated part separately into the conjugated spin-pack (Figure 1.5). Barmag take-up winder was employed for collecting the yarns with a winding speed of 3,500 m/min. A 30-min filament package with a denier pf 150 denier / 24 filaments was gathered for each experimental condition. The processing temperature of PET must be 20ºC-30ºC higher than that of PTT and PBT to achieve the same melt viscosity. The results indicate that, in the same cross sectional area, the triangular shapes are superior to the round cross section. The calculations, derived from classical mechanics [19], the crimp curvature of triangular shape is twice that of round shape. This theoretical calculation agrees well with the experimental results. Furthermore, Figure 1.4 demonstrates the one in a triangular shape with a higher shrinkage component on the top, denoted the “regular triangle” exhibits greater crimp curvature than the other triangle with reversed order, and denoted the “reversed triangle”. The crimp tests illustrate that the triangular shapes are found to be superior to the round cross section. The optimum volume ratio for making a self-crimp bi-component skein is 50/50. Moreover, the optimal fiber thickness is 8 denier per filament. Thermal shrinkage differs among individual polyesters, with the maximum difference in shrinkage accruing for the combination of PET/PTT, than PET/PBT and lowest curvature is in PET/CD (Figure 1.4). Figure 1.6 shows the photos of curved skeins for PET/PBT, PET/CD and PET/PTT respectively. The stability results reveal that

PET/CD completely lost its crimp potential. PET/PTT still exhibits a good crimp stability ratio.

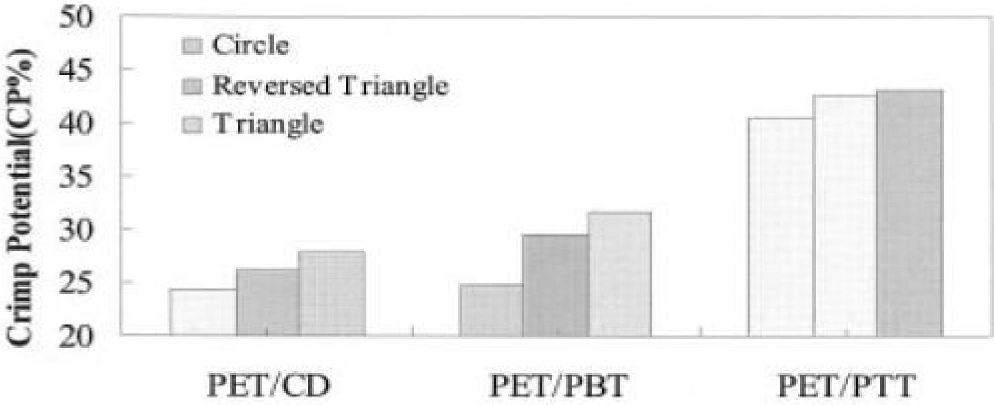


Figure 1.4 Crimp potential for bicomponent fibers (50/50 by volume) in combinations of various polyesters with different cross-sectional shapes [18].

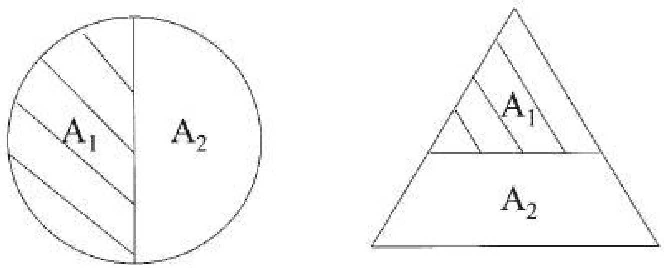


Figure 1.5 Side-by-side model employing round and triangular cross-section shapes [18]

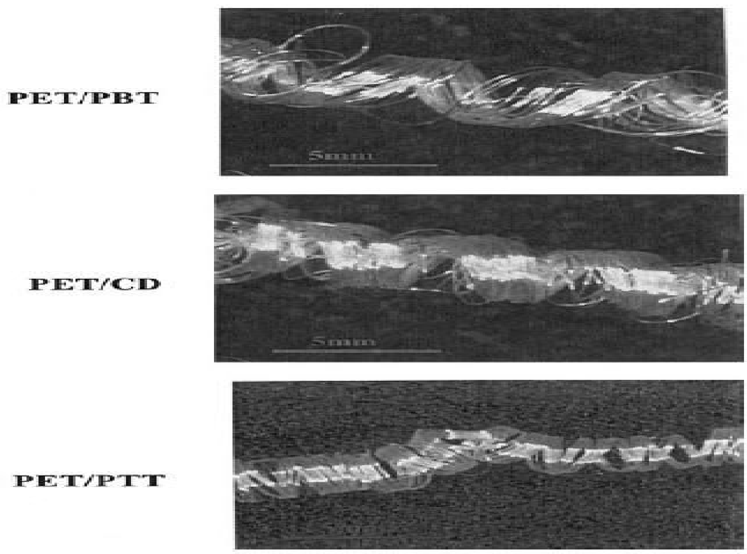


Figure 1.6 Photos of curved skeins for PET/PBT, PET/CD and PET/PTT respectively [18]

Lin, T., Wang, H., Wnag, X. [20], have studied self crimping bi-component nanofibers electrospun from polyacrylontirile and elastomeric Polyurethane (2005). In this study, bi-component nanofibers produced by side by side electrospinning of two different polymer solutions using a microfluidic device as a spinneret. By dissolving one of the polymer components from the nanofibers, the side-by-side bi-component morphology can be clearly demonstrated. Using this technique, it is possible to prepare even smaller nanofibers from by sacrificing one of the polymer components, or to create multicomponent nanofibers. The process example, if one of the bi-component sides is electrically conductive while the other is able to absorb chemicals selectively, the differential shrinkage triggered by the absorption of chemicals on one component side would make fiber bend. This bending may then switch an electrical circuit on or off due to the mechanical bending of the conductive side. This nanofiber could be potentially used as a nanomechanical chemical sensor, similar to micromechanical chemical sensor. Also, is the differential shrinkage of twp nanofibers could be triggered by an external stimulus, such as humidity, temperature, optical irradiation, electrical pulses or chemicals then these fibers could be used as nanotweezers or other forms of nanoactuators.

Tae Hwan Oh [21], has studied melt spinning and drawing process of PET side-by-side bi-component fibers (2005). Regular PET and modified PET were selected to make a latent crimp yarn. The modified PET was synthesized to increase thermal shrinkage. The crimp contraction is mainly dependent on drawing conditions such as draw ratio, heat-set temperature and drawing temperature. Difference in shrinkage between the PET and the modified PET causes the self-crimping of bi-component fibers. As the heat-set temperature and drawing temperature decreases, the crimp contraction increases. Obtainable maximum crimp contraction is 42% at draw ratio of 3,1, heat-set temperature of 80ºC. Difference in elongation also affects the crimp contraction in effect of draw ratio. When the modified PET with neopently group was used for highly shrinkable part, the crimp contraction is greater in comparison with modified PET with dimethly isophthalate.

Fernstorm, George, A., Hebaler, Harold, H., Lin, Perry, H., Robert, R. [22], have studied of Self-crimping polyamide fibers (1981). A process is provided for preparing self-crimpable monocomponent fibers by the sequential steps of melt-spinning a polymer of polyhexamethylene adipamide or polycaproamide into filaments, quenching the filaments by a cross-flow of air to an average surface temperature of about 40.degree. to 130.degree. C., applying an effective amount of water to the filaments while they are in said temperature range, and then drawing the filaments at a draw ratio of at least 1.3:1 to obtain a tenacity of at least 1.3 gpd, a break elongation of less than 120% and a latent, substantially helical, frequently reversing crimp of at least 6 filament crimp index. The novel products of the invention, which include fibers and yarns, in self-crimpable or crimped condition, are particularly suited for use in carpets.

Black, William B.B. [23], has studied of Self-crimping polyester yarn (1987). Polyester polymer is extruded at different speeds through groups of parallel closely spaced orifices at relatively high spinning speeds. The resulting filaments have high and low shrinkage regions substantially regularly spaced apart along their length. A yarn including a number of these filaments spontaneously develops crimp when relaxed.

Jessee, R.T., Strachan, D.R. [24], have studied of Self-crimping fibers and methods for their preparation (1999). Embodiments are provided in which fibers are melt-spun from a non-elastomeric polyamide and a thermoplastic elastomer selected from the group consisting of a polyether block polyamide copolymer and a polycaprolactone polyester. The fibers may be knit or woven into textile articles including, hosiery, pantyhose and stockings.

Travelute, F.L., Hoffman, R.E. [25], have studied of; Method of forming self-texturing filaments and resulting self-texturing filaments (1995). A method is disclosed of producing self-texturing filaments that exhibit a desirable tendency to coil rather than to bend sharply or zig zag. The method comprises directing a quenching fluid at extruded hollow filaments of a liquid polymer predominantly from one side of the hollow filaments to thereby produce hollow filaments with different orientations on each side. Thereafter the temperature of the hollow filaments is raised to a temperature sufficient for the filaments to relax, but less than the temperature at which the filaments would shrink.

1.4. Layout of Thesis

In Chapter 2, the general properties and characteristic of polypropylene material are explained. The principle and the steps of BCF system are examined. The materials, the machine parts and the organization of the BCF process and its production are explained. Furthermore, the last situation of the BCF market in the world is given.

Chapter 3 comprises the information of texturing methods applied on synthetic fibers. The descriptions and the working principle of different types of texturing methods are examined. Also, the theory of self-crimp FYS is explained.

Chapter 4 contains the description of the used materials, methods and apparatus, design of the new spinneret, local cooling unit for the self-crimp FYS, and the studies of experiments. Especially, the parts and the apparatus of the experimental set-up are examined. The new design of apparatus and materials are mentioned. In addition, it includes the working steps of the experiments, experimental studies and the production of the sample yarns.

Chapter 5 covers the experimental results and data discussed with the reference values. The crimp levels, shrink, strength, count (dtex), and elongation of the sample yarns produced on the experimental set-up by using the self-crimp FYS are tested and discussed. Moreover, the results of these sample yarns are discussed and compared with hot air-jet test reference yarns. Successfully, the self-crimp FYS is analyzed.

Finally the conclusions on the study and the recommendations on the experimental set-up for further studies are given in Chapter 6.

CHAPTER 2

BULK CONTINUOUS FILAMENT (BCF) YARN

2.1. Introduction

Melt spinning system is the one of the production types of synthetic fibers. The bulk continuous filament (BCF) is formed by melt spinning systems. BCF yarns for carpets are generally produced by %100 polypropylene (PP) material, because the carpet yarns need to have more efficiency, more strength, lower price and need to be textured and bulky.

2.2. Polypropylene Fiber

Polypropylene is a thermoplastic material produced by polymerizing propylene molecules, which are the monomer units, into very long polymer molecule or chains [26]. There are number of different ways to link the monomers together, but the PP most widely used form is made with catalysts producing crystallizable polymer chains. There are three product referred as "Isotactic" (crystallizable) (see Figure 2.1) PP (i-PP) and "atactic" (noncrystallizable) PP (a-PP) and "Sindiotactic" respectively [26,27]. Their molecular properties are given in Table 2.1 [26]. The only difference of these polypropylene molecules comes from the different confirmation of molecule chains. Isotactic materials are widely use in industrial areas.

The most thermoplastic materials, the main properties of PP in the melt state are derived from the average length of the polymer chains and the breadth of the distribution of the polymer chain lengths in a given product. In the solid-state, the main properties of the PP material reflect the type and amount of crystalline amorphous region formed from the polymer chains [27].

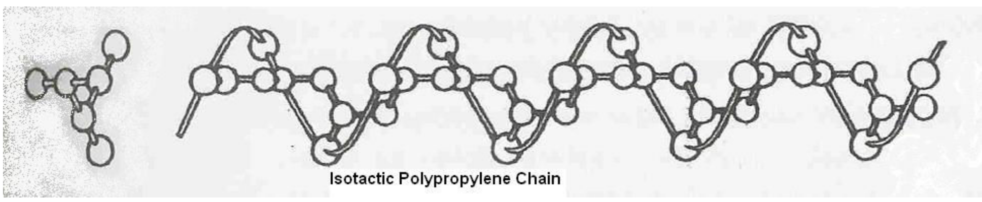


Figure 2.1 The Isotactic polypropylene chain configuration [26]

Table 2.1 Isotactic, sindiotactic and atactic polypropylene molecule properties [26].

	Isotactic	**Sindiotactic**	**Atactic**
Density g/cm3	0,92-0,94	0,89-0,91	0,85-0,90
Melting point, ºC	165	135	135
At 20 ºC, the solubility in hydrocarbons	None	Partially	High
Bend resistance	High	Partially	Very low

Semicrystalline PP is a thermoplastic material containing both crystalline and amorphous phases. The relative amount of each phase depends on structural and stereochemical characteristics of the polymer chains and the conditions under which the resin is converted the final products such as fibers, films and various other geometric shapes during fabrication by extrusion, thermoforming or molding [27].

Many identical small reactive molecules lines up in a large long-chain molecules, or macromolecule. Depending on the polymerization process, fibers, e.g. polyamide 6 (PA6), acrylic (PAN), polyvinylchloride (CFL) and polypropylene (PP) fibers are produced [28]. The primary materials are synthesized by polymerization, polycondensation and polyaddition must be processed so that they can be formed into fibers. To do this, they are dissolved into a liquid or heated to transform them into syrup like, viscous mass. The resulting spinnable substance is called a polymer [28]. A polymeric fiber is a polymer whose chains are stretched out straight (or close to straight) and lined up next to each other, all along the same axis. Polymers arranged in fibers can be spun into threads and used as textiles. The clothes you're wearing are made out of polymeric fibers, so is carpet and rope [29].

Polypropylene has excellent and desirable physical, mechanical, and thermal properties when used in room-temperature applications. It is relatively stiff and has a high melting point, low density and relatively good resistance to impact. The polypropylene chemical formula is given as $-\!\!\left[CH_2-\underset{CH_3}{\underset{|}{CH}}\right]\!\!-_n$ [29]. Polypropylene is one of those rather versatile polymers. It serves double duty, both as a plastic and as a fiber. As a fiber, polypropylene is used to make indoor-outdoor carpeting, the kind that you always find around swimming pools and miniature golf courses. It works well for outdoor carpet because it is easy to make colored polypropylene, and because polypropylene doesn't absorb water, like polyamide does absorb water [29].

In BCF melt spinning yarn, the polypropylene raw-material produced in the governments petrochemical industries. So the technologically developed countries produced the polypropylene homopolymer chips for fiber (SABIC, Hellenic, NPA, Basell, Lipol, Exxonmobil etc.). SABIC - PP514A polypropylene raw-material are used in this study. The technical and chemical properties of them are given in Chapter 4.

2.3. BCF Working Process

In the world, a few companies produce the BCF carpet yarn machines. The major companies in this field are “Neumag, Rieter, SML, and Özçelik”. Working systems and production lines of all the machine producers are the same. The differences between these companies’ productions stem from the technical apparatus, inventions, energy consumptions and price. The Machines of PP BCF carpet yarn production uses melt spinning system. The main sections of melt spinning system are illustrated in Figure 2.2 and Figure 2.3 respectively. Figure 2.4 shows a photograph of the BFC machine. BCF production line working steps are: Dozing Unit (Polypropylene Chips & Masterbatch) – Extruder (Melting) – Spinning – Cooling Air (Quench) – Spinfinish Oil – Drafting – Texturing – Intermingling – Winding [30].

2.3.1. Process Steps of BCF

2.3.1.1. Raw Material: The raw materials of the yarn are %100 granule chips polypropylene (see in Figure 2.5) and masterbatch monomers. Because of the polymer structure and smooth glass-like surface, polypropylene material can not be dyed after be shaped as yarn. Dye material can not be absorbed by solid PP material and moisture too. Therefore, the PP material is dyed in molten form in the extrusion process step.

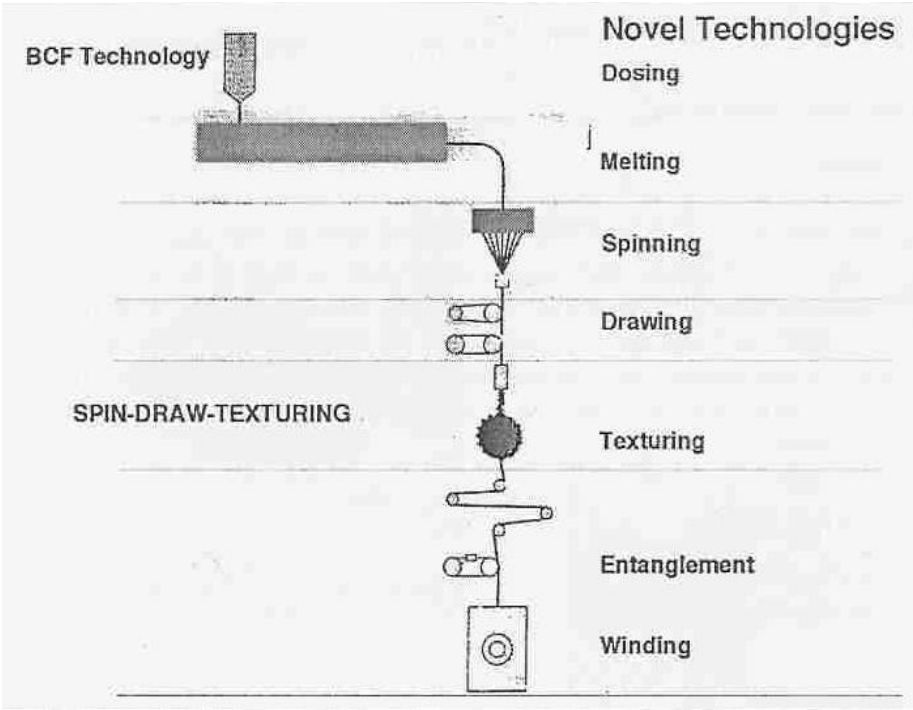


Figure 2.2 The BCF Carpet Yarn Production Line [4]

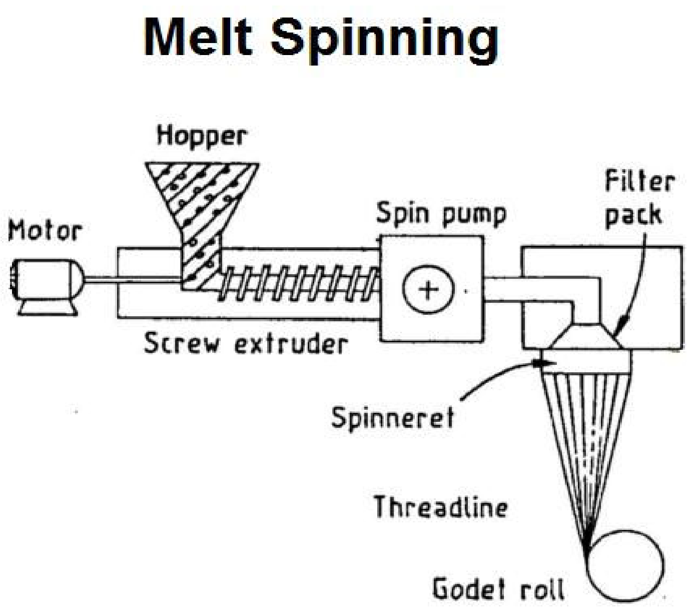


Figure 2.3 Melt spinning process [29]

Figure 2.4 The SML BCF production machine [31].

Figure 2.5 %100 Polypropylene and masterbatch chips

2.3.1.2. Dosing Unit: PP chips and masterbatch monomers are mixed in the calculated percentages by gravimetric measurement in the dosing unit as shown in Figure 2.6. PP and masterbacth are sucked by a vacuum pump from the storage tanks and put in to the dosing buckets. The dosing machine mixes the PP chips and masterbatch in the given ratio by means of screws. The percentage calculated by dosing machine is adjusted properly to the selected color as required in the recipe. After dosing step, mixer buckets fill the extruder mouth with the prepared mix.

2.3.1.3. Extruder: The mix, composed of PP chips and masterbatch, coming from dosing unit enters to the extruder. The mix is heated step by step. When the material is molten by the extruder, the granule form of the material turns into the liquid form. The screw in the extruder transports the molten material to the spinnerets as shown in Figure 2.7.

2.3.1.4. Spinning Pumps and Spinnerets: The molten material is pumped to the spinneret pores by means of metering pumps (spinning pumps). The spinneret pores are also heated as shown in Figure 2.8 and Figure 2.9. The molten material is pushed to the spinneret holes in order to turn molten material into the monofilament form by effect of pressure. The molten materials are flowed inside the spinneret package by means of 50 bar pressure. After that, the polymer passes through the spinneret holes and forms as filaments. The spinnerets which are generally used for BCF have 100 holes – 200 holes. That means that the yarn will have 100 filaments – 200 filaments. The holes of spinnerets differ in shape. The shape of holes depends on the raw-material and usage area of the produced yarn in the industry. The cross section and structural type of the fiber are achieved by the shape of spinneret holes as shown in Figure 2.10.

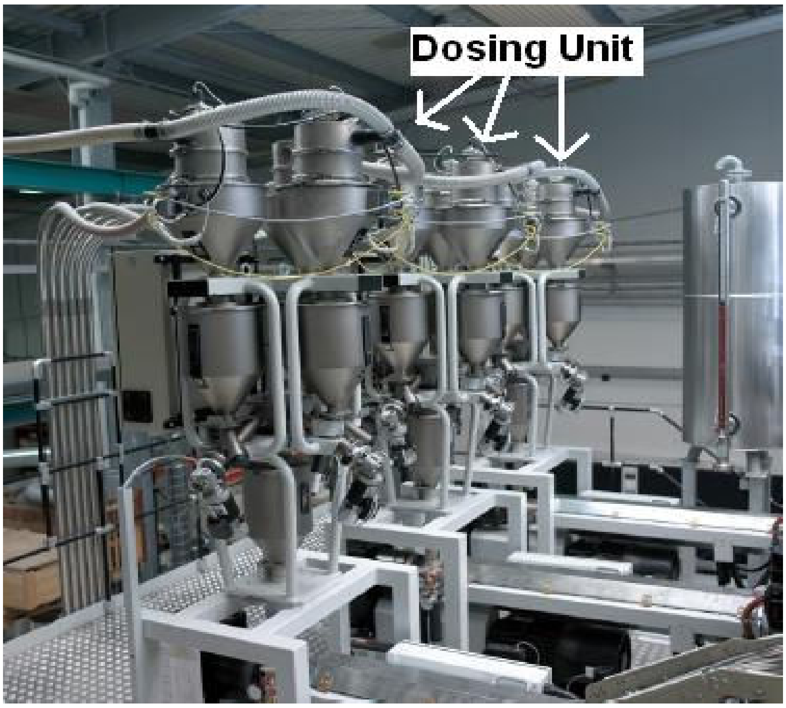


Figure 2.6 SML machine dosing unit [31]

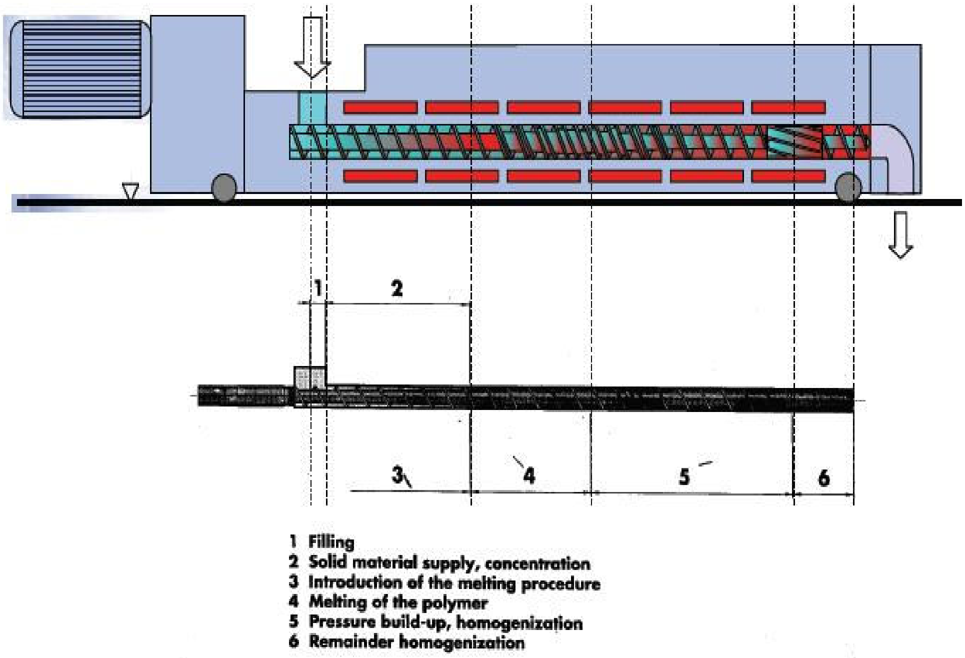
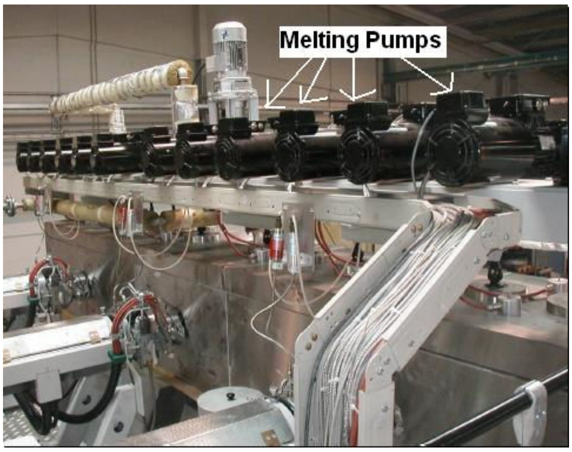


Figure 2.7 Extruder model [32,33]



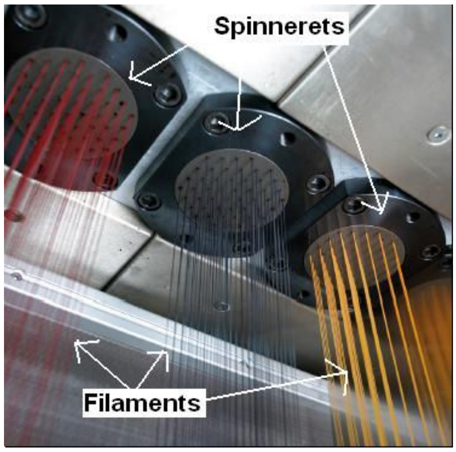


Figure 2.8 Spinning pump [31]

Figure 2.9 Spinnerets[31]

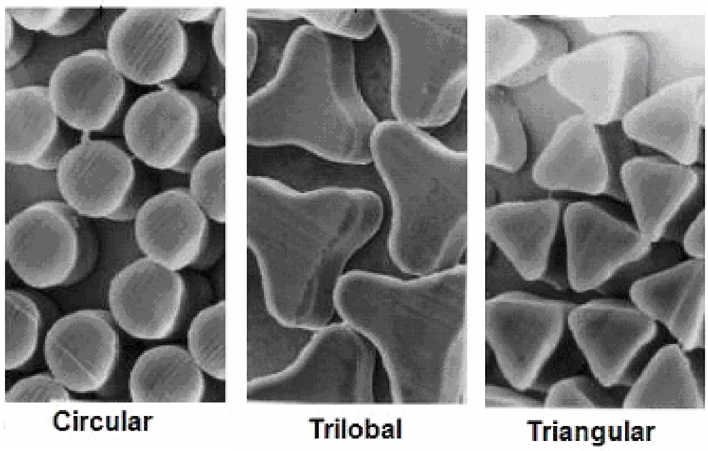


Figure 2.10 The Cross sectional shapes of the filaments [29]

2.3.1.5. Cooling (Quench): The multifilament flowed from the spinneret is cooled by means of cooled air. The filaments are moved perpendicular to the quench of the machine. The cold air is passed among the intervals of filaments. Thereafter, the temperatures of the filaments are cooled down. By this cooling process, the molten polymer is crystallized and converted to solid filament form as shown in Figure 2.11 [33]. In the cooling step, the air temperature is about 12-16 ºC, and the air flow rate is 0,6 m/s.

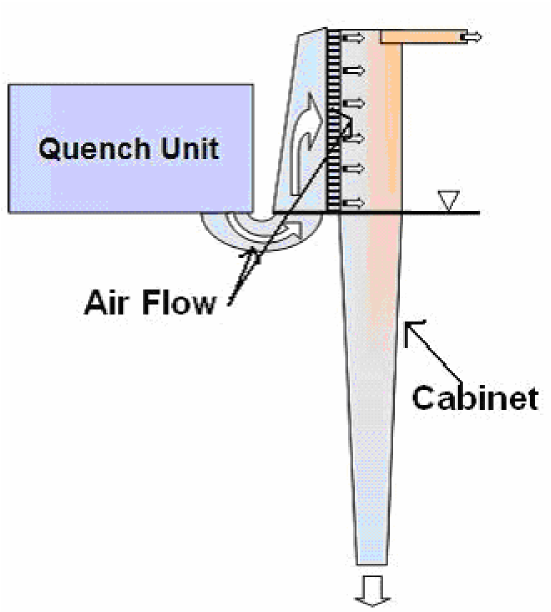


Figure 2.11 Cooling unit (Quench unit) [33]

2.3.1.6. Spin-finish Oiling: The multifilaments which are solidified by cooling process are passed through the nozzles to take the required oil. In the drawing process, the filaments are passed through various drawing and guiding elements. The spin finish oil is required to give correspondingly good sliding characteristics so that the filaments slide easily over guiding elements and while preventing slip at the galette rolls [34]. The spin finish gives the thermal stable and antistatic properties to the yarn as shown in Figure 2.12.

2.3.1.7. Drafting: The multifilaments are stretched between the heated godets to obtain 3 % drafting rate by the drafting rollers. The different speeds of roller Duo1 and roller Duo2 and heat provide to orient the yarn and to lengthen filaments as shown in Figure 2.13. The godets are heated to approximately 100 ºC – 150 ºC to make it easy for drafting PP material on the machine. Duo1 are turned 3 times slower than Duo2. Thus, yarn is lengthened and its strength is increased. The speeds of Duo2 drafting rollers can be reached to 3500 m/min.

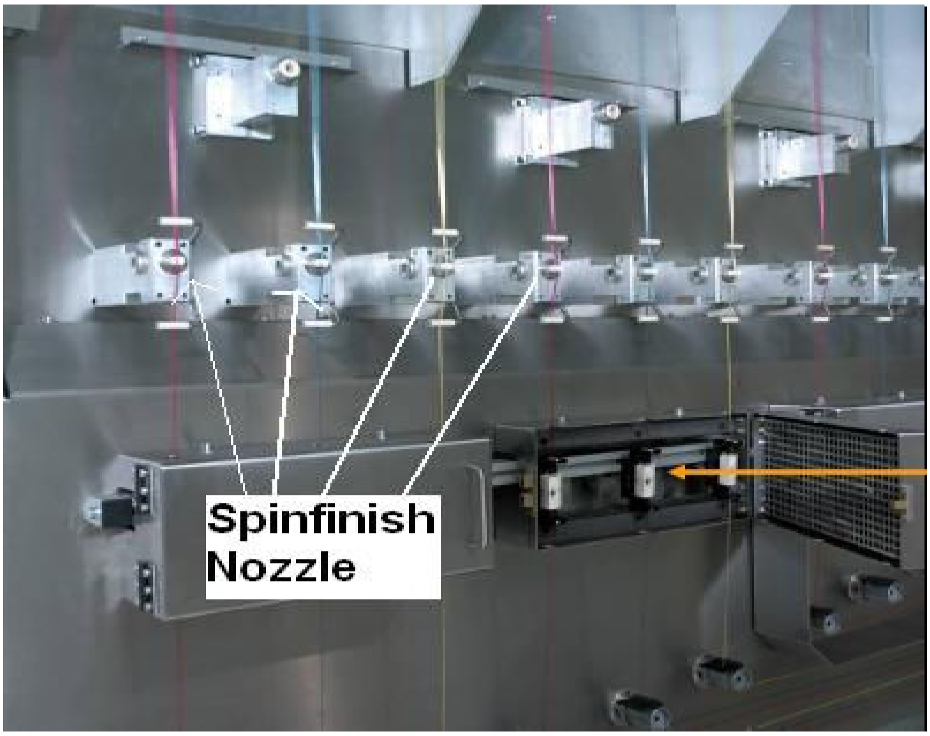


Figure 2.12 Spin-finish process [31]

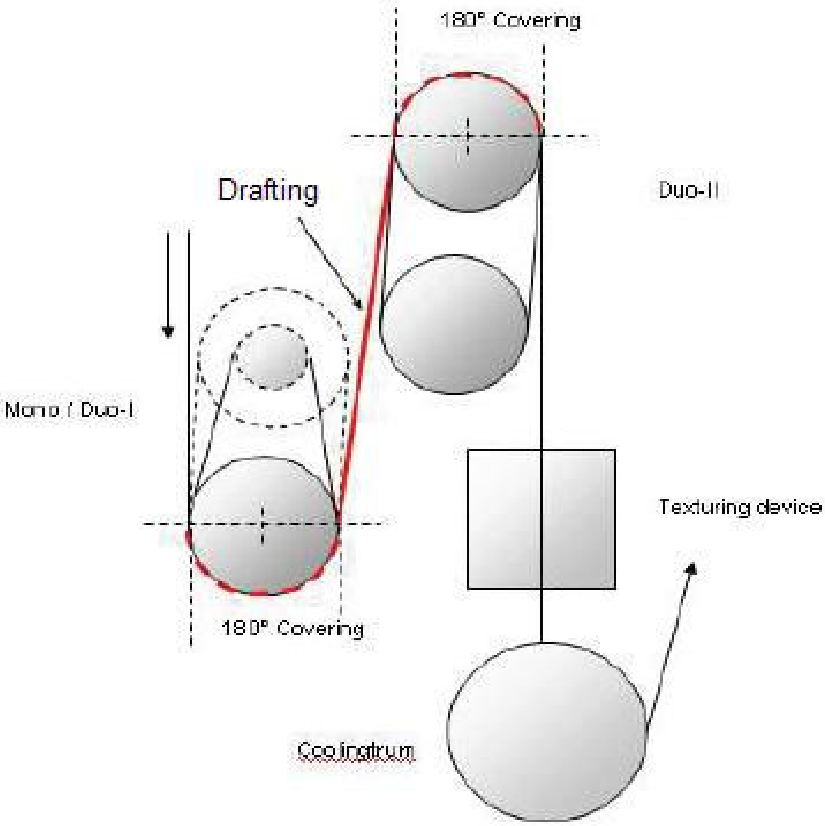


Figure 2.13 Drafting rollers [33]

2.3.1.8. Texturing and Intermingling: The metal plate where the multifilament are bulked by means of high air pressure and high air temperature is called as "texturing device", shown in Figure 2.14 and Figure 2.15. High air pressure is used to hold filaments together to obtain intermingled form. The drafted yarn is needed to be in a bulky form for being used in carpets. Therefore, in the same system filaments are moved inside the hot air-jet texturing device. In the hot air-jet texturing device pressure and heated air are crimped the filaments. Afterwards, the crimped filaments are rolled on a cooling drum to be fixed and to make a stable texturing effect on the yarn. If the yarn is directly used in the carpet, the filaments must be passed through the intermingling step. A high air pressure is applied onto the filaments in the intermingling to stick filaments together. The texturing methods are elaborately explained in Chapter 3.

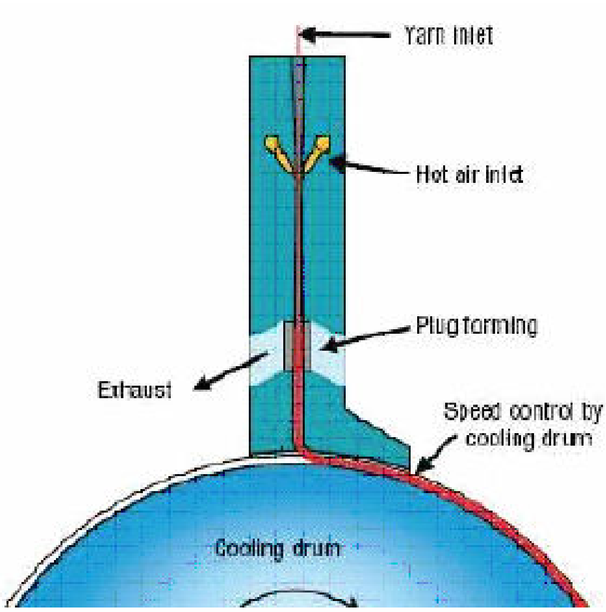


Figure 2.14 Rieter texturing device [33]

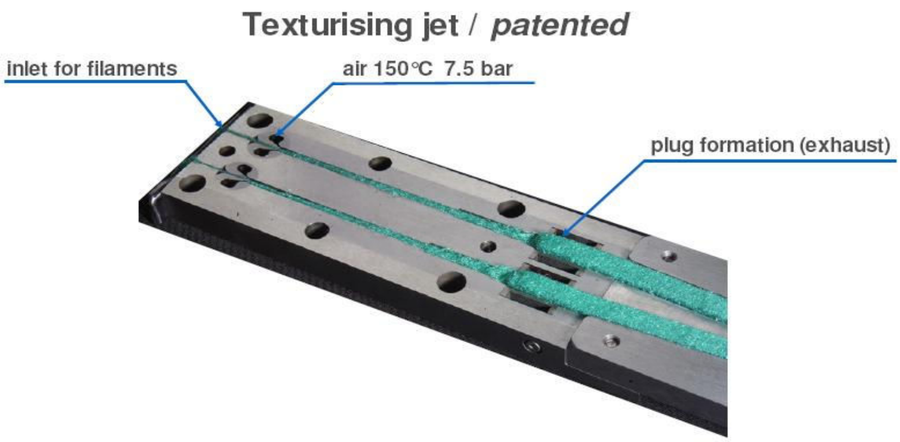


Figure 2.15 SML texturing device [31]

2.3.1.9. Winding: After the intermingled process, yarns are wound onto cartoon bobbins by given tension, as seen in Figure 2.16.

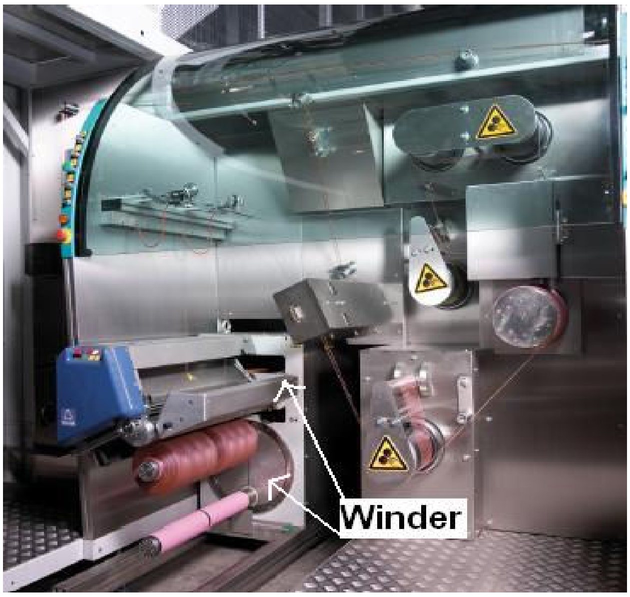


Figure 2.16 The winding and drafting units of SML BCF machine [31]

2.4. BCF Market

The world capacity of BCF yarn production plant up to 2005 year is shown in Figure 2.18. The most PP BCF plant is located in Türkiye. Türkiye is the biggest BCF and Carpet manufacturer in the world. Approximately Gaziantep/Türkiye produces 1000 tons/day PP BCF yarn in a day. This high production capacity gives a important role in the carpet industry for Türkiye [33]. In 2005, world BCF production capacity is approximately 3000 tons/day.

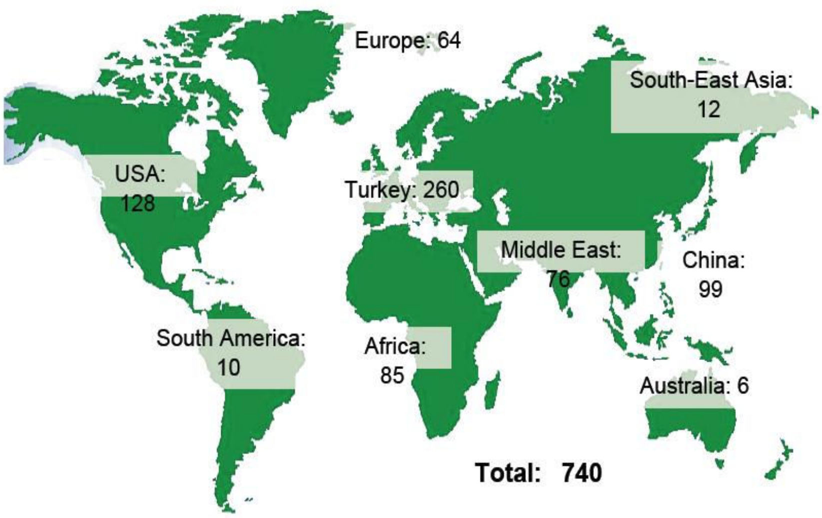


Figure 2.17 Capacity of BCF Plant in the world [33].

CHAPTER 3

TEXTURING METHODS

3.1. Introduction

In general, meaning texturing is a technique by which closely packed parallel arrangements of continuous synthetic filaments are changed into more open voluminous structures to extend the use of manufactured fibers into varied fabric effects [1,35]. In texturing process, the compact structure of continuous filament yarn is modified to give texture without cutting or breaking the filaments. The application of durable crimps, coils, loops, or other fine distortions extends the length of the filaments.

Texturing is mostly applied on 100 % PP carpet yarns (Bulk Continuous Filament yarn). The bulkiness of the yarn is achieved by the texturing process. In Figure 3.1 and Figure 3.2, differences between the textured and non-textured filaments are shown, so the textured filament yarns are bulkier than the non-textured yarns.

Fig 3.1 Flat 100 % PP Yarn

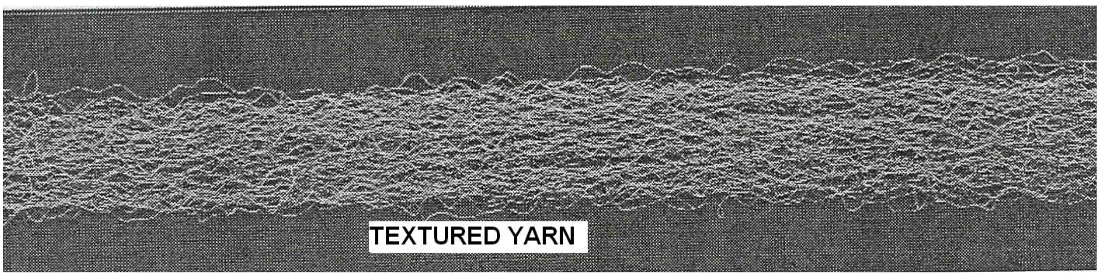


Fig 3.2 Textured 100 % PP Yarn

Bulk formation on synthetic fibers is required in textile industry. Accordingly, different methods are developed to bulk the yarn in the technology of synthetic yarn texturing. In the literature, there are different types of synthetic filament texturing methods as the following [1,2,35]:

- False-twist Texturing Technology
- Air-jet Texturing Technology
- Stuffer Box Technology
- Knit-de-knit Technology
- Gear Crimped technology
- Knife Edge Method
- Bi-Component Technology

As a new method "Self Crimped Filament Yarn Spinning" process is currently being developed.

3.2. False-Twist Texturing Technology

False-twist texturing process can be examined in Figure 3.3. The yarn is taken from the supply package and fed at controlled tension through the heating unit (200-230°C), through a false-twist spindle or over a friction surface that is typically a stack of rotating discs called an aggregate, through a set of take-up rolls, and onto a take-up package. The twist is set into the yarn by the action of the heater tube and subsequently is removed above the spindle or aggregate resulting in a group of filaments with the potential to form helical springs. Much higher processing speeds can be achieved with friction false twisting than with conventional spindle false twisting. Both stretch and bulked yarns can be produced by either process [35].

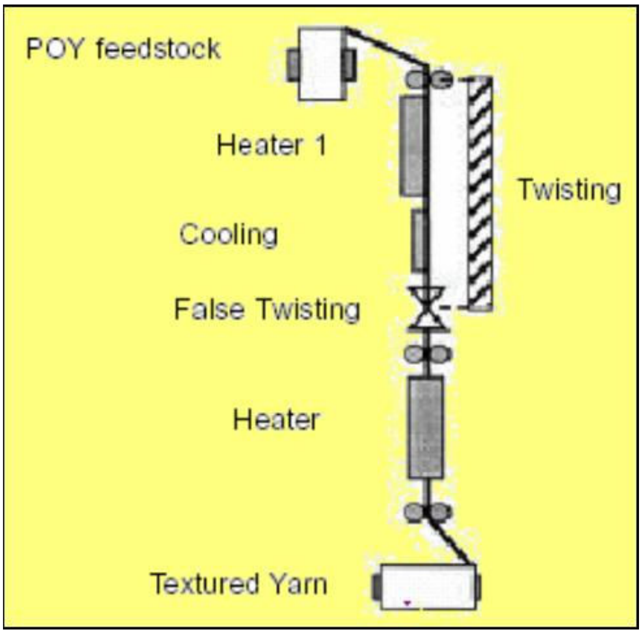


Fig 3.3 False-twist texturing process

In the friction false-twist texturing (Figure 3.4), POY (partially oriented yarns) are fed into machines that put twist into the yarns by using friction surfaces rather than false-twisters or spindles. Shaft 1 is the input feeding device for the POY. From here the yarn is fed to the shaft 2. When POY is fed into the machine, the yarn has to be drawn. The speed of the shaft 2 is always higher by the factor of the necessary draw ratio for the particular yarn and process. The yarn is simultaneously twisted and drawn. The twisting is done with a friction device, such as a set of rotating friction disks. But there are other devices. After the shaft 1 there is a yarn heater, which heats the yarn to a temperature where it can be thermo-set. Adjoining the heater is a cooling plate, which must cool the yarn to a substantially lower temperature in order to permanently thermo-set the twist. As the yarn is released from the shaft 2, we observe how each single filament is trying to assume the three dimensional helix formations it was set in. The result is a voluminous bulked stretch yarn [35,36].

The friction-type false-twist mechanisms present considerable advantages over the rotor-type mechanisms. Their design is simpler and the number of turns inserted into the yarn per unit of time reaches about 5 m/min. These mechanisms do not employ complicated and costly bearings. New friction-type false-twist mechanisms ensure textured yarn of the same quality as those produced in rotor-type mechanisms. The friction-type twisting mechanisms may be classified into mechanisms with an interior friction surface (bushings, rings) and mechanisms with an exterior friction surface (disks, spherical surfaces).

Only synthetic filament yarns can be false twist textured because of their thermoplastic properties.

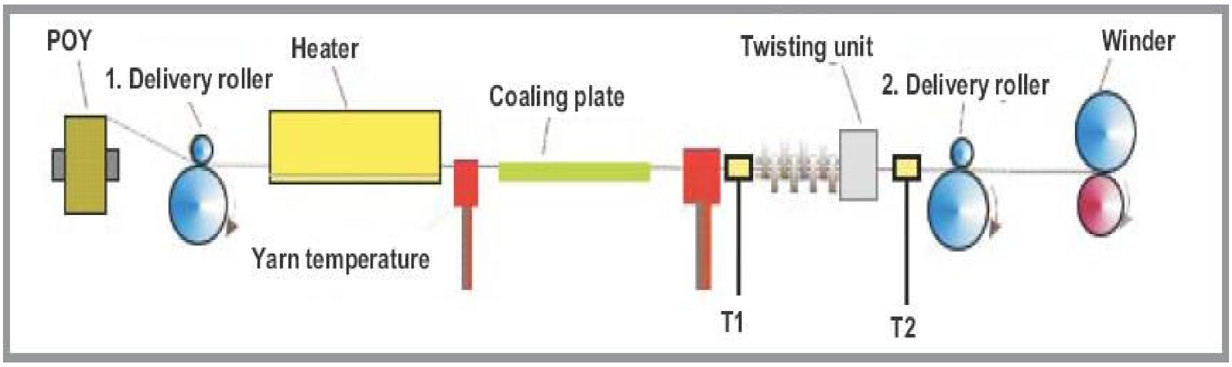
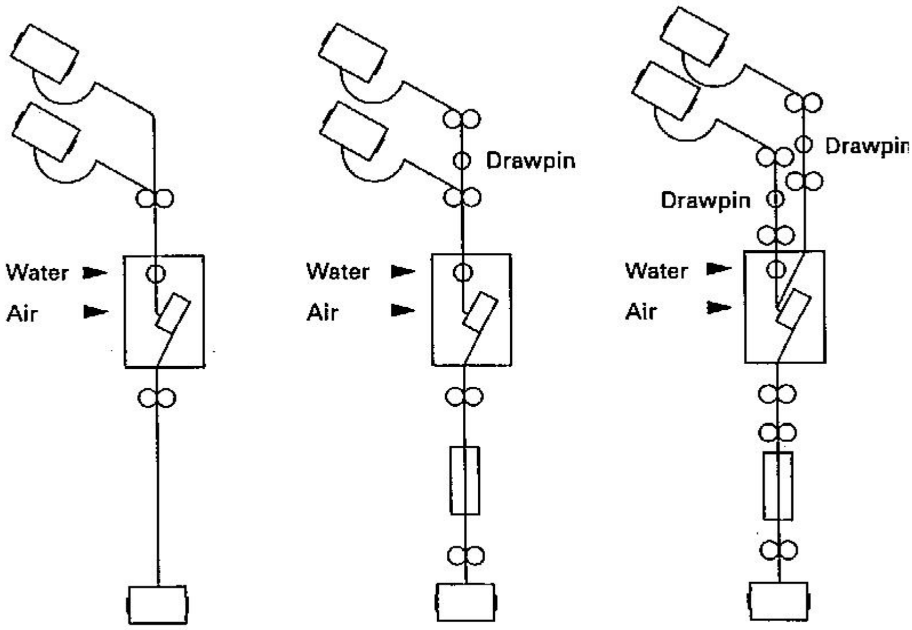


Fig 3.4 Schematic of the false-twist friction texturing process [37]

3.3. Air-Jet Texturing Technology

Air-jet textured yarns are produced generally from the thermoplastic filament yarns as; Polyester, Polyamide and Polypropylene filament yarns. And also air-jet textured yarns are produced from the other materials as; cellulose, rayon, acetate and non organic filament yarn using a turbulent fluid, which is usually, compressed air. Loops are formed on the surface of the filament yarn, giving it a voluminous character. In air-jet texturing, very wide range of yarns that can be produced and by the fact that each machine position can be set up to produce a different yarn [26,35].

The first Air-jet texturing processes patent is announced in 1950, and then the air-jet process is grown up and developed today. The production capacity is increased at 10 m/min up to 800 m/min, but the developments of the studies are already continuous. The high consumption of air pressure and energy is slowing down the progress of air-jet texturing. But now a day, the dense academic and industrial studies reached the 800-900 m/min production speeds [26].



Air-jet texturing processes – single, parallel and core-effect (left to right).

Figure 3.5 The Schematic of Air-Jet Texturing Processes [35]

In this method of texturing, yarn is led through the turbulent region of an air jet at a rate faster than it is drawn off on the far side of the jet. In the jet, the yarn structure is opened, loops are formed, and the structure is closed again. Some loops are locked inside and others are locked on the surface of the yarn [38].

The main schematically parts of air-jet texturing shown in Figure 3.5. Process includes that, the feeding yarn speed feds the yarn faster than the exit of the yarn. So the feeding yarns feds immoderate the air-jet inside. This feeding yarns fed from the feeding cylinders, which are turns slower than the purchase cylinders. This immoderate yarn passes inside the jet and by the help of the air pressure repulses the yarns exits from the jet. The effect of the air turbulence inside the jet is textured the yarn. The yarn is textured between of the two shafts. The texturing jet is housed in a sound-proof box, which also contains a device for wetting the yarn before it enters the jet [26,35].

The air-jet texturing process has three types (Figure 3.5);

- Single Texture
- Parallel Texture
- Core-Effect Texture

The investigations of the air-jet texturing yarns are starting with the Wray's studies. Then "Du pont" company working on the "Taslan" air-jet yarns properties [26]. The air-jets developed for the following steps.

1- The beginnings and the "wrong beginning" of Taslan IX jet.
2- Taslan X and XI developments
3- The future developments of Taslan jets (Taslan XIV and Taslan V) and the other companies interest the air-jets.
4- Taslan XX , Cylindrical type jets and Heberlein (Hema Jets) developed.
5- After DuPont developed phase [26].

3.4. Hot Air-Jet Texturing Technology

The preparatory works are very similar to ordinary textured yarns. Air-jet texturing is the compression of the filaments and the formation into a yarn plug whilst hot which causes the properties of bulk to be imparted to the yarn. Since the yarn is hot, the deformation of the individual filaments results in the well-known, three-dimensional yarn crimp, which is the characteristic of a BCF yarn [35].

The process speeds of BCF yarn production can be reached at 6,000 m/min levels 26]. The working principle of Hot Air-Jet is illustrated in Figure 3.6, when the hot fluid air enters the jets its high pressure (7-8 Bar) causes it to enter with a high velocity and degree (135ºC -150ºC) of turbulence and to carry the filaments forward. However, the design of the jets enables the fluid to expand as it passes through the jet and therefore to slow down. This retards the forward movement of the yarn causes a plug to form [35].

Modern jets must have an opening mechanism; other wise the threading would be impossible in this yielding, a continuous process in Figure 3.7 [39]. Furthermore the jets are usually supplied for two or three thread-lines. This is quite a challenge and hot-fluid jet is a good example of modern precision engineering. It is also necessary to use corrosion-resistant and hardwearing materials [35]. Generally the hot air is preferred.

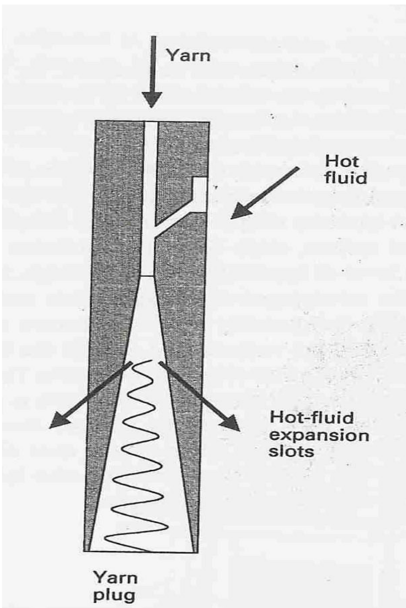


Figure 3.6 Hot Air-jet texturing systems

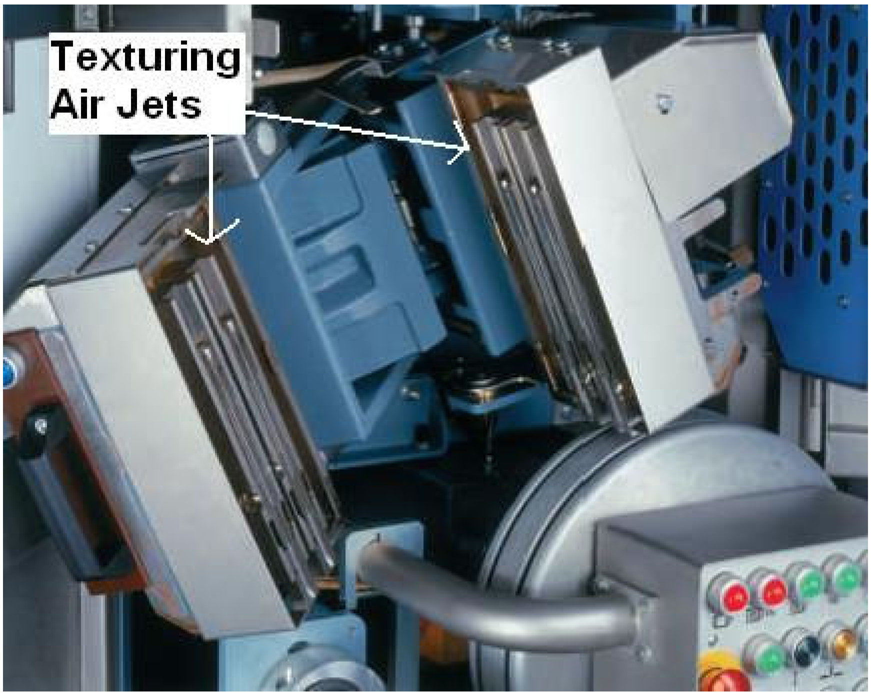


Figure 3.7 The Rieter BCF machine texture apparatus [39].

In contrast air-texturing jets, it is not the turbulence which causes the bulk formation but rather the constraint on the movement of the hot yarn during its passage through the jet. However, the bulk is not permanent unless it is retained whilst the yarn is cooled. The physical shape of the cooling device varies but most often it consists of a slow-moving, cooled surface on to which the hot yarn plug is impinged [26,35].

The cooling drum in Figure 3.8 consists of a rotating drum with a mesh surface through which air is drawn. The ambient air passes through the bulked yarn, which is still in the form of a plug through less compressed, and this passage of air provides the required cooling. It is the combination of the flow of fluid in the jet, its regulated temperature, flow and pressure and the action of this cooling drum that determines the uniformity of texture in the yarn. A monomer extraction device may also be provided for fume removal [35].

Machine manufacturers design and patent their own texturing systems on technologically advanced BCF machines. Most of the manufacturers prefer hot air-jet texturing systems because of the higher speed of the production, higher demand of crimp on the yarn and lower maintenance cost. 20 % - 25 % crimp on the yarn can be obtained from contemporary hot air-jet texturing devices.

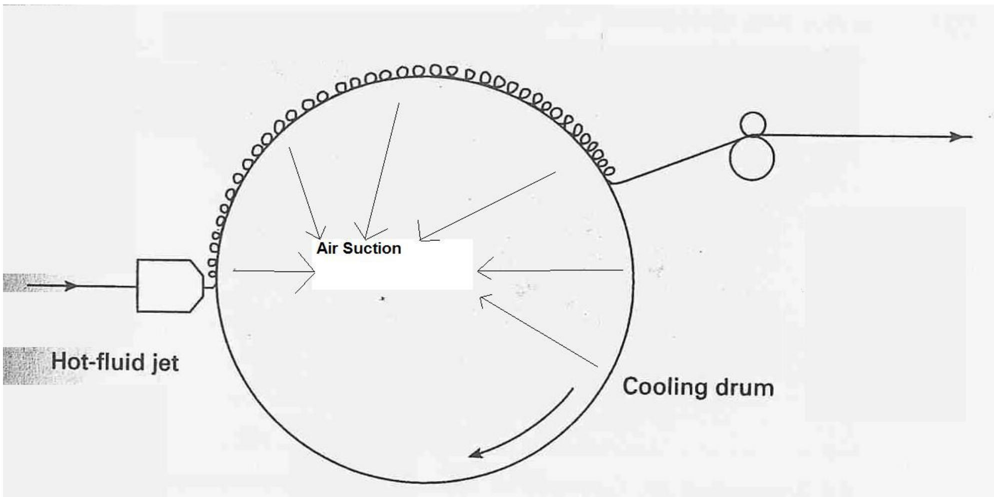


Figure 3.8 The cooling drum of BCF plant [35]

3.5. Stuffer Box Technology

In this method; the crimping unit consists of two feed rolls and a brass tube stuffer box. By compressing the yarn into the heated stuffer box, the individual filaments are caused to fold or bend at a sharp angle, while being simultaneously set by a heating device in Figure 3.9 [33]. Modern crimping machines, as a rule, effect stretching together with texturing which is carried out at high speeds. Crimping machines used for compressing the yarns with air, steam or liquid allow processing of stretched or un-stretched yarns at speeds up to 2000 m/min [36,38].

One of the disadvantages of available crimping machines is that each yarn is textured separately. This reduces machine efficiency and requires larger industrial areas for machine installation. Some machine-building firms have endeavored to construct machines for texturing of multiple yarns. One of these machines was designed by Spunize of the USA. The texturing device of this machine allows up to 60 yarns to be processed simultaneously with a speed up to 800 m/min. As the yarns come out of the stuffer box, they are separated and wound on take-up packages or loosely laid in cans [35,36,38].

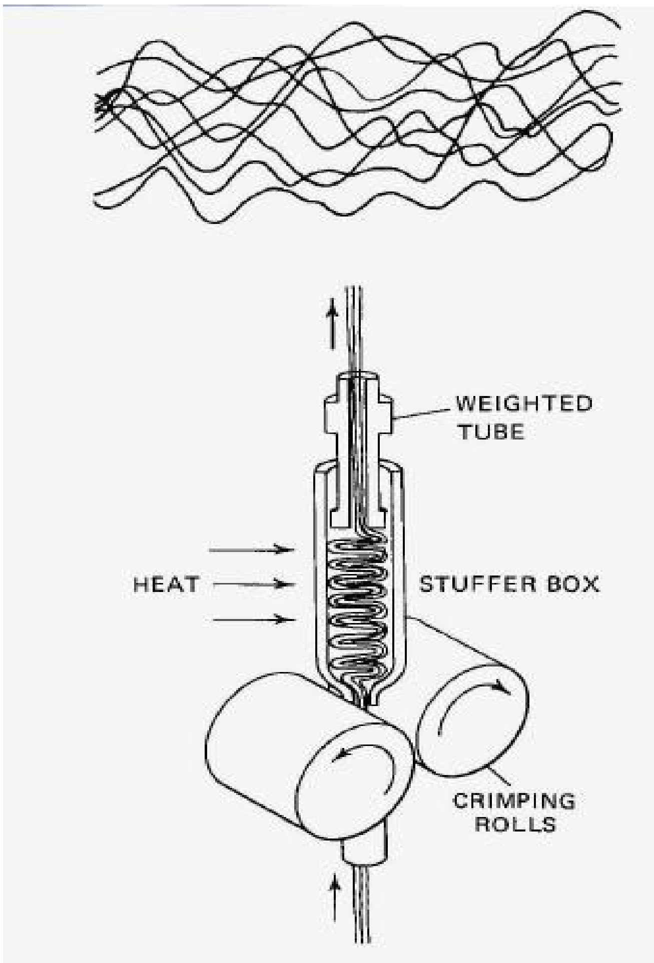


Figure 3.9 Stuffer box texturing technology [33]

This method has proved especially efficient for manufacturing low-count textured yarns for the carpet industry and stuffer-box textured yarns are used in the home textiles.

3.6. Knit-De-Knit Technology

This method is can be seen in Figure 3.10, The stretched yarn coming from supply package runs around guiding rods, enters head of the knitting machine and the obtained fabric is subjected to thermal stabilization in box after which it is wound in balls or packed in boxes. The stabilized fabric is unraveled on a high speed machine. The balls of fabric are placed in a box and the yarn end is drawn from the fabric by delivery cylinders and further wound onto take-up package. Usually the machine is provided with an auxiliary device to make the yarn more bulky and fluffy [36,38].

The production of crimped yarn by this method has proved highly efficient and high-speed circular knitters are developed for this aim. For example, special machines are running at a speed of 450-900 m/min (depending on the count of processed yarn), the knitting speed being in the range of 480-1000 m/min.

One of the advantages of the knit-de knit method of crimped yarn manufacturing is the possibility of varying the yarn extensibility, crispiness, etc. by using various knitting heads, different depth of sinking, needles in different shape and various initial yarns and these yarns exhibit highly uniform properties.

3.7. Gear Crimped Technology

This texturing process can be seen in Figure 3.11, the filament yarn passes between the teeth of two heated gears that mesh and thus gives the yarn the shape of the gear teeth– a saw-tooth crimp. The bends are angular in contrast to the rounded waves and bends of natural crimp [36,38].

The initial yarn coming from supply package passes tension arrangement, guiding hook, feed couple, and damage to runs around the hot braking stud and is subjected to texturing between cold rotating gears. Further, the twisted yarn passes through the eyelet of antiballoner and is wound onto take-up package. To avoid filaments, a clearance is set between the gears, which depend on the thickness of processed filament yarns. Texturing gears are usually mounted in draw twisters instead of the delivery arrangement. Thermoplastic fibers are gear crimped [35,36,38].

Figure 3.10 The Knit-de knit yarn [36]

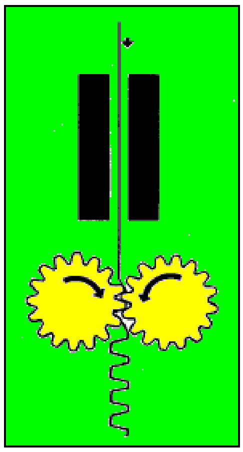


Figure 3.11 Gear crimping texturing process [38]

3.8. Knife Edge Method

The essence of this method is that the yarn when drawn over the edge of a steel plate or knife is subjected to a strong deformation. Here, the yarn side contacting the knife edge is compressed while its opposite side is stretched. During the yarn continuous movement, the point of its bending is constantly displaced. With its compressed side the yarn tends to turn to the exterior and the exterior side of the yarn comes in contact with the knife edge. As a result, some portions of the yarn length are continuously passing from stretched to a compressed state. As soon as the yarn leaves the knife edge, it is rapidly cooled and the yarn configuration obtained by deformation is set, so that individual filaments acquire the shape of a coiled spring with different direction of their coils shown in Figure 3.12 [35,36,38].

Consequently, the bending of yarns on the knife edge is the main factor determining their crimpiness. This factor is called the bending effect. In addition to the crimpiness, obtained on bending, the yarns are given crimp due to the reorientation of molecules, caused by the friction of yarns bent over the knife edge (friction effect) [35].

The yarn side contacting the knife edge becomes flat. The macromolecules in this plane tend to occupy a position which is parallel to the rubbing surface, i.e. perpendicular to the yarn axis. This orientation of macromolecules makes the yarn shorter from the side of its contact with the knife edge and imparts a complementary crimpiness to yarn. The crimpiness potentiality of yarn obtained by bending it over a sharp edge depends on many factors, including the manner of threading, the heating temperature, the speed and the tension of yarn and others [35,38].

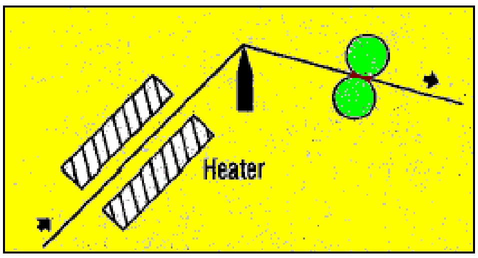


Figure 3.12 Knife Edge Method [38]

This method, advisable for processing any thermoplastic yarns, is especially efficient for producing crimped polyamide yarns. The yarn may be processed by preliminary heating it on contact with a heated plate followed by subsequent drawing over a cold knife edge or by drawing a cold yarn over a heated edge.

For producing a stabilized crimped yarn it is subjected to double heating: before bringing it in contact with the knife edge and during or after its drawing over the knife edge. The polyamide filament yarns are processed at temperatures in the range of 180 to 190°C, depending on the thickness and number of filaments. Monofilament yarns are processed at lower temperatures (150-160°C). The tension must be maintained in the range of 10% of the breaking load. The speed of yarn motion is up to 125 m/min.

3.9. Bi-Component Technology

Another way of introducing crimp is to produce bi-component fibers. This method is used on cellulose fibers in 1950. However, the advantages of the method ensure its revivals. In order to produce crimp, bi-component fibers, the usual method is to feed two streams with different composition to two sides of the spinnerets shown in Figure 3.13. Subsequent heat treatment causes differential shrinkage, which forces the fibers to bend. Since there can be no net twist, the filaments form alternating helices with reversals between [4,26,35]. A method that is much used for staple fiber yarns, but in principle, could be applied to continuous filament yarns is to combine mixed-shrinkage fibers [35].

There are three production types of bi-component fiber are: Side by side as seen in Figure 3.14, one within the other and Island in the Sea [26].

In bi-component method, the different characteristic of two materials mixed on the two sides of the yarn cross section, and different material chemical characteristic shrinkage occurs a crimp on the yarn. One side has more shrinkage than the others and bending the filaments.

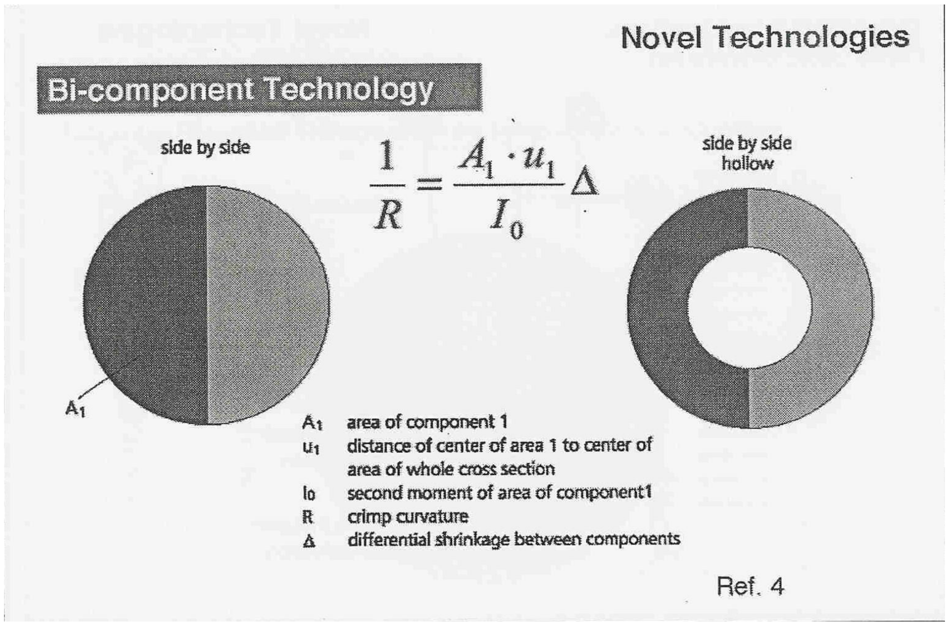


Figure 3.13 Bi-component technology fiber cross-sections [4]

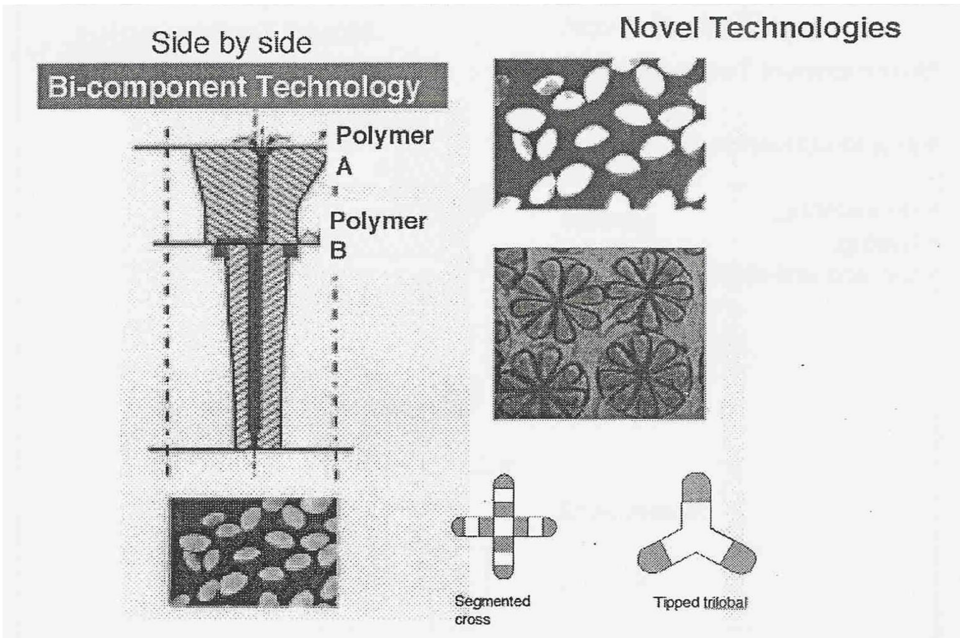


Figure 3.14 The schematic of bi-component Polymer techniques of side by side [4]

3.10. Theory of Self-Crimp Filament Yarn Spinning

In the self crimp FYS, the polypropylene (PP) filament yarns are affected by local-cooling and as a result the cross section of the fibers gets molecular orientation. Theoretically, this situation causes to create crimp effect on the yarn as shown in Figure 3.15. Practically, this method is made to analyze the crimp level and physical properties of the yarn.

Theoretically, local cooling unit is touched to the section of the filaments to acquire the self crimp effect on the yarn. When the local cooling plate is touched to hot PP filament, some sections of the filament get cold (it causes the molecular structure deformation as shown in Figure 3.16) and make a curve on the filament. As a result, the crimp is occurred on the yarn. As shown in Figure 3.16, the touching place area temperature T1 is different than the temperature T2. This difference between the temperatures is caused to different shrinkages on the filaments. Accordingly, new dissimilar molecular orientation formations give result to bend the filaments. A crimp effect is obtained on the yarn by this way.

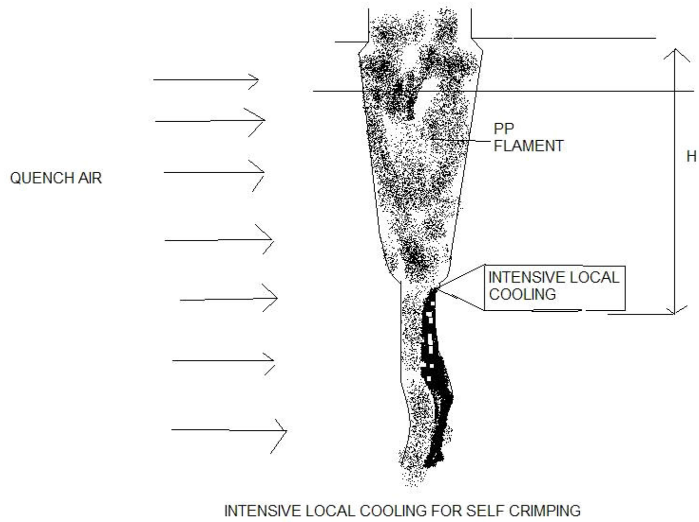


Figure 3.15 The schematic of local cooling system [4]

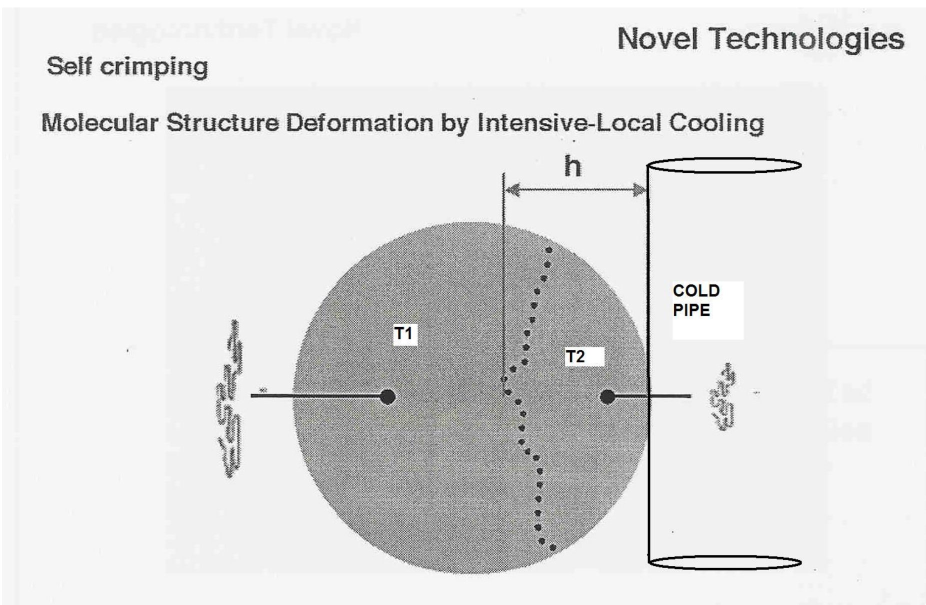


Figure 3.16 The cross section of the self-crimp texture filament

General shape of the texture systems are shown in Figure 3.17 [4].

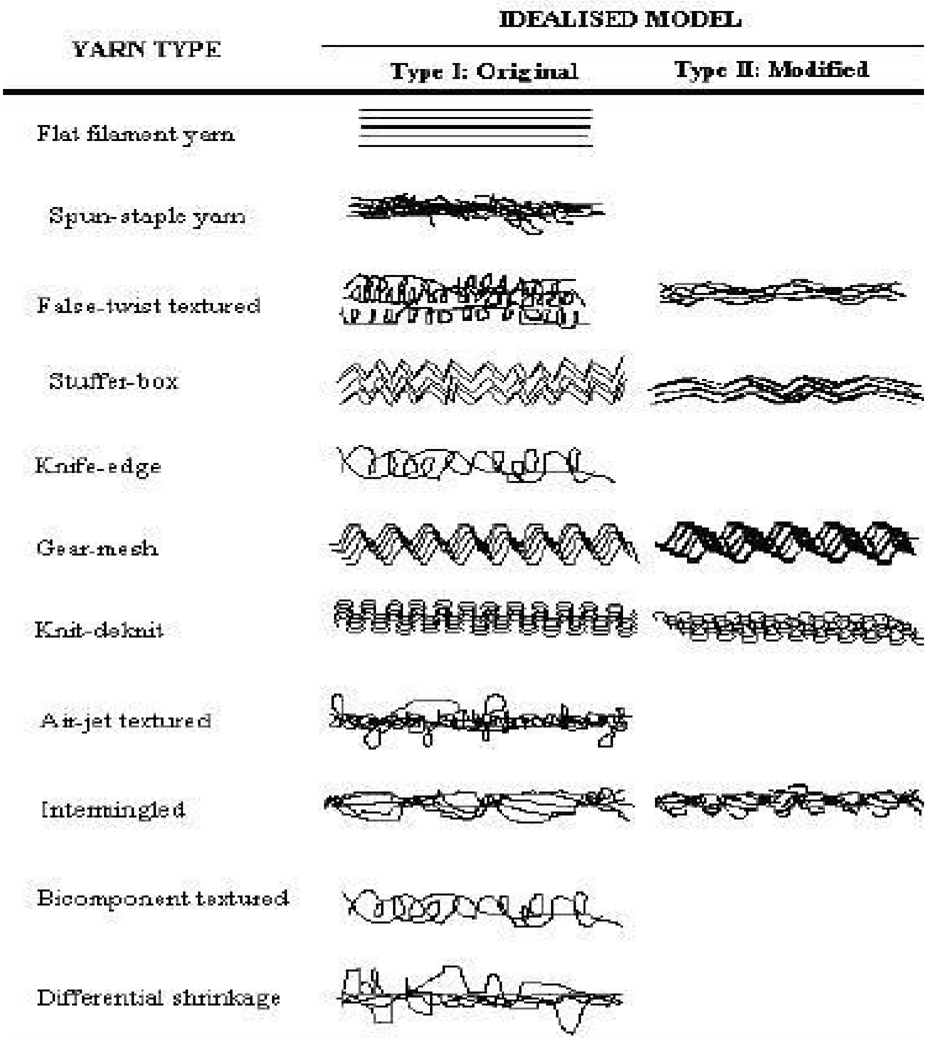


Figure 3.17 Ideal model and shape of texturing systems [33]

CHAPTER 4

MATERIALS AND METHOD

4.1. Introduction

In this study, self crimped FYS process is applied on the BCF spinning machine (shown in Figure 4.1) whose trademark is SML (Starlinger Maschinengesellschaft Lenzing mbH) Company. SML has achieved a name in the international market by tailoring extrusion lines according to customer requirements. Over the last decade, SML has focused on the development of co-extrusion lines for film, sheet and laminates as well as on extrusion spinning lines for multifilament [31]. Firstly, the necessary devices and apparatus for the process of self crimped FYS on the BCF spinning machine are designed and manufactured. After that, the sample yarns for experiment are produced on the machine by changing some process parameters. Finally, the physical properties of the sample yarns are investigated and compared with the references yarns.

In the following sections; materials, method and apparatus, design of the new spinneret, developing the local cooling unit for the self crimped FYS process, and the experimental studies are presented.

Figure 4.1 The BCF Spinning Machine made by SML

4.2. Materials

One of the important materials used in synthetic yarn industry is the polypropylene because polypropylene fibers and yarns are well-known and are widely used in textile and other applications owing to a desirable combination of features. These include low cost, ease of processing, strength, chemical inertness and hydrophobicity. Examples of textile applications for the fibers and yarns include backing fabrics and pile or face yarns for carpets; upholstery fabrics; geotextile fabrics; walk over fabrics; automotive fabrics, such as carpets, trunk liners and kick panels; diaper cover stock; and apparel fabrics.

In this study, the polypropylene called "SABIC-PP 514 A" is used as the main raw material. SABIC (Saudi Basic Industries Corporation) PP 514A is a PP Homopoly (Polypropylene Homopolymer) plastic material. Its technical and chemical properties are given in Table 4.1. It is characterized by high flow and medium molecular weight distribution. It contains a sophisticated anti gas fading stabilization, offering

Table 4.1. Technical and Chemical Properties of the SABIC PP 514A [40]

Properties	Unit (SI)	Values	Test Methods
Polymer properties			
Melt Flow rate (MFR) At 230 ºC and 2,16 kg	g/10 min	24.0	ISO 1133
Density	Kg/m³	905	ISO 1183
Molecular Weight Distribution	-	Medium	SABIC Method
Isotacticity	-	Medium	SABIC Method
Formulation			
Anti block agent	-	No	SABIC Method
Slip Agent	-	No	SABIC Method
Anti static agent	-	No	SABIC Method
Nucleating agent	-	No	SABIC Method
Gas fading stabilized	-	Yes	SABIC Method
Mechanical Properties			
Tensile test			ISO 527
stress at yield	MPa	42	
stress at break	MPa	45	
Stress at break	%	600	
Flexural test			ASTM D 790
Flexural modulus	MPa	1700	
Thermal Properties			
Vicat softening temperature			
At 10 N (VST/A)	C	151	ISO 306/A
At 50 N (VST/B)	C	92	ISO 306/B

consistent spinning, improved melt and UV stability. It is suitable for bulked continuous filament, including tri-color carpet yarns, POY and also for fine denier staple fiber, used for hygienic applications. In addition, the BCF PP material begins to melt about 150 ºC, but the working values are about 215 ºC–250 ºC. Melt flow rate (MFR) is about 24, depends on the raw material generally in BCF yarns 20–25 MFR uses. Its density is about 905 Kg/m^3, and the physical form of the PP is granule form called as "chips" [40].

4.3. Methods and Apparatus

Except for the hot air-jet texturing unit, the self crimped FYS process lines are the same as regular melt spinning system. New devices and apparatus are designed and constructed in spite of the hot air-jet texturing. These are designing a new spinneret and developing a new intensive local cooling apparatus for the quench unit. Those investments are made by Karaveli Tekstil San. ve Tic A.Ş.

The study may be summarized as follows;

i. Designing a new spinneret.

ii. Developing and preparing a local-cooling system to change the molecular orientation on the fiber.

iii. Investigating the effects of the following process parameters on the physical properties of the sample BCF yarns which are crimp, strength, elongation, shrink and Dtex.

   - Position of intensive local cooling (H)
   - Intensive-cooling medium
   - Intensive-cooling temperature
   - Winding speed

iv. Comparing the experimental test results with two references yarns. One of them is the BCF carpet yarn produced on the SML spinning lines having air-jet texturing unit, and the other is continuous filament yarn produced on the same machine having no texturing unit.

The first two parts in the above are presented in the following sections. The last two parts are given in Chapter 5.

4.4. Design of the New Spinneret for Self-Crimp FYS

Spinneret, a metal disc containing numerous minute holes used in manufactured fiber extrusion, is one of the important parts in BCF machine. The melted polymer is forced through the holes to form the fiber filaments. Spinnerets are shaped in a particular way to give the fiber its desired shape for a particular purpose,i.e., trilobal fibers hide soil better than round fibers. Since, most manufactured carpet fibers have a trilobal shape which is intended to obscure the appearance of soil. Only a small amount of light is transmitted though a trilobal fiber resulting in the ability to hide particles trapped on the surface of the fiber. On the other hand, round fibers magnify the surface particles due to the large amount of light transmitted through the fiber. That's why the holes in the spinneret are mostly in trilobal shape as seen in Figure 4.2 used in producing PP carpet yarns.

The spinneret in the BCF machine is present in a spinneret package. The spinneret package consists of spinning package holder, spinneret, support plate, strainer element, melt funnel and sealing shown in Figure 4.3. Two different types of the spinnerets having dissimilar cross-sections are designed and constructed in this study. These studies are presented in detail, in the following sections.

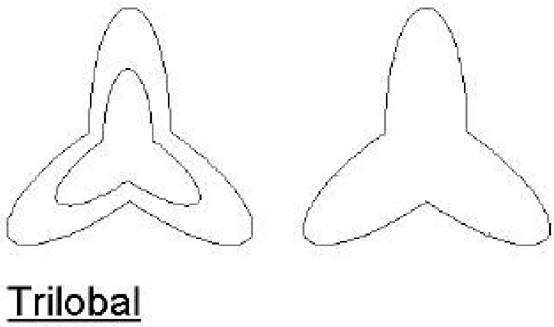
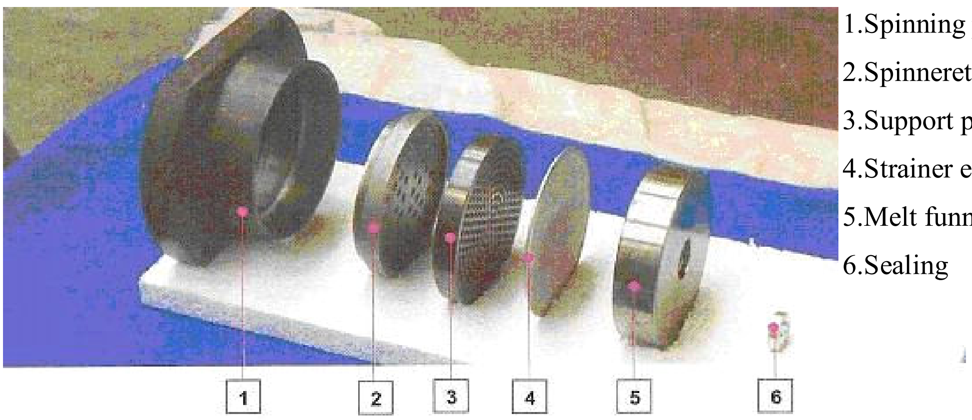


Figure 4.2 Trilobal shape of the spinneret [41]



1.Spinning package holder
2.Spinneret
3.Support plate
4.Strainer element
5.Melt funnel
6.Sealing

Figure 4.3 Components of the spinning package [42]

4.4.1. The first design of the spinneret

In the first design, the original SML BCF machinery spinneret with a trilobal cross section shape as seen in Figure 4.4 is modified. Number of holes in this spinneret is 144. 130 of them are filled and closed with brass metal. The others (14 holes) are empty to be extruded the melted PP passed inside spinneret. These holes in the spinneret are designed at the same horizontal line to apply the self crimped FYS. Each hole produces a filament of yarn. Following photographs (Figure 4.5 and Figure 4.6) show adaptation and preparation of spinnerets, and spinning package to the spare of the melt pump holder. In the experimental studies, the surfaces of the filaments having trilobal cross sections during production do not entirely touch the local cooling unit. That's why the carpet yarn having uniform filaments are not produced.

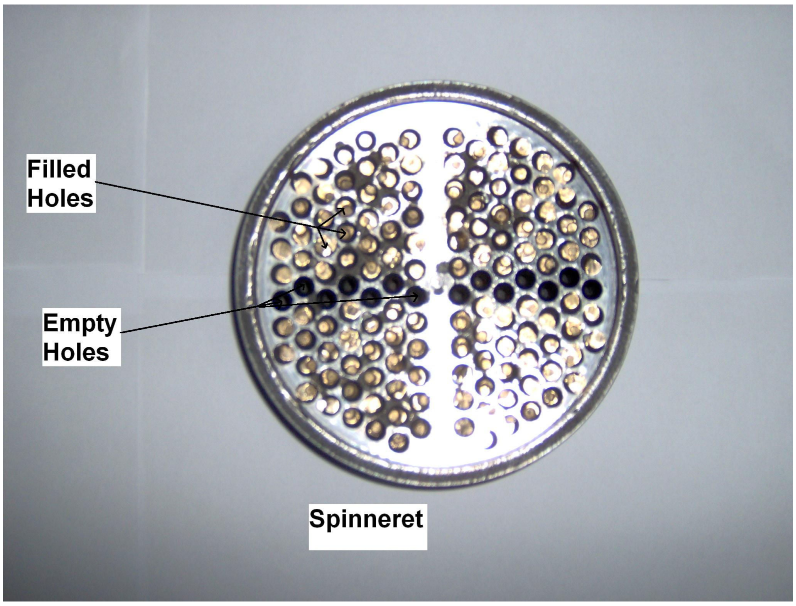


Figure 4.4 Modification of the original SML machinery spinneret (First design)

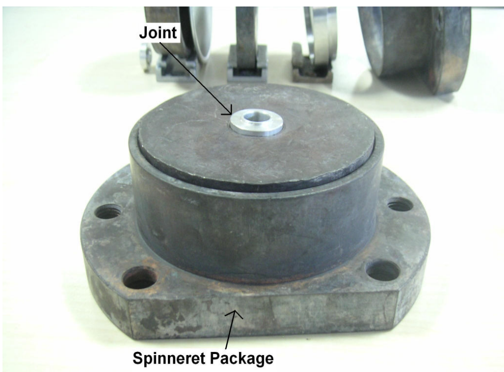
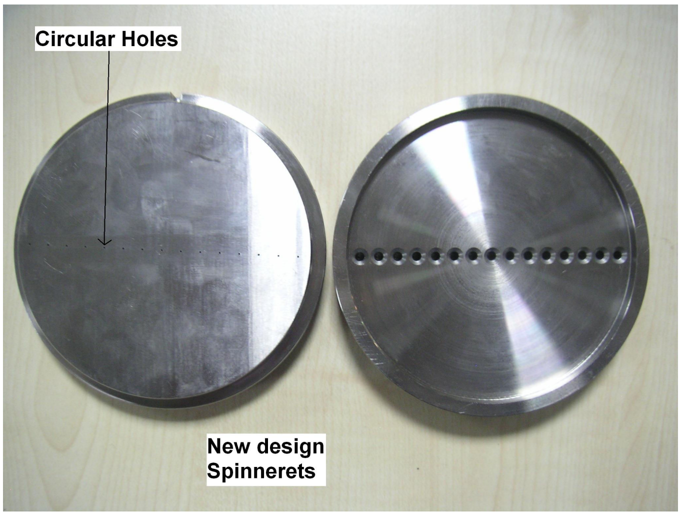


Figure 4.5 Spinneret package

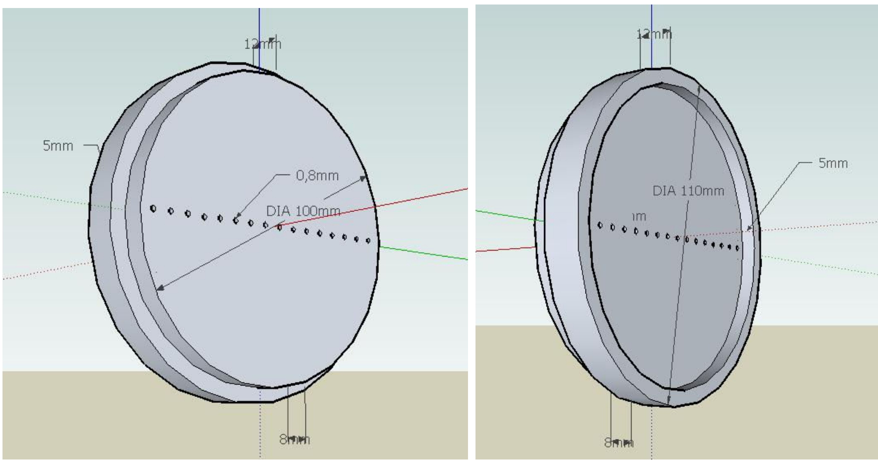
Figure 4.6 Spinning package and spinnerets on the BCF machine

4.4.2. The second design of the spinneret

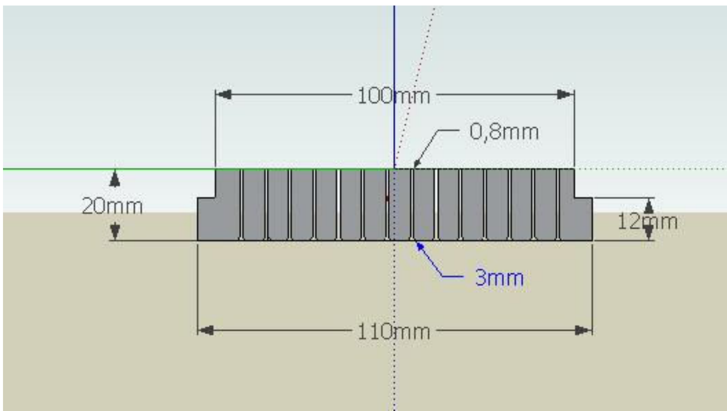
Figure 4.7 shows the second design of the spinneret made by Özçelik A.Ş. In the SML BCF machinery, one melting pump is required for two spinnerets and each spinneret has 144 holes. The melt pump forced the melted polymer to two spinning



a. Photograph of the spinneret



b. Isometric view of the spinneret



c. Isometric view of the cross section of the spinneret

Figure 4.7 The second design of the spinneret packages in the normal processing. In this design, two spinnerets are used to produce a single yarn. Each of them has 15 filaments holes and thickness of each hole is 25 mm. The cross section of the holes is circular shape, and its diameter is 0.8 mm.

The main reason of using circular cross section in holes of the spinneret is that, the circular surface is smooth, when touching the local cooling apparatus; it is easy to exchange the heat into the polymer and can be easily touched to one point of the surface without any difference of the other filaments. All the filaments have the same touching surface and get the same level molecular orientation difference.

4.5. Developing the Local Cooling System for Self-Crimp FYS

In self crimped FYS process, the hot filaments touch the cold pipe in the quench unit. The shock cold gets molecular orientation and this situation gives rise to the crimp effect on the yarn. Two different local cooling models are developed.

4.5.1. The First Model of the Local Cooling Unit

In the first model, the cooling unit is designed by the chrome metal pipe represented in Figure 4.8. It consists of two water sockets, chrome pipe and two screws. However, it has some difficulties. The pipe is pressed with difficulty between the separators of cooling cabinet (quench unit) and it is hard to move up and down the pipe. Since, it is difficult to connect filaments to the adjusted the pipe. Another problem is that chrome steel pipe has low heat permeability. Also, because of pipe's small diameter (10 mm), the cold water passes hardly through it.

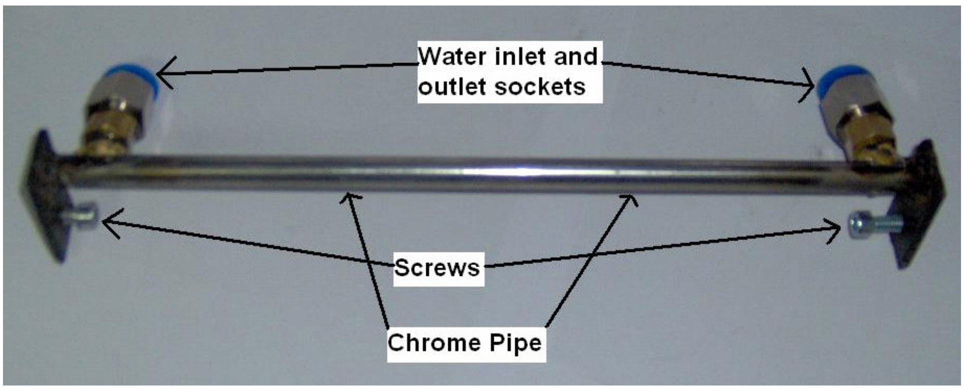


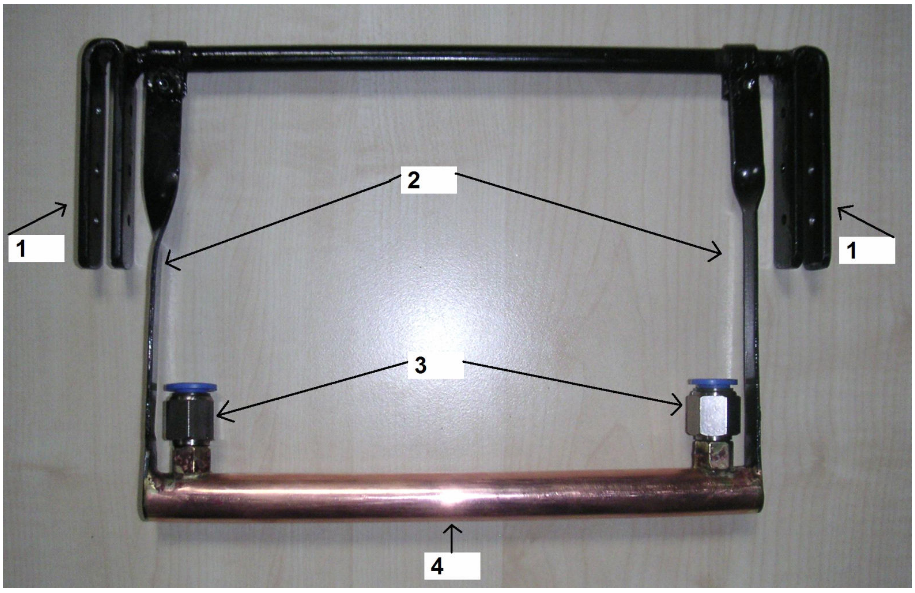
Figure 4.8 Local cooling unit made by chrome pipe (the first model)

4.5.2. The Second Model of the Local Cooling Unit

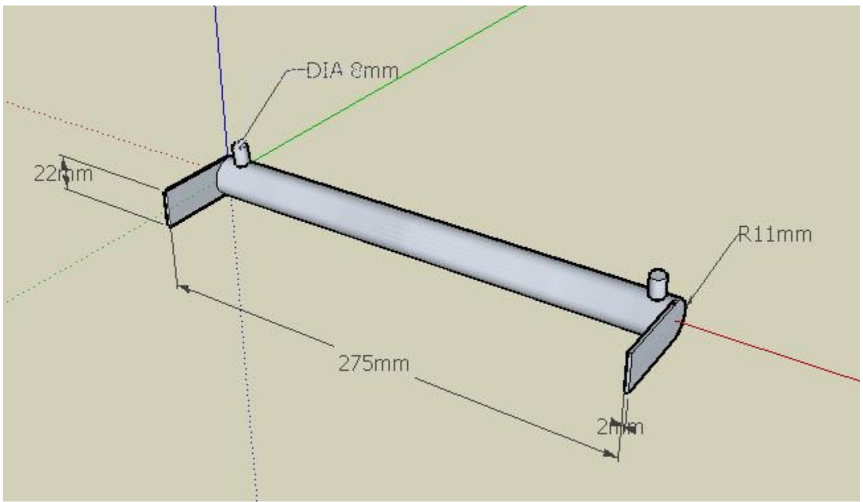
Figure 4.9 shows the second model of the local cooling unit. It can easily be mounted on the cabinet. Moreover, an adjustable pipe is designed and constructed according to the flow direction of filaments in order to obtain easy and straight touch surface of the filaments.

The second model contains the following parts;

(1) Holder of the pipe; the holders lock the platform of the cooling cabinet separators and adjust the position to the cooling cabinet by pressing screws.



a. A photograph of the cooling unit



b. Isometric view of copper pipe

Figure 4.9 Local cooling unit made by copper (the second model)

(2) The arm of the tube (Figure 4.10); the arms of the tube provide for adjusting the angel between the cabinet and the cooling unit. It's working principle; firstly, the melted PP flows into the spinnerets and passed through the quench. After that, the suction pipe sucks the filaments. Meanwhile, the arm attached the cooling unit is moved slowly down up to touch the filaments. Thus, a required angel between the cabinet and the cooling unit is obtained to supply the touch to the surface of the all filaments on the cooling pipe. Finally, the arms screws are used to be pressed to hold its position and angel without any changes.

(3) The pipe water inlet and outlet holder; the plastic water feed pipes stick in to those holders. So, the cold water passes and turns over in to the copper tube.

(4) Copper tube; Surface of the tube is smoothed by lathe. And silicon is sprayed on the surface of the tube. Thus, it has smooth, slick and slippery surface. The filaments easily touch and flow on the surface of the tube without any stick.

The pipe is made by copper because its heat permeability is better than the chrome. The tube diameter is selected as 22 mm, so the water can pass easily through the tube. The cooling system works like that; the cooled water at 3,5 ºC runs through the

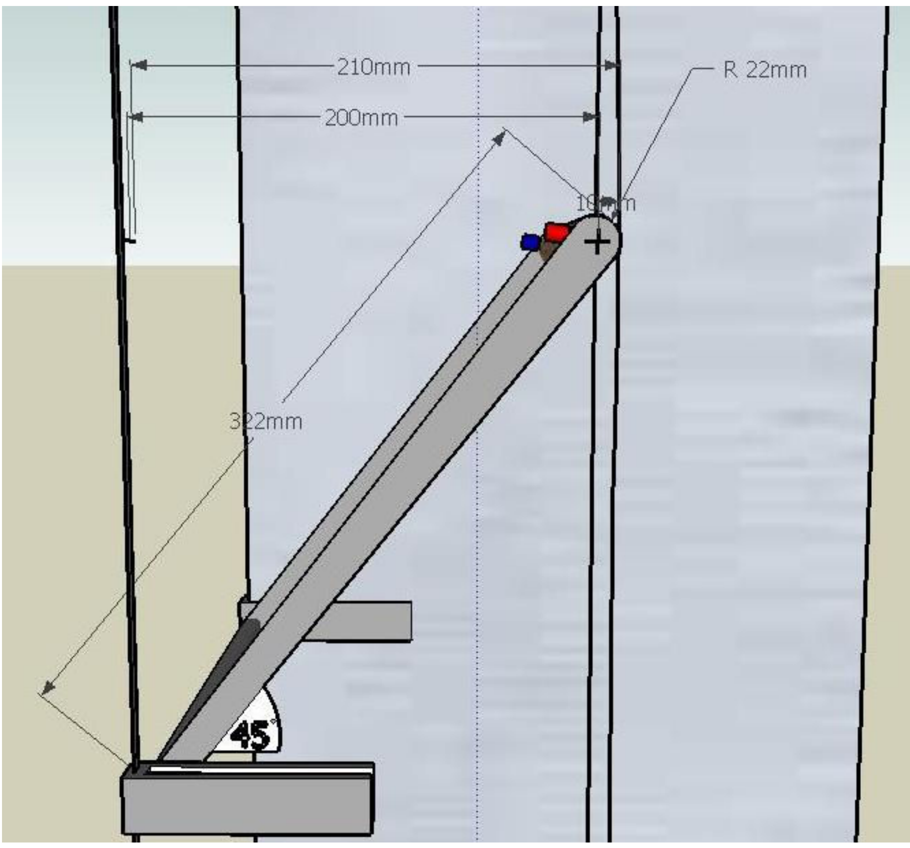


Figure 4.10 Isometric view of the arm of the cooling unit

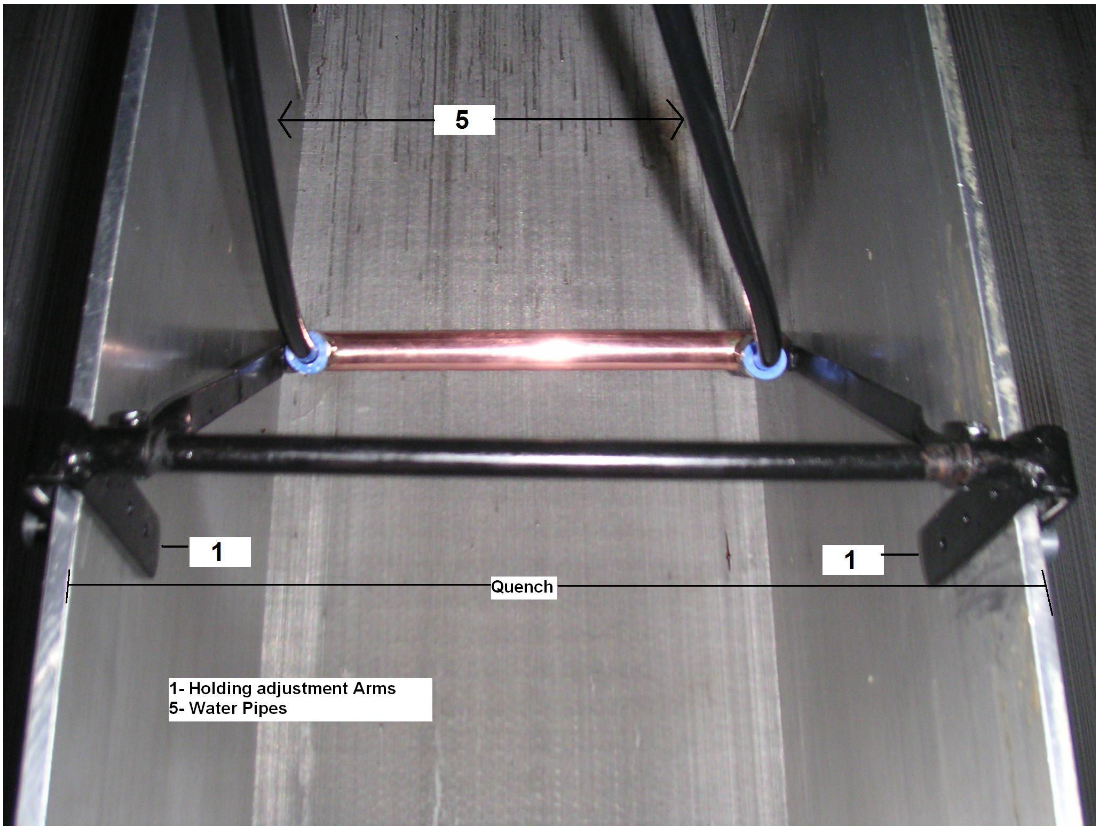


Figure 4.11 A photograph of the place of the local cooling apparatus

copper tube having a temperature of 5 ºC touching the hot filaments by the given distance denoted by “H” (seen in Figure 4.17). As shown in Figure 4.11, the holder of the pipes (1) stick to the quench cabinet platform and pressed by screws to hold its position. The plastic water feeder pipes (5) connect to the pipe holder and the cooled water flows inside the copper tube (4).

4.6. Experimental Studies on Design of Spinneret and Local Cooling Unit

The SML BCF machine capacity is 220 kg/hr. Its winding speed is up to 3500 m/min. The room temperature is regulated at 25 ºC. The quench flows at 0,8 m/sec across thread lines. The other conditions as heating, spin-finish and drawing are proper to standards in the experimental procedure. Two experimental studies are done on SML BCF machine having different spinneret and local cooling units. First experimental studies are applied SML BCF machine by using the first model of the spinneret shown in Figure 4.4 with the first model of the local cooling unit shown in Figure 4.8. The second studies are done on the same machine by using the second model of the spinneret shown in Figure 4.7 with the second model of the local cooling unit shown in Figure 4.9.

4.6.1. The First Experimental Study

The first design spinneret (Figure 4.4) is mounted on the SML BCF machine and the cooling unit (Figure 4.8) is placed into the right place in the quench unit. The experimental studies are started with placing the cooling pipe at a distance 60 cm down from spinneret. After the cooling unit is posited, distance of the cooling pipe is changed at different values. Then, the cooled water source of chiller pipes is connected to the cooling unit (Figure 4.12). In the beginning, the cooled water has a temperature of 5 ºC., and the temperature of the melted PP is 235 ºC. The temperatures on the surfaces of the spinnerets are measured 210 ºC by the laser gun. Moreover, the speed of the melt pump is adjusted at 5 rpm due to the high pressure at the spinneret having 14 holes. Normally, the melt pump in the SML BCF machine with spinneret having 144 filaments holes has the speed of 35 rpm.

When the melted PP filaments flow down from the spinnerets, the filaments are sucked by the air suction gun before put into the waste bag. If flow of filament is symmetric, the speed of melt pumps is increased to 12 rpm and pressure in the spinneret is adjusted at 50 atm in order to see the normal flow of filament (Figure 4.13).

After the normal flow, the cooling pipe is adjusted to the right place to touch the flow filaments (Figure 4.14 and Figure 4.15) by hand. However, the filaments stick on the pipe, afterwards the silicon spray is painted on the surface of the pipes to be sliding the filaments on the pipe. The process is repeated again.

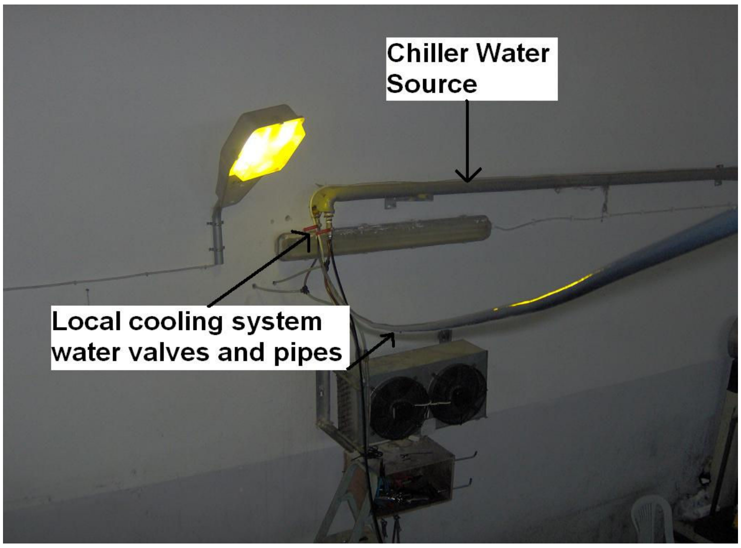


Figure 4.12 The cold water supply pipes

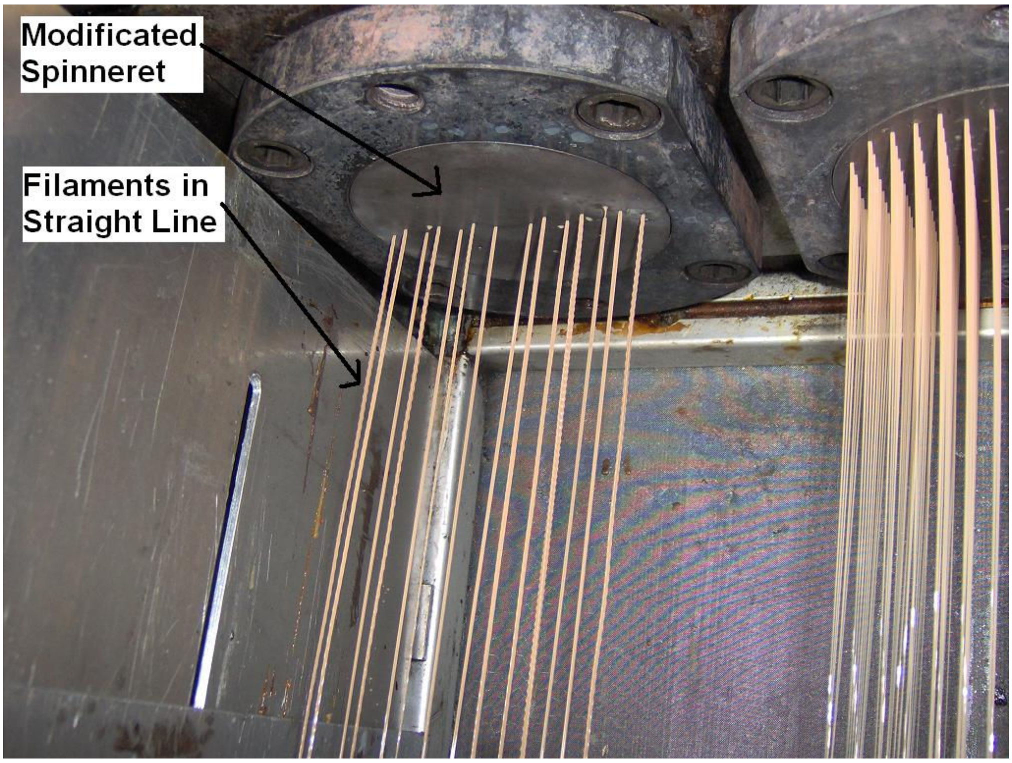


Figure 4.13 Flowing the melt PP filaments from the spinnerets

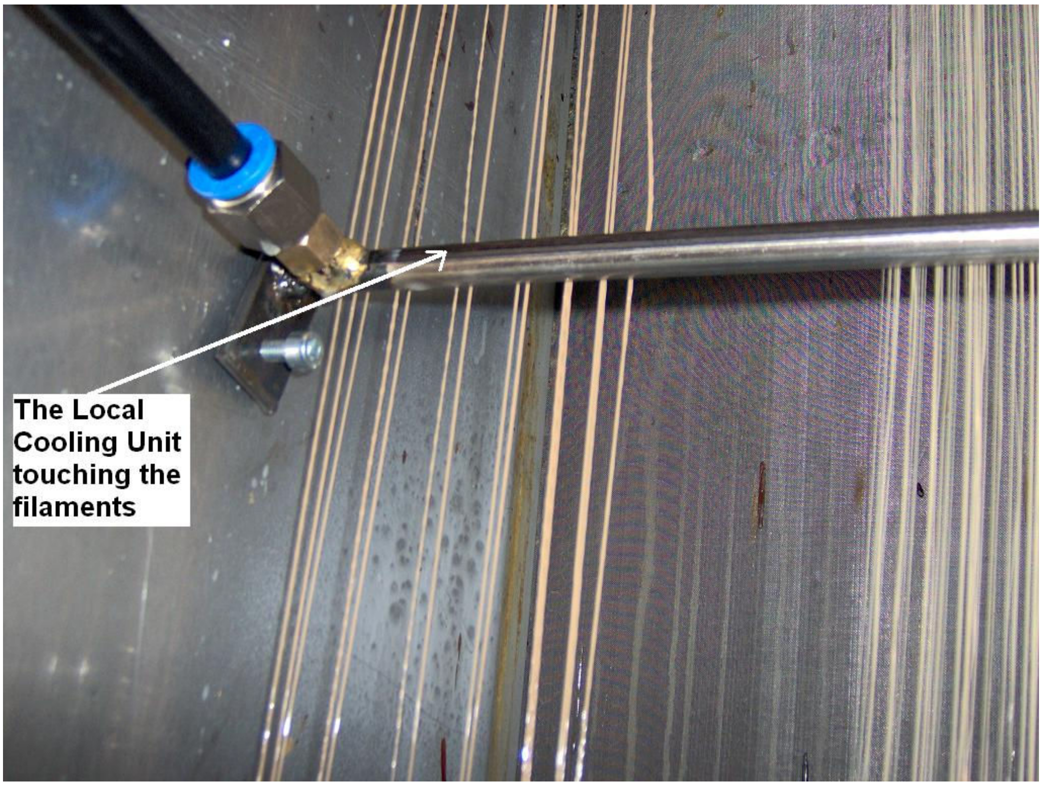


Figure 4.14 A photograph of touching the filaments on the surface of cold pipe

Figure 4.15 Adjusted the cooling pipe by hand.

The sample yarns are stored in the waste bag. The sample yarns are checked and the crimped effects are seen on the yarns as shown in the Figure 4.16. But it is observed that the level of the crimped of this system is lower than that of the hot air-jet texturing system.

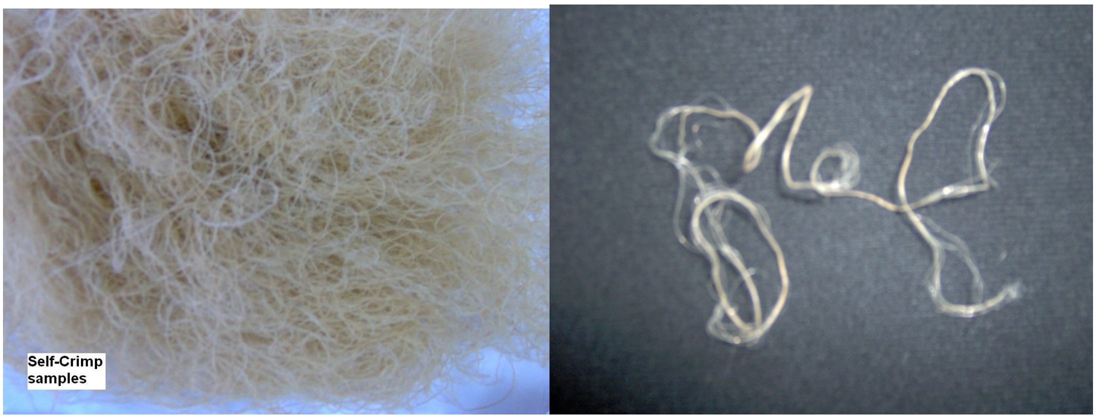


Figure 4.16 The first samples of self crimped FYS (the first experiment)

Some problems are encountered in the first experimental studies. The first problem is that: In the melt pump section there are two spinneret packages and the one melt pump. So, one of them has 14 filaments and other has 144 filaments. This gives rise to the pressure and flow action problems. The other problems are that normally the filaments are sucked from the suction gun and can be taken from the draw unit and winder. But in the first experiment studies, the yarns can not be drawn and winded on the bobbin. Furthermore, important problem is that the trilobal cross section of filaments sticks each other and could not uniformly touch to the cooling pipe.

4.6.2. The Second Experimental Study

The second design of the spinneret (Figure 4.7) is placed on the right position of the SML BCF machine. Also, the cooling unit (Figure 4.9) is mounted into the right place in the quench unit. In the experiment, it is important to find the right position of intensive local cooling represented by "H" (Figure 4.17). Therefore, some trials are done and the position of the cooling pipe (H) is selected as 30 cm, 50 cm, 70 cm, 90 cm, 100 cm and 110 cm down from the spinneret. Before performing experimental tests, the silicon spray is used for the surface of the copper tube, so the filaments slide down the surface of the tube without any stick.

4.6.2.1. Observation the results at the different position of the cooling unit

When the position of the cooling is set at 30 cm down from the spinneret, the hot melt PP does not flow correctly. Since the filaments move together, stick each other and stick on the copper tube. Another problem is to adjust the speed of the spinning pump. Because, the filaments cannot move down without any brake and cannot get the suction gun without touching the copper tube. For instant, when the melt pump speed is adjusted at 12 rpm many problems are occurred during

Figure 4.17 The distance of the local cooling apparatus

production. These are; the melt flow is too hot, there are a lot of brakes in filament, the filament cannot get the suction gun and can not be draft on the drafting godets. After that, the processing is observed when the pump speed is decreased at 1 by 1 rpm. Up to 9 rpm, the filaments cannot get to the suction gun. Yet, the filaments flow smooth, can be gotten the suction gun, and can be drafted on the godets without touching the copper tube while the pump speed is 8 rpm and the quench speed is 47 rpm and the quench air temperature is 7 ºC. Meanwhile, we touch the cold tube to the filaments, the filaments stick to the tube and stick each other and brake. So, the right process parameter as the speed of the pump and quench and quench temperature can be found by this trials error method. In addition, the other process parameters in the SML machine depended on these parameters are given in Table 4.2. Afterwards, these parameters will be used in the other experimental tests.

At a distances of H=40 cm and H=50 cm, the same problems are continuously occurred during the processing. But, the filaments do not stick each other and can be taken from the suction gun when the position of the cooling unit is 70 cm down from spinneret. And after that the filaments passed inside the spinfinish nozzles, drawing godets and winding on carton bobbins well.

Thus, one of the important process parameters in the study as the position of the local cooling unit is found at 70 cm down from the spinnerets. Later studies, the position of the cooling unit is chosen as 70 cm, 90 cm, 100 cm, and 110 cm down from the spinneret. The following figures (Figure 4.19-24) show the process steps of the self crimped FYS process applied on the SML BCF machine.

The filaments position distance between the outside point of the quench cabinet and the spinneret middle point is 20 cm. The distance between the outside point of the quench cabin and the cooper tube is 21 cm. The touch pressing surface of the tube gives 1 cm tension on the filaments (Figure 4.20b).

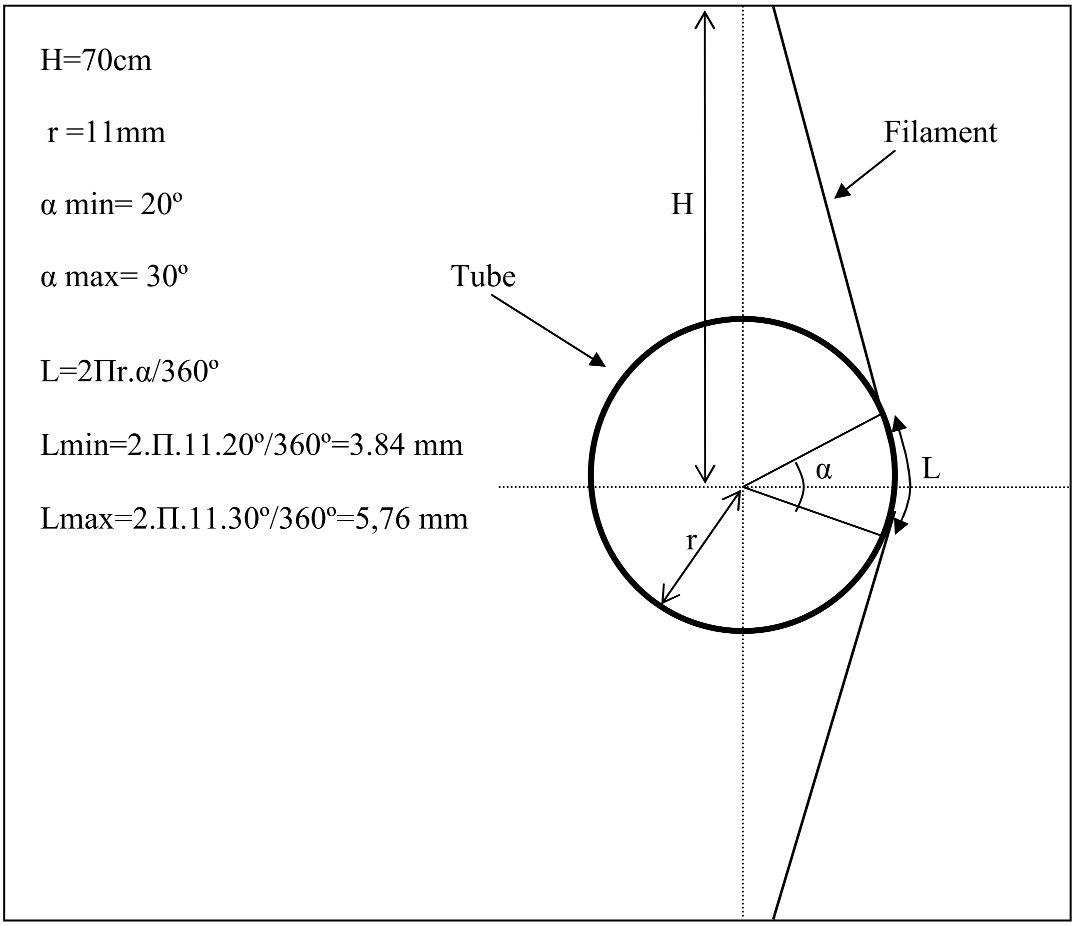


Figure 4.18 The schematic of touching tube

The radius is 11 mm for the tube, the distance down from the spinneret is 70 cm, and the touching surface angle is approximately "α= 20º~30º". The touching surface length is L as shown in the Figure 4.18. As the result of the calculations, the filaments touch the surface of the tube length is between 3,84 mm and 5,76 mm.

Table 4.2 The process parameters of the SML machine used in the self crimped FYS

EXTRUDER TEMPERATURES	PRESSURES
Feedzone: 90 ºC	P-BEFORE FILTER: 91 BAR
Zone1: 180 ºC	P-AFTER FILTER: 50 BAR
Zone2: 190 ºC	SPİNNERETS PRESSURE: 50 BAR
Zone3: 195 ºC	
Zone4: 199 ºC	SCREW SPEED: 73 RPM
Adapter: 201 ºC	MOTOR CURRENT: 84 AMP
Screen: 202 ºC	
Adapter2: 203 ºC	
Blender: 204 ºC	
Spinning heat: 203 ºC	
Quench: %47 Fan speed	
Air quench temp: 7 ºC	
Spinfinish: 31 RPM	
Copper pipe temp: 5 ºC	
Spinning pump: 8 RPM	
15 FILAMENT X 2 : 30 FILAMENT SINGLE YARN	
DRAWING FRAME	
FEEDROLL: 751 m/min	
DUO1: 754 m/min – 115 ºC	
DUO2: 2190 m/min – 120 ºC	
Draft: 2,904 %	
Tension on the winder: 100 cN	

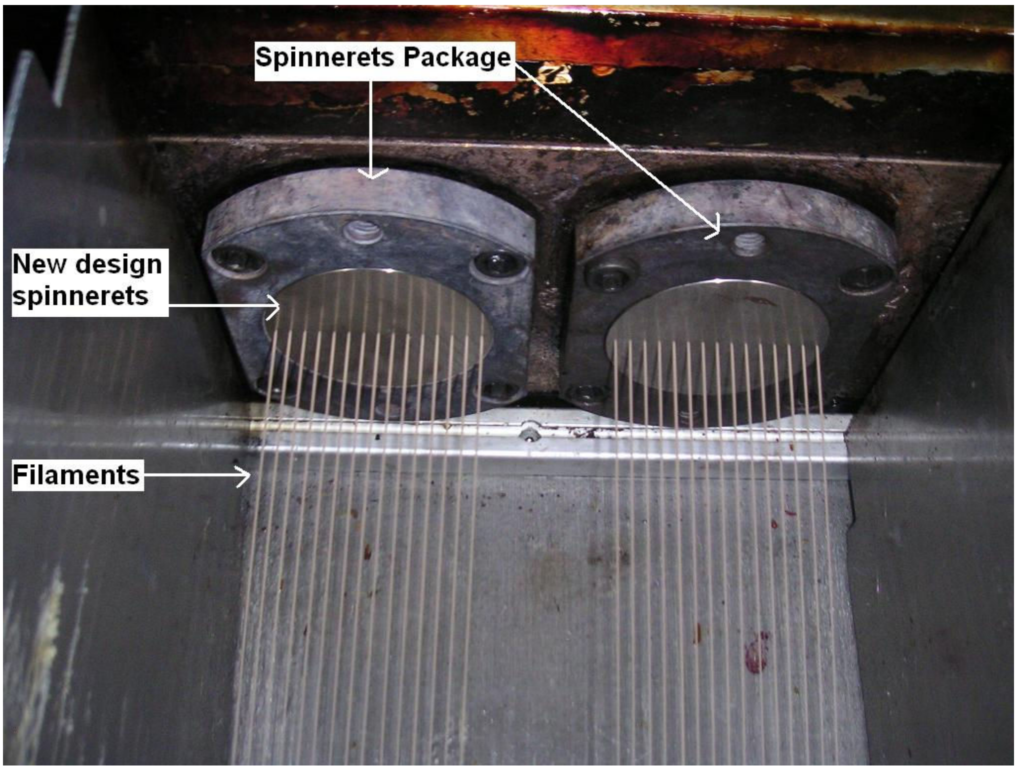
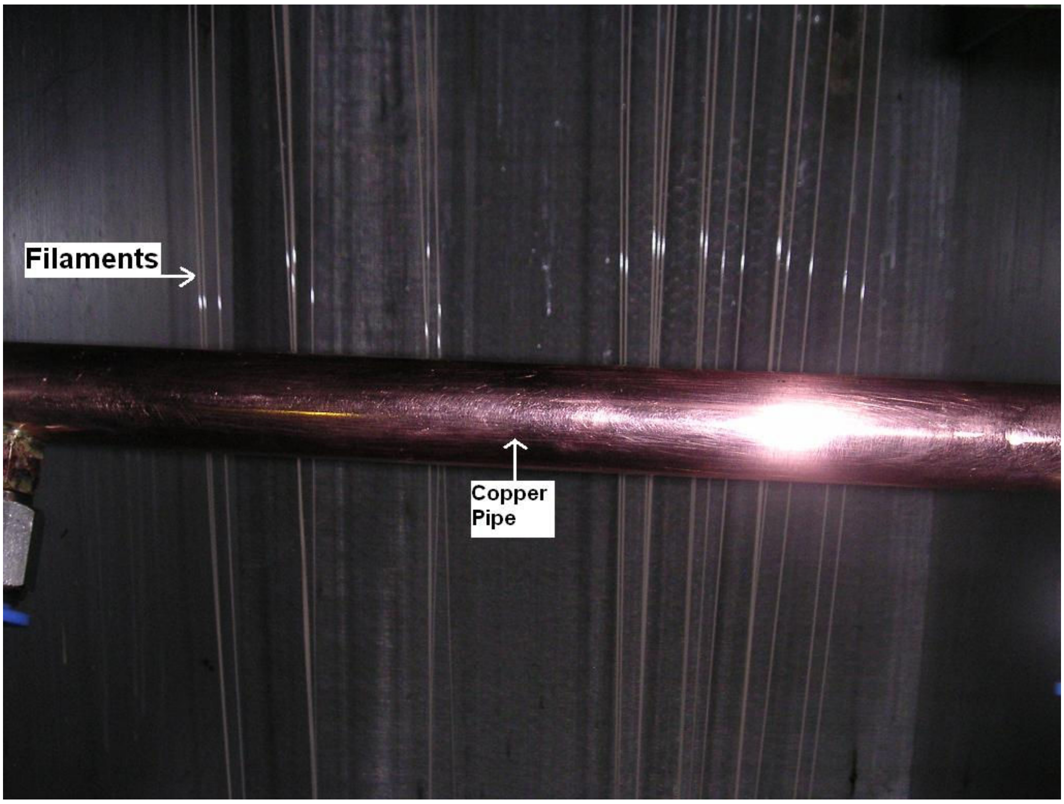
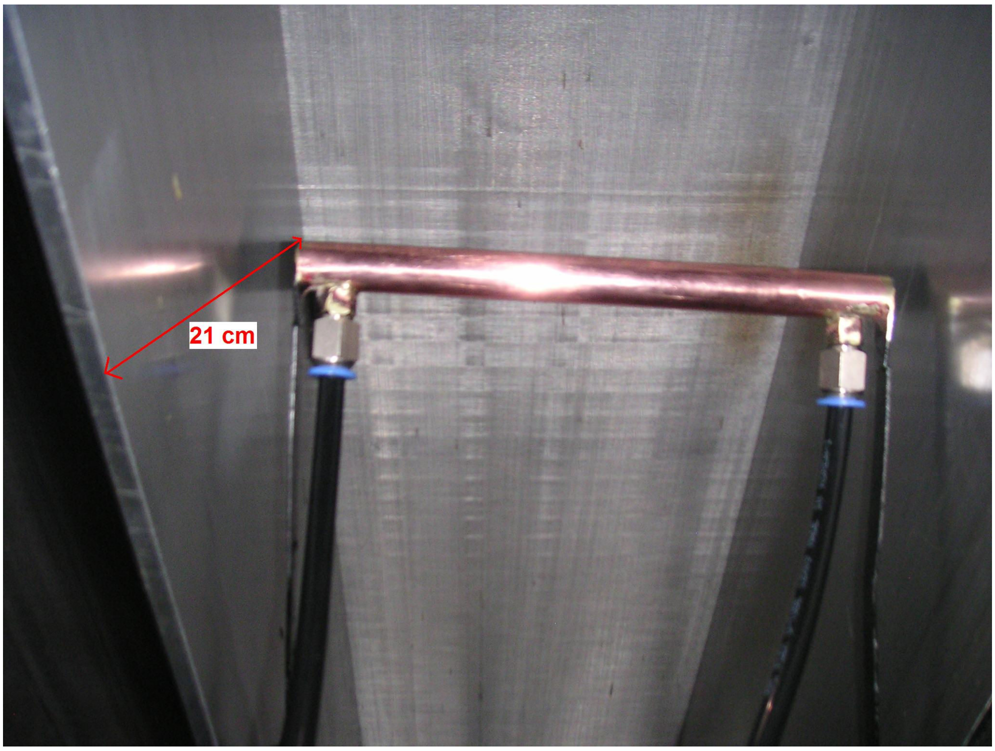


Figure 4.19 The melted PP flowing from the spinnerets in the quench



(a)



(b)
Figure 4.20 The filaments touch the local cooling unit.

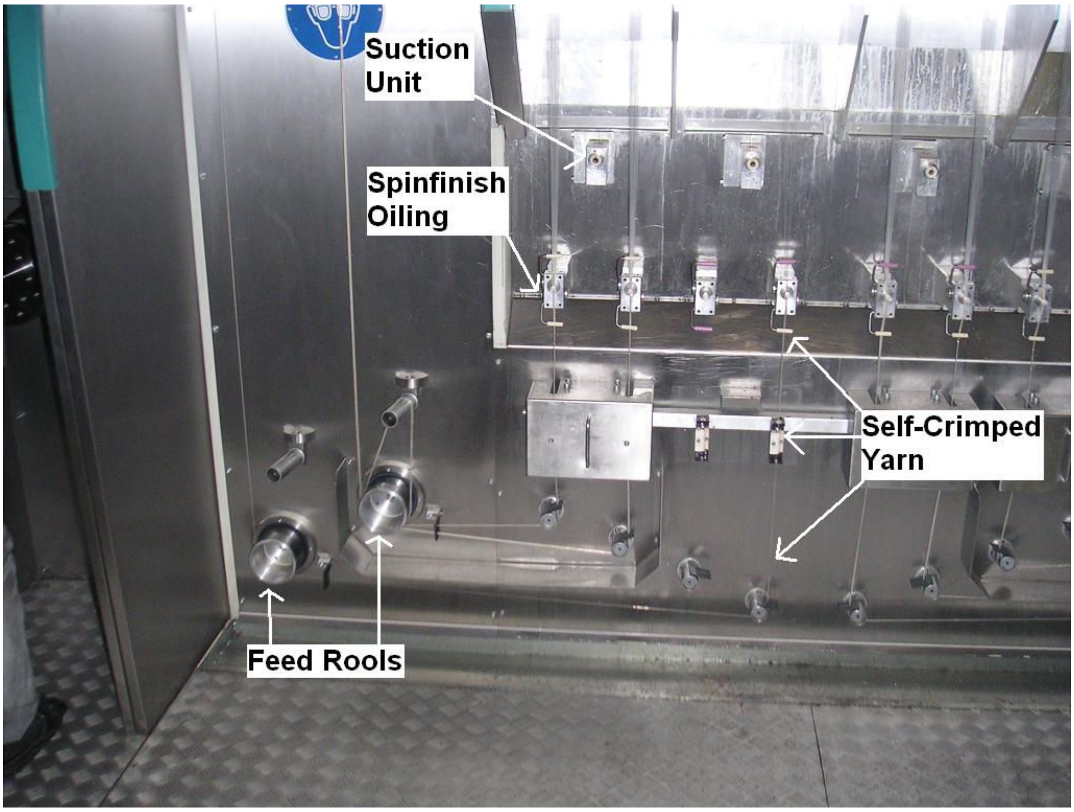


Figure 4.21 The spin-finish oil added on the yarn.

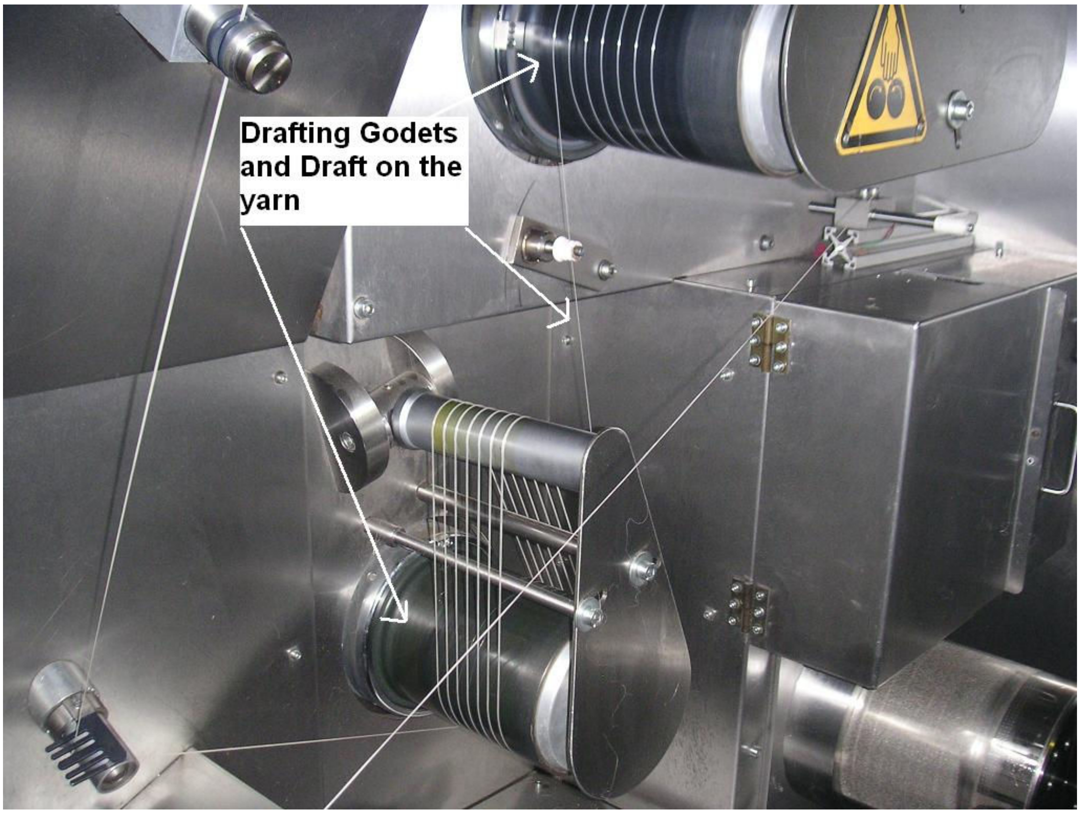


Figure 4.22 The drafting unit drafts the yarn about %3

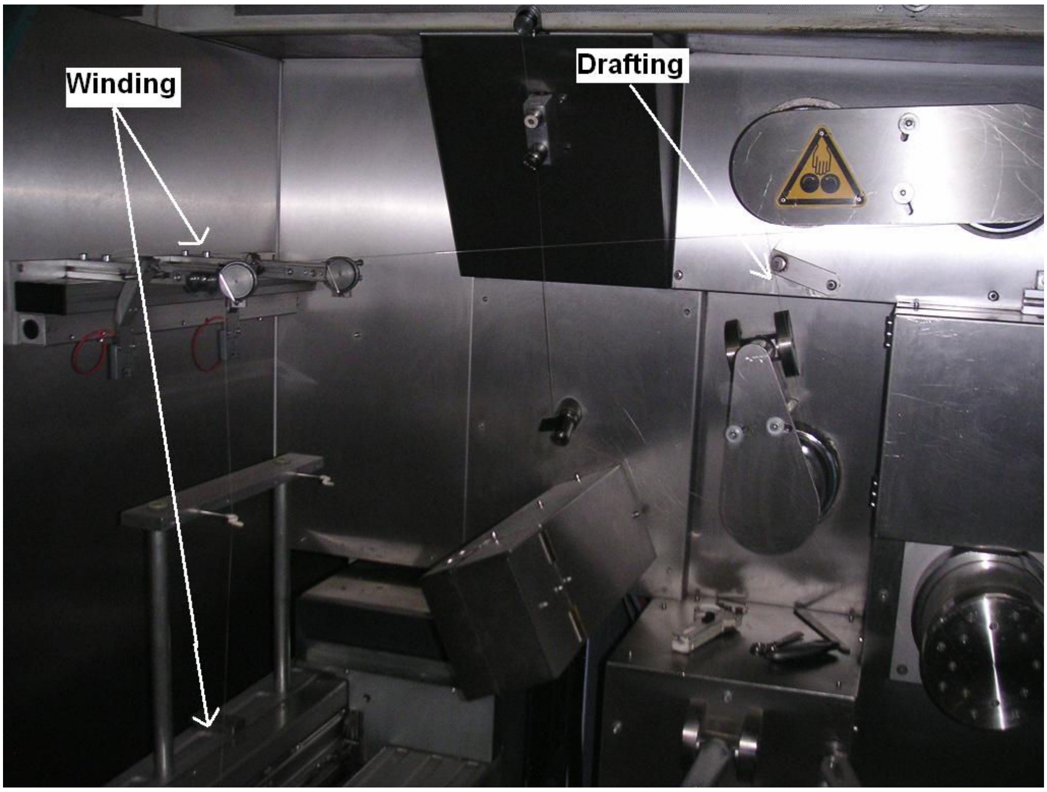


Figure 4.23 The draft and the winding yarn.

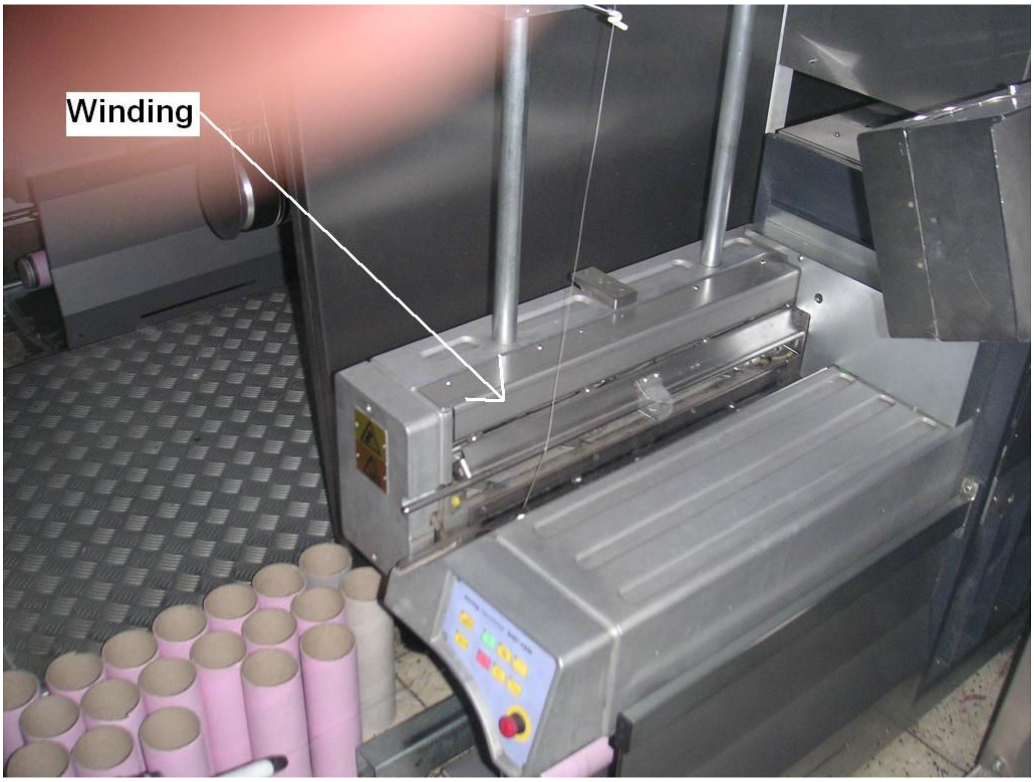


Figure 4.24 The yarn winding only one bobbin on the winder.

Normally BCF yarns wind 150-200 cN between the last godet and winder. However, due to high tension, the first and second bobbins pressed the carton tubes and yarn had to be cut and bobbins had to be taken out from the winder spindle. Then tension is decreased to 100cN and adjusted. In addition, thick carton bobbins are selected to be used without any damage. Finally, yarn was winded on the carton bobbins and first sample is obtained like Figure 4.25. The experiment duration is about 9 hours. In the end of this experiment, the process is observed to continue without any interruption. More than 48 sample bobbins are taken. Figure 4.26 and Figure 4.27 illustrate the sample test yarns obtained by using the self crimped FYS process.

The effects of the above process parameters on the physical properties of these sample BCF yarns are investigated and discussed in the following chapter.

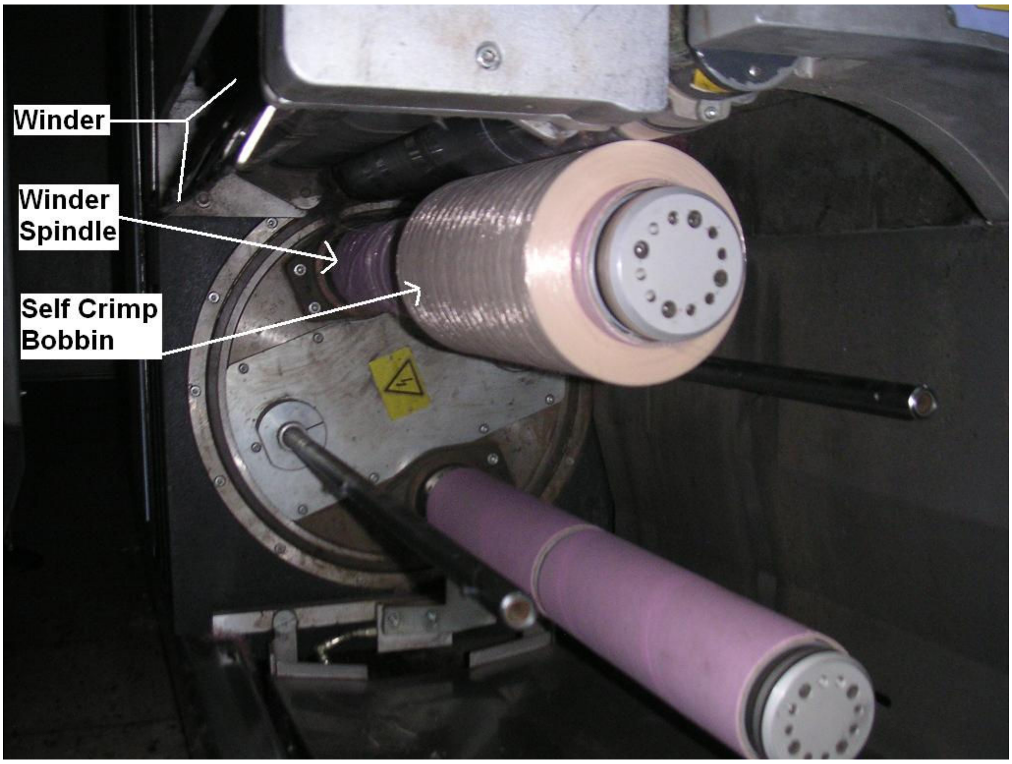


Figure 4.25 The yarns wind on the carton bobbins

Figure 4.26 The Self-Crimp FYS yarn samples

Figure 4.27 The Self-Crimp texturing yarns wind on the carton bobbins

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1. Introduction

In this chapter, the results which are obtained from the evaluation of the samples formed by using an experimental set-up, given as the second experimental studies in Chapter 4, are discussed. Firstly, information about the process parameters used in producing samples yarns and their physical properties are given. Secondly, the yarn test techniques are described. After, two reference yarns which have different properties are presented to compare the experimental results. Finally, the effects of the process parameters on the physical properties of the samples are investigated. The experimental test results are compared with two reference yarns and they are given in experimental results and discussions.

5.2. Process Parameters

In the study, forty eight different yarn samples are produced on developed SML BCF machine by using the process parameters given below. These parameters are described in detail in the previous chapter.

- Four different distances of the local cooling are given; the distances down from the spinneret H=70 cm, H=90 cm, H=100 cm and H=110 cm.
- Intensive cooling medium; Quench temperature changes: 7 ºC, 9 ºC and 11 ºC
- Intensive cooling temperature; Chiller (water) temperature changes: 3 ºC, 5 ºC and 7 ºC
- Winding Speed changes: 1990 m/min, 2000 m/min, 2010 m/min and 2020 m/min.

Following physical properties are examined on the samples.

Crimp; Some fibers posses a wavy, undulating physical structure. This characteristic is called crimp. Wool has a natural three-dimensional crimp. A number of texturing processes can be used to add crimp to manufactured fibers or yarns. Fabrics made from crimped fibers or yarns tend to be more resilient and have increased bulk, cohesiveness, and warmth. Cohesiveness is the ability of fibers to cling together [35].

Strength; The mechanical properties of textiles describe the textile material's behavior under applied forces and deformation. Deformation is a change of shape or size of materials under applied force [3,38].

Elongation; Elongation is the amount of stretching or lengthening of a fiber under a tensile force. Elongation does not imply that the fiber will return to its original form, but the fiber length can be elongated or extended [3,38].

Shrink; Shrink refers to the ability of a fiber to spring back to its natural position after folding, creasing or other deformations [3,38].

Dtex; It is the numerate system of synthetic fibers. tex= Gram/1000 meter [3]

1 Dtex= 1 Dg/km = 0,1 mg/m

5.3. The Characterization Test Techniques

The physical properties of sample yarns such as the crimp level, strength, elongation, shrink and dtex are examined. The sensitive balance apparatus, wrap reel, tensile strength tester, oven and weights are used to determine the characteristics of samples. The experimental tests are made in Yasin Kaplan Halı A.Ş.

The apparatus used in examining physical properties of yarns are described below.

5.3.1. Sensitive Balance Apparatus

The "Mettler Toledo" sensitive (0,001 gram) weight balance apparatus (Figure 5.1) is used to measure the weight of the filaments and to help to determine the number of the samples.

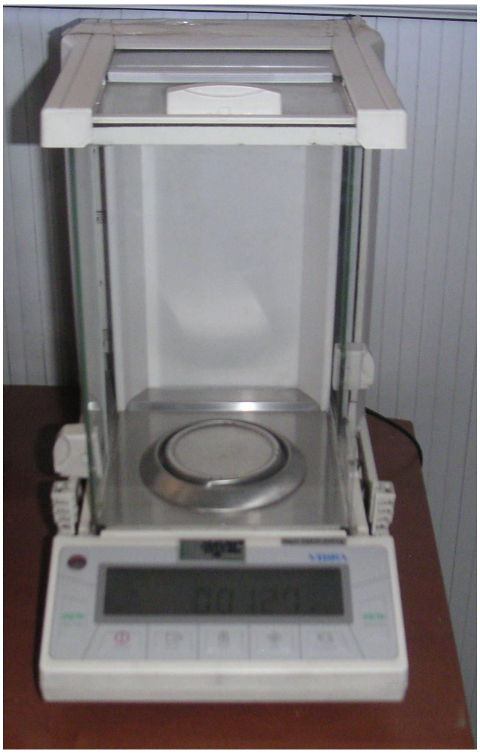


Figure 5.1 Digital sensitive weight balance apparatus

5.3.2. Wrap Reel

The count of sample yarn is determined by winding wheel apparatus (Figure 5.2). Firstly, end point of the yarn is locked to one plate of the winding wheel. Then the winding wheel is turned and the yarn is consequently turned over the wheel at a length of 100 meters. The yarn having 100 m length is taken from the winding wheel and put onto sensitive weight balance to be measured its weight. For example; the weight of 100 meter length yarn is measured as 7,8 gram. That means that its count is 780 dtex.

Reels have up to 10 yarn skeins. The reel starts gently and smoothly to increase normal speed under microprocessor control, before reaching the pre-selected measuring length, it slows down and approaches the end of the measurement slowly and stops at an accurate position, which ensures uniform winding without any stretch. Stainless steel reel is used for accurate length measurement and better stability. Separate yarn stand is provided to accommodate 10 cops. The unique Statex is designed adjustable pre-tension mechanism tension as per ASTM standard to suit individual yarn through common selector. This advanced pretension mechanism ensures uniform tension throughout winding.

Figure 5.2 The wrap reel

Figure 5.3 Yarn Tensile Strength Tester

5.3.3. Yarn Tensile Strength Tester

"Tensostate" (Figure 5.3) is an accurate and fully automatic computer controlled instrument which is used to check the parameters of tensile strength of yarn, elongation, time to break, tenacity, etc. Pre-programmed number of tests and cops are automatically controlled and tested without operator influence. Selection of specimen length and testing speed is chosen from computer. Upper and lower jaws are pneumatically operated. Results can be obtained in numerical form.

5.3.4. Oven

In the shrink and crimp test, oven and weights are used. Determination of parameters for the crimp of textured filament yarns (> 500 dtex) are based on DIN 53840 Teil 2 [43].

Crimp Contraction: CC = (Lg-Lz) x 100/Lg

Crimp Modulus: CM = (LG-Lf) x 100/Lg

Crimp Stability: CS = (Lg-Lb) x 100/(Lg-Lz)

Figure 5.4 The Oven

This standard specifies a method for determining crimp contraction as a parameter serving to characterize the crimp properties of a yarn. The method can be applied to all texturing process used. Crimp development of filament yarns of a nominal linear density exceeding 500 dtex is effected in 135ºC oven (Figure 5.4) [43].

5.3.4.1. Crimp Contraction

The crimp contraction E is the reduction in length of a textured filament yarn as a result of its crimped structure when the crimp is developed. The crimp contraction E is expressed as the ratio of the differences between the straightened length Lg and the contracted length Lz to the straightened length Lg.

$$E = (Lg-Lz)/Lg$$

The crimp of a specimen of a textured filament yarn in the form of a skein of specified linear density is developed by treatment with hot water. Then, the straightened length Lg is measured under a high tensile force. After a specified recovery time, the contracted length Lz of the filament yarn, shortened by the effect of its crimp, is measured under a low pre-tensioning load. The tests are made 5 times for each sample [43].

5.4. Reference Samples

The experimental results obtained in the self-crimp method are compared with two different reference yarns according to the physical properties. The first reference yarn is the BCF carpet yarn produced on the SML machine by using hot air-jet texturing system. This yarn is referred as “Ref or RF”. Except the hot air-jet texturing unit, the whole processes parameters are the same as the experimental studies. These parameters are the extruder heat settings; the spinnerets heat settings, the quench air speed, the spin-finish oil, the drawing speeds and temperatures, and winding parameters. Here, only the spinnerets types, temperature of the local cooling and the texturing unit are changed.

The second reference yarn is continuous filament yarn called as “CF”. It is produced on the SML CF machine having no texturing unit in STAR iplik A.Ş. CF machine looks like BCF, but CF has a few differences on drafting godets, and machinery speeds. Due to lack of texturing apparatus on CF machine, there can not be observed a real crimp effect on CF yarn.

5.5. Experimental results and discussions

The experimental results with process parameters are given in Table 5.1. The effects of process parameters on graphs and the results are discussed in the following sections.

Table 5.1 Parameters of Samples

PARAMETERS					TEST RESULTS				
NO	DISTANCE (cm)	QUENCH (ºC)	CHILLER (ºC)	WINDING SPEED (m/min)	COUNT (DTEX)	STRENGTH (%)	ELONGATION (%)	SHRINK (%)	CRIMP (%)
1	70	7	3	1990	797	2,4	113,1	5,1	8,3
2	70	7	3	2000	792	2,2	121,6	5,8	9
3	70	7	3	2010	791	2,1	126,3	6,3	10,6
4	70	7	3	2020	788	2,1	107,4	6,3	10,8
5	90	7	3	1990	791	2,4	140,1	5	7,6
6	90	7	3	2000	794	2,3	124,5	5,1	8,8
7	90	7	3	2010	788	2,5	141,1	6	8,6
8	90	7	3	2020	787	2,3	128,7	6,8	9,1
9	100	7	3	1990	793	2,3	137,3	6,1	9
10	100	7	3	2000	789	2,1	92,3	7	9,8
11	100	7	3	2010	791	2,3	142,4	6,5	9
12	100	7	3	2020	788	2,3	123,5	6,1	8,8
13	110	7	3	1990	788	2,2	131,6	5,8	9,1
14	110	7	3	2000	791	2,2	94,7	6,3	9,3
15	110	7	3	2010	783	2,2	124	5,8	9,3
16	110	7	3	2020	785	2,1	117,8	6,5	9,5
17	70	9	5	1990	790	2,3	112,6	4,8	7,3
18	70	9	5	2000	757	2,2	117,4	5,8	8,8
19	70	9	5	2010	786	2,3	135,7	6,6	9,3
20	70	9	5	2020	788	2,3	108,8	7	9,6
21	90	9	5	1990	802	2,3	137,7	5	7,6
22	90	9	5	2000	783	2,3	119,2	6,1	8,8
23	90	9	5	2010	793	2,4	125,9	5,1	8
24	90	9	5	2020	784	2,1	97	6,3	9,1
25	100	9	5	1990	782	2,4	120,6	5,3	7,8
26	100	9	5	2000	791	2,4	132,5	5,8	8,1
27	100	9	5	2010	779	2,2	126,8	6,5	9,3
28	100	9	5	2020	780	2,3	129,2	7	9,8
29	110	9	5	1990	792	2,2	120,2	5,8	8,8
30	110	9	5	2000	788	2,4	137,2	6,1	9
31	110	9	5	2010	780	2,3	133	7,1	10,3
32	110	9	5	2020	790	2,2	133,4	7	10,3
33	70	11	7	1990	798	2,1	124	6,1	9,3
34	70	11	7	2000	793	2,3	119,7	6	9,1
35	70	11	7	2010	800	2,2	121,6	6,3	9,5
36	70	11	7	2020	793	2,1	102,6	7,1	10
37	90	11	7	1990	801	2,2	123	6,1	8,8
38	90	11	7	2000	785	2,2	115	6	9
39	90	11	7	2010	796	2,2	122,1	6,8	9,5
40	90	11	7	2020	796	2,2	133,4	7,3	9,8
41	100	11	7	1990	789	2,3	125,4	6,3	9,1
42	100	11	7	2000	796	2,2	124	6,1	9
43	100	11	7	2010	795	2,3	118,3	6	8,3
44	100	11	7	2020	793	2,3	123,6	6	8,5
45	110	11	7	1990	797	2,3	135,4	5	7,1
46	110	11	7	2000	793	2,3	124	5,5	8
47	110	11	7	2010	784	2,3	142	6	8
48	110	11	7	2020	791	2,1	102,2	6,3	8,5
RF	x	7	3	x	795	2,7	39,8	3,1	12,1
CF	x	7	3	x	719	4,2	20,88	3,2	5,3

5.5.1. Yarn Crimp of self-Crimp FYS

The yarn crimp values of self-crimp samples obtained from the crimp measurement are given in Table 5.2.

Table 5.2 Crimp values of samples

Sample No	1	2	3	4	5	6	7	8	9	10
Crimp (%)	8,3	9	10,6	10,8	7,6	8,8	8,6	9,1	9	9,8
Sample No	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Crimp (%)	9	8,8	9,1	9,3	9,3	9,5	7,3	8,8	9,3	9,6
Sample No	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Crimp (%)	7,6	8,8	8	9,1	7,8	8,1	9,3	9,8	8,8	9
Sample No	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Crimp (%)	10,3	10,3	9,3	9,1	9,5	10	8,8	9	9,5	9,8
Sample No	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**RF**	**CF**
Crimp (%)	9,1	9	8,3	8,5	7,1	8	8	8,5	12,1	5,3

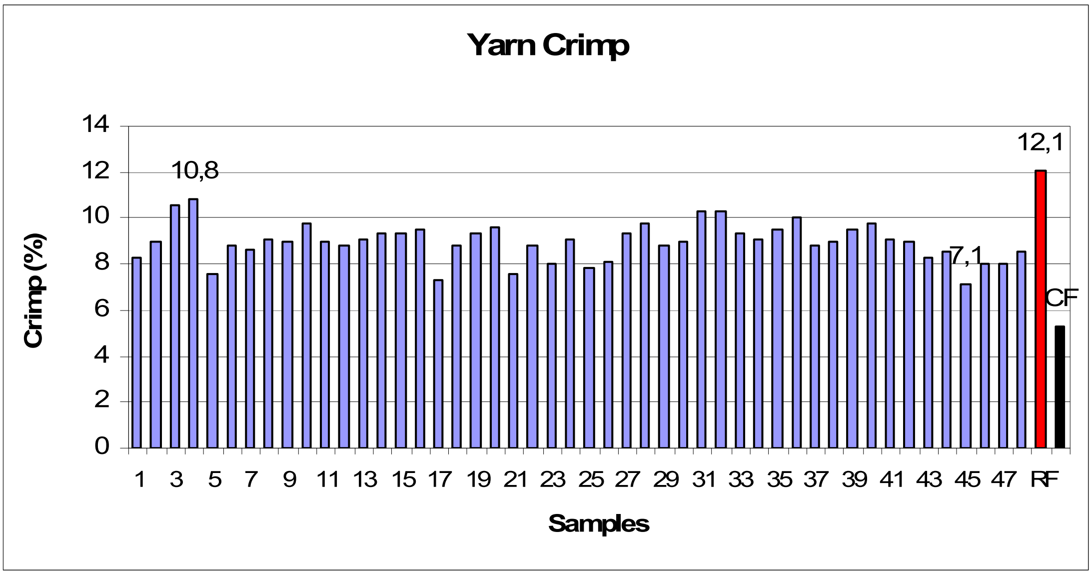


Figure 5.5 Yarn Crimp of self-crimp FYS samples

It is obvious from Figure 5.5 and Table 5.2 that yarn crimp value of RF sample is greater than that of self-crimp sample. The yarn crimp value of CF sample is lower than that of self-crimp FYS. As a result, it is observed that there occurs crimp on the self-crimp FYS samples and this crimp level is greater than crimp level of CF sample and closer to the crimp level of RF sample. As shown in Figure 5.5 and Table 5.1, Sample 4 has the highest crimp value (10,8%) and its test parameters are; Distance down from spinneret H=70 cm, the quench temperature is 7ºC, the Chiller temperature is 3ºC and the winder speed is 2020 m/min. On the other hand, the lowest crimp value (7,1%) belongs to Sample 45. Its test parameters are; Distance down from spinneret H=110 cm, the quench temperature is 11ºC, the Chiller temperature is 7ºC and the winder speed is 1990 m/min.

In this thesis the quench temperature called as "Q" and the Chiller temperature called as "C". The quench temperature depends on the chiller temperature. When the chiller temperature is adjusted to 3ºC, quench temperature is obtained at 7ºC. The quench-chiller temperature relationships show in the thesis as "Q-C (7ºC-3ºC)".

5.5.1.1. Crimp – Distance Effect

Table 5.3 Crimp – Distance effect (1990 m/min winding speed)

Winding Speed: 1990 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	8,3	7,3	9,3	12,1	5,3
90	7,6	7,6	8,8	12,1	5,3
100	9	7,8	9,1	12,1	5,3
110	9,1	8,8	7,1	12,1	5,3

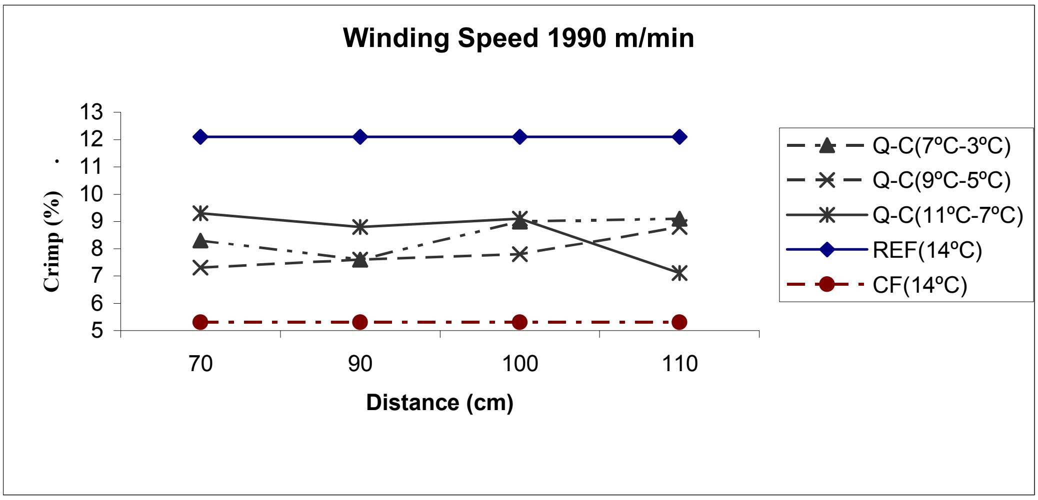


Figure 5.6 Crimp – Distance Effect (1990 m/min winding speed)

The experimental result of the relationship between distance (H) and the crimp percentage at 1990 m/min is shown in Table 5.3 and in Figure 5.6. The crimp percentage of RF sample is 12,1% and that of CF sample is 5,3%. That means that the minimum level of crimp is 5,3%, and the nominal BCF crimp is 12,1%. At 1990 m/min winding speed, the maximum crimp effect (9,3%) is seen in Sample 33 with the distance is 70 cm and Q-C (11ºC-7ºC).

Table 5.4 Crimp – Distance effect (2000 m/min winding speed)

Winding Speed: 2000 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	9	8,8	9,1	12,1	5,3
90	8,8	8,8	9	12,1	5,3
100	9,8	8,1	9	12,1	5,3
110	9,1	9	8	12,1	5,3

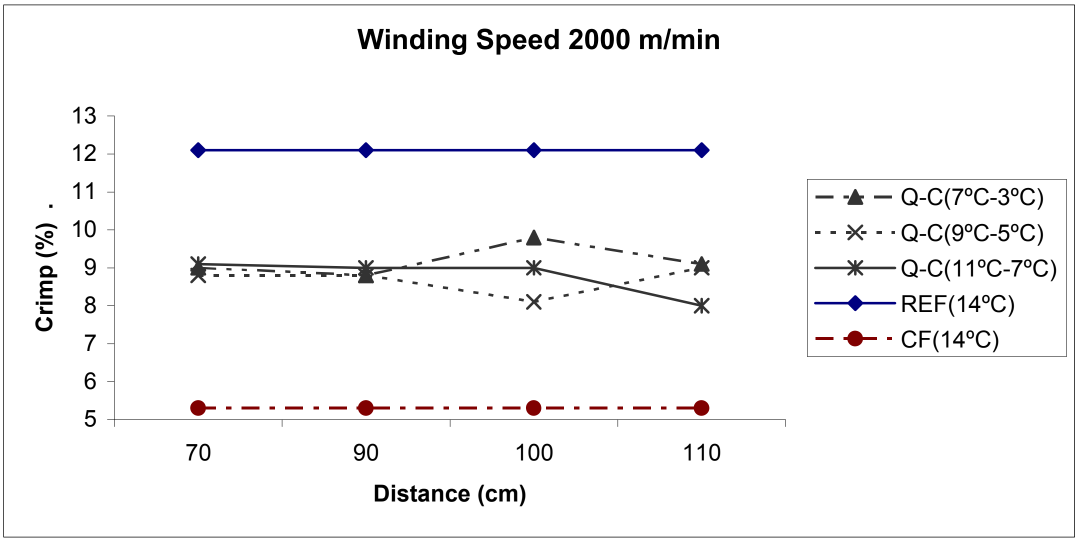


Figure 5.7 Crimp – Distance Effect (2000 m/min winding speed)

The experimental result of the relationship between distance (H) and the crimp percentage at 2000 m/min is shown in Table 5.4 and in Figure 5.7. At 2000 m/min winding speed, the maximum crimp effect, 9,8%, is observed in Sample 10 with the 100 cm distance and Q-C (7ºC-3ºC).

Table 5.5 Crimp – Distance effect (2010 m/min winding speed)

Winding Speed: 2010 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	10,6	9,3	9,5	12,1	5,3
90	8,6	8	9,5	12,1	5,3
100	9	9,3	8,3	12,1	5,3
110	9,3	10,3	8	12,1	5,3

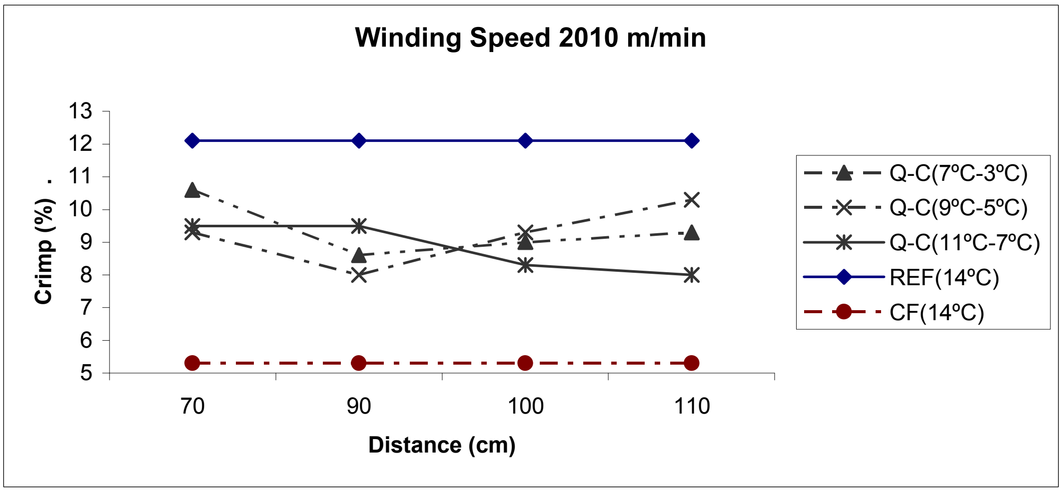


Figure 5.8 Crimp – Distance Effect (2010 m/min winding speed)

The experimental result of the relationship between the distance (H) and the crimp percentage at 2010 m/min is shown in Table 5.5 and in Figure 5.8. At 2010 m/min winding speed, the maximum crimp effect is examined in Sample 3, 10,6 %, with 70 cm distance and Q-C (7°C-3°C).

Table 5.6 Crimp – Distance effect (2020 m/min winding speed)

Winding Speed: 2020 m/min					
Distance H (cm)	Q-C (7°C-3°C) (%)	Q-C (9°C-5°C) (%)	Q-C (11°C-7°C) (%)	REF(14°C) (%)	CF(14°C) (%)
70	10,8	9,6	10	12,1	5,3
90	9,1	9,1	9,8	12,1	5,3
100	8,8	9,8	8,5	12,1	5,3
110	9,5	10,3	8,5	12,1	5,3

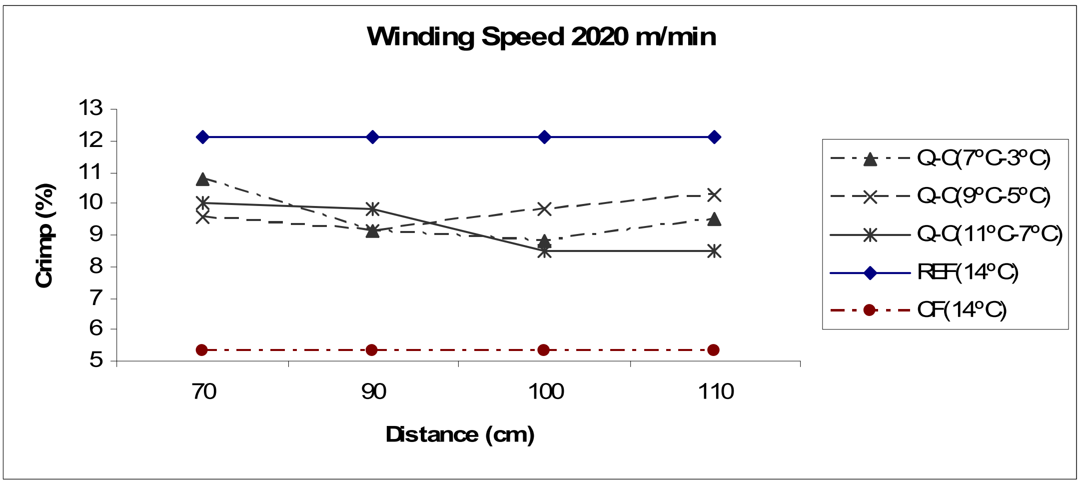


Figure 5.9 Crimp – Distance Effect (2020 m/min winding speed)

The experimental result of the relationship between distance (H) and the crimp percentage at 2020 m/min is shown in Table 5.6 and in Figure 5.9. At 2020 m/min winding speed, the maximum crimp effect is determined in Sample 4, the distance is 70 cm and Q-C (7ºC-3ºC) at 10,8% crimp effect. And the minimum crimp level is determined as 8,5% at Q-C (11ºC-7ºC) at distances are 100 and 110 cm.

In general, best results are obtained in the distance of 70 cm for the crimp levels in different winding speeds and different Q-C temperatures. Thus, it can be said that while the local cooling unit is closer to the spinneret, the distance H value gives better crimp.

Another result is about the winding speeds. Crimps of samples which are processed in higher winding speeds are better than the crimp of samples which are processed in slower winding speeds. Highest crimp level is examined at 2020 m/min winding speed. Second better crimp effect is observed at 2010 m/min winding speed. Crimp effects of samples which are processed at 2000 m/min winding speed are better than that of samples treated at 1990 m/min. Therefore, the lowest crimp level is observed at 1990 m/min winding speed.

The last result of the test is the effect of different Q-C temperatures on crimping. The better crimp is gotten at Q-C (7ºC-3ºC). Consequently, the greater Q-C temperature, the lower crimp level values.

As a result of the test, from overall of the samples, it is determined that the best crimp level is obtained from the lowest distance, the lowest quench-chiller temperature and the maximum winding speed.

5.5.2. Yarn Shrink of self-Crimp FYS

In Table 5.7, the yarn shrink values of self-crimp samples obtained from the shrink measurements are given.

Table 5.7 Shrink values of samples

Sample No	1	2	3	4	5	6	7	8	9	10
Shrink (%)	5,1	5,8	6,3	6,3	5	5,1	6	6,8	6,1	7
Sample No	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Shrink (%)	6,5	6,1	5,8	6,3	5,8	6,5	4,8	5,8	6,6	7
Sample No	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Shrink (%)	5	6,1	5,1	6,3	5,3	5,8	6,5	7	5,8	6,1
Sample No	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Shrink (%)	7,1	7	6,1	6	6,3	7,1	6,1	6	6,8	7,3
Sample No	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**RF**	**CF**
Shrink (%)	6,3	6,1	6	6	5	5,5	6	6,3	3,1	3,2

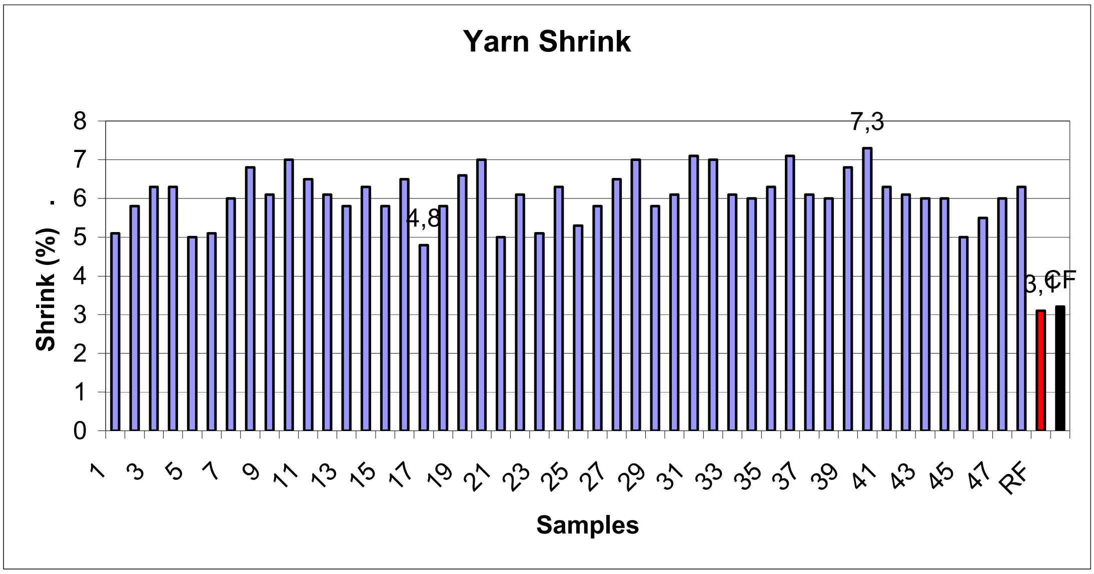


Figure 5.10 Yarn Shrink of self-crimp FYS samples

It is obvious from Figure 5.10 and Table 5.7 that the yarn shrink value of RF and that of CF samples are very closer to each other. But the shrink value of the self-crimp samples are considerably higher than the yarn shrink values of RF and CF. Therefore, shrink value which is closer to RF shrink value is the minimum one and it is the best value among the values of all self-crimp FYS samples. As shown in Figure 5.10, in Table 5.1 and in Table 5.7, Sample 40 has the highest shrink value

(7,3%). The test parameters for Sample 40 are; Distance down from spinneret H=90 cm, Q-C (11ºC-7ºC) and the winder speed is 2020 m/min.

On the other hand, the lowest shrink value (4,8%) belongs to the Sample 17. Sample 17 has the best shrink value in samples. The test parameters for the sample 17 are; Distance down from spinneret H=70 cm, Q-C (9ºC-5ºC) and the winder speed is 1990 m/min.

5.5.2.1. Shrink – Distance Effect

Table 5.8 Shrink – Distance effect (1990 m/min winding speed)

Winding Speed: 1990 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	5,1	4,8	6,1	3,1	3,2
90	5	5	6,1	3,1	3,2
100	6,1	5,3	6,3	3,1	3,2
110	5,8	5,8	5	3,1	3,2

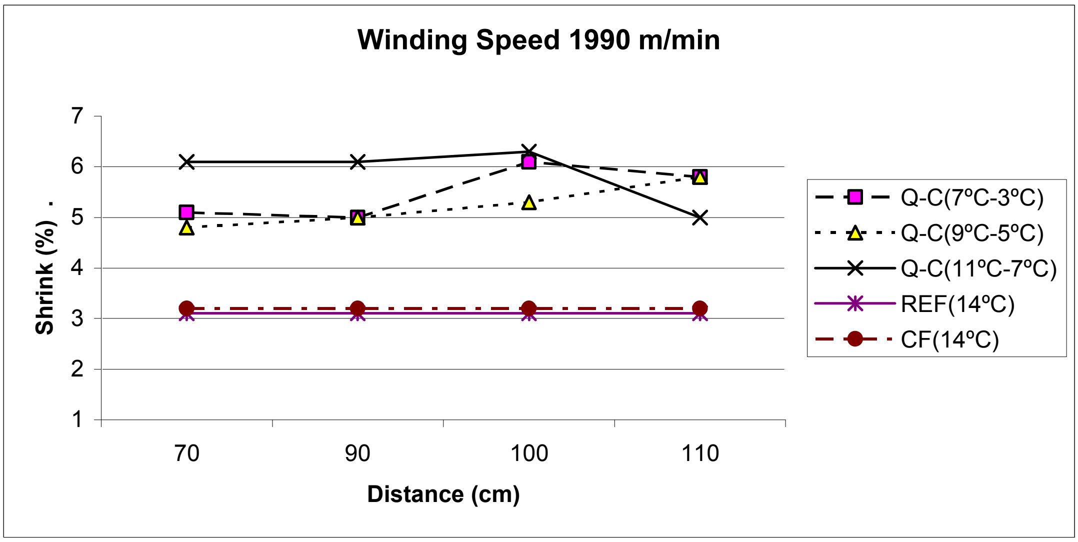


Figure 5.11 Shrink – Distance Effect (1990 m/min winding speed)

The experimental result of the relationship between distance (H) and the shrink percentage at 1990 m/min is shown in Table 5.8 and in Figure 5.11. The shrink percentage of RF sample is 3,1% and that of CF sample is 3,2%. The shrink levels of RF and CF samples are nearly same.

At 1990 m/min winding speed, the best shrink effect (4,8%) is observed in Sample 17 with 70 cm distance and Q-C (9ºC-5ºC).

Table 5.9 Shrink – Distance effect (2000 m/min winding speed)

Winding Speed: 2000 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	5,8	5,8	6	3,1	3,2
90	5,1	6,1	6	3,1	3,2
100	7	5,8	6,1	3,1	3,2
110	6,3	6,1	5,5	3,1	3,2

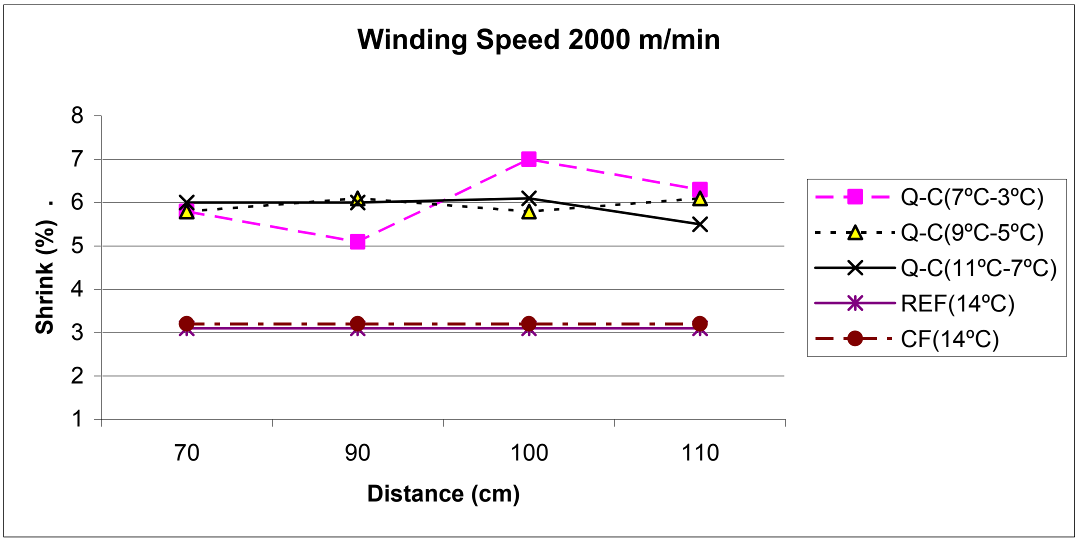


Figure 5.12 Shrink – Distance Effect (2000 m/min winding speed)

The experimental result of the relationship between distance (H) and the shrink percentage at 2000 m/min is shown in Table 5.9 and in Figure 5.12. At 2000 m/min speed of winding the best shrink effect (5,1%), which means that the value closer to RF shrink effect, is observed in Sample 6 with 90 cm distance and Q-C (7ºC-3ºC).. Yet, other shrink values are higher at 2000 m/min winder speed than shrink values at 1990 m/min winder speed.

Table 5.10 Shrink – Distance effect (2010 m/min winding speed)

Winding Speed: 2010 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	6,3	6,6	6,3	3,1	3,2
90	6	5,1	6,8	3,1	3,2
100	6,5	6,5	6	3,1	3,2
110	5,8	7,1	6	3,1	3,2

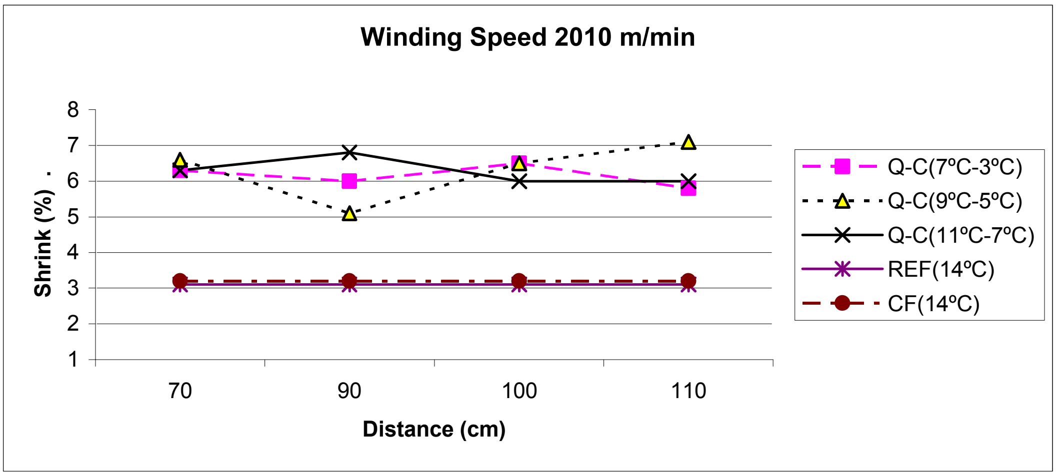


Figure 5.13 Shrink – Distance Effect (2010 m/min winding speed)

The experimental result of the relationship between distance (H) and the shrink percentage at 2010 m/min is shown in Table 5.10 and in Figure 5.13. At 2010 m/min speed of winding, the best shrink effect (5,1%), value closer to RF shrink effect, is obtained from Sample 23 with 90 cm distance and Q-C (9ºC-5ºC). In general, shrink levels at 2010 m/min winding speed are higher than shrink levels at 2000 m/min winding speed.

Table 5.11 Shrink – Distance effect (2020 m/min winding speed)

Winding Speed: 2020 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	6,3	7	7,1	3,1	3,2
90	6,8	6,3	7,3	3,1	3,2
100	6,1	7	6	3,1	3,2
110	6,5	7	6,3	3,1	3,2

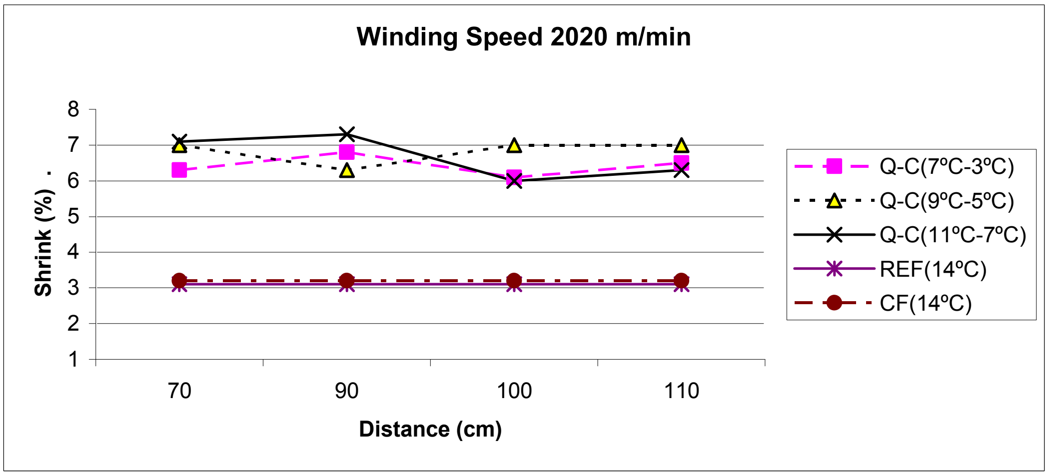


Figure 5.14 Shrink – Distance Effect (2020 m/min winding speed)

The experimental result of the relationship between distance (H) and the shrink percentage at 2020 m/min is shown in Table 5.11 and in Figure 5.14. At 2020 m/min speed of winding the best shrink effect (6%) , value closer to RF value, is seen in Sample 44 with 100 cm distance and Q-C (11ºC-7ºC). However, shrink levels at 2020 m/min winding speed are greater than shrink levels at 2010 m/min winding speed.

In all figures, it is seen that the quench temperatures do not have much effect on shrink levels. Yet, as shown in above figures, if the winding speed is increased, the shrink level is increased and it is deviated far from RF values. Samples at 1990 m/min winding speed have minimum shrink values and these values are much closer to shrink values of RF.

5.5.3. Yarn Elongation of Self-Crimp FYS

In Table 5.12, the yarn elongation values of self-crimp samples obtained from the elongation measurements are given.

Table 5.12 Elongation values of samples

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Elongation (%)	113,1	121,6	126,3	107,4	140,1	124,5	141,1	128,7	137,3	92,3
Sample No	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Elongation (%)	142,4	123,5	131,6	94,7	124	117,8	112,6	117,4	135,7	108,8
Sample No	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Elongation (%)	137,7	119,2	125,9	97	120,6	132,5	126,8	129,2	120,2	137,2
Sample No	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Elongation (%)	133	133,4	124	119,7	121,6	102,6	123	115	122,1	133,4
Sample No	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**RF**	**CF**
Elongation (%)	125,4	124	118,3	123,6	135,4	124	142	102,2	39,8	20,88

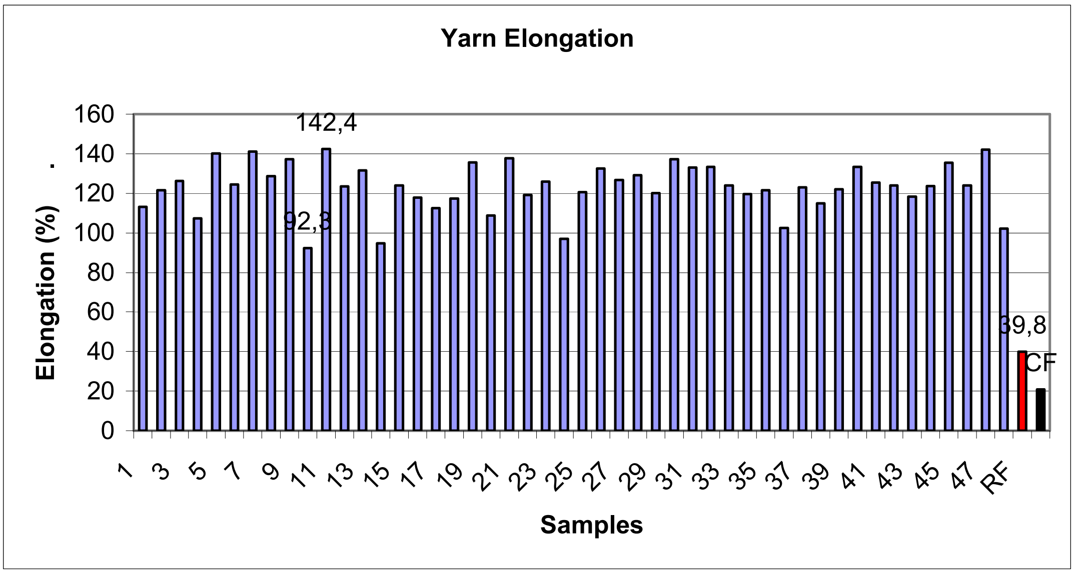


Figure 5.15 Yarn Elongation of self-crimp FYS samples

It is obvious from both Figure 5.15 and Table 5.12 that percentage of yarn elongation of RF is 39,8% and that of CF sample is 20,88%. As to be understood, CF elongation value is lesser than RF elongation value. However, elongation values of the self-crimp samples are considerably higher than yarn elongation values of RF and CF. It means that drafting ratio applied on the self crimp samples is not enough to reach the RF sample value.

The minimum elongation of sample which is closer to that of RF is the best value among values of all self-crimp FYS samples. As shown in Figure 5.15, Table 5.1 and Table 5.12, Sample 11 has the highest elongation value (142,4%). The test parameters for Sample 11 are; Distance down from spinneret H=100 cm, Q-C (7ºC-3ºC) and winder speed is 2010 m/min. On the other hand, the lowest elongation value (92,3%) belongs to Sample 10. Sample 10 has the best elongation value among all samples. The test parameters for the sample 10 are; Distance down from spinneret H=100 cm, Q-C (7ºC-3ºC) and the winder speed is 2000 m/min. The highest and the lowest elongation values are found in the same distance and in the same Q-C temperatures. Only the winding speeds differ.

5.5.3.1. Elongation – Distance Effect

Table 5.13 Elongation – Distance effect (1990 m/min winding speed)

Winding Speed: 1990 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	113,1	112,6	124	39,8	20,88
90	140,1	137,7	123	39,8	20,88
100	137,3	120,6	125,4	39,8	20,88
110	131,6	120,2	135,4	39,8	20,88

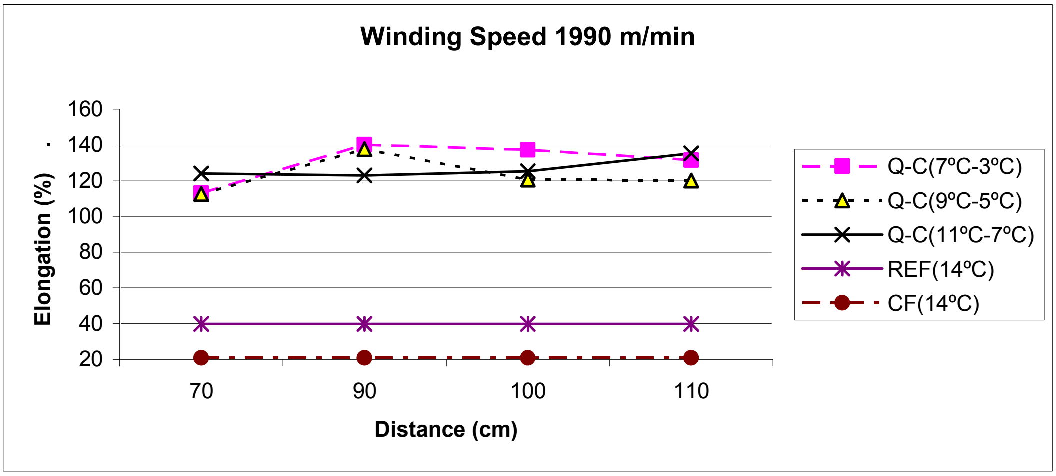


Figure 5.16 Elongation – Distance Effect (1990 m/min winding speed)

The experimental result of the relationship between distance (H) and the elongation percentage at 1990 m/min is shown in Table 5.13 and in Figure 5.16. At 1990 m/min speed of winding the closer elongation effect (112,6%) to RF value is attained from Sample 17 with 70 cm distance and Q-C (9ºC-5ºC). Sample 17 also has the lowest shrink value. The elongation percentage of RF is 39,80% and that of CF is 20,88%. BCF yarns are drawn at 3% percentage, and the self-crimp experiments done at same drafting point (3%) as normal percentages. But as seen from the results, the elongation values obtained are too high and the self-crimp samples are needed to be more drafted.

Table 5.14 Elongation – Distance effect (2000 m/min winding speed)

Winding Speed: 2000 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	121,6	117,4	119,7	39,8	20,88
90	124,5	119,2	115	39,8	20,88
100	92,3	132,5	124	39,8	20,88
110	94,7	137,2	124	39,8	20,88

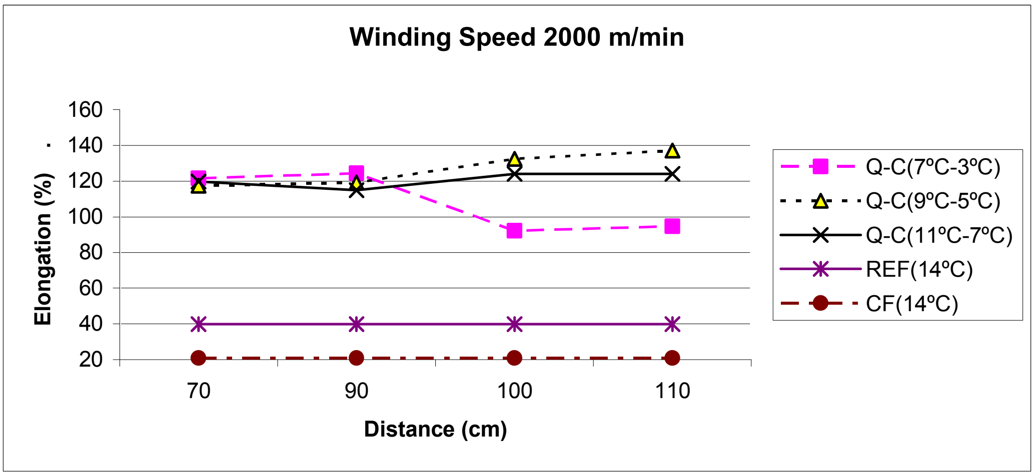


Figure 5.17 Elongation – Distance Effect (2000 m/min winding speed)

The experimental result of the relationship between distance (H) and the elongation percentage at 2000 m/min is shown in Table 5.14 and in Figure 5.17. At 2000 m/min speed of winding, the elongation effect (92,3%) which is closer to RF elongation is observed in Sample 10, with 100 cm distance and Q-C (7ºC-3ºC). Sample 10 has the lowest elongation value among all samples obtained by self-crimp FYS.

Table 5.15 Elongation – Distance effect (2010 m/min winding speed)

Winding Speed: 2010 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	126,3	135,7	121,6	39,8	20,88
90	141,1	125,9	122,1	39,8	20,88
100	142,4	126,8	118,3	39,8	20,88
110	124	133	142	39,8	20,88

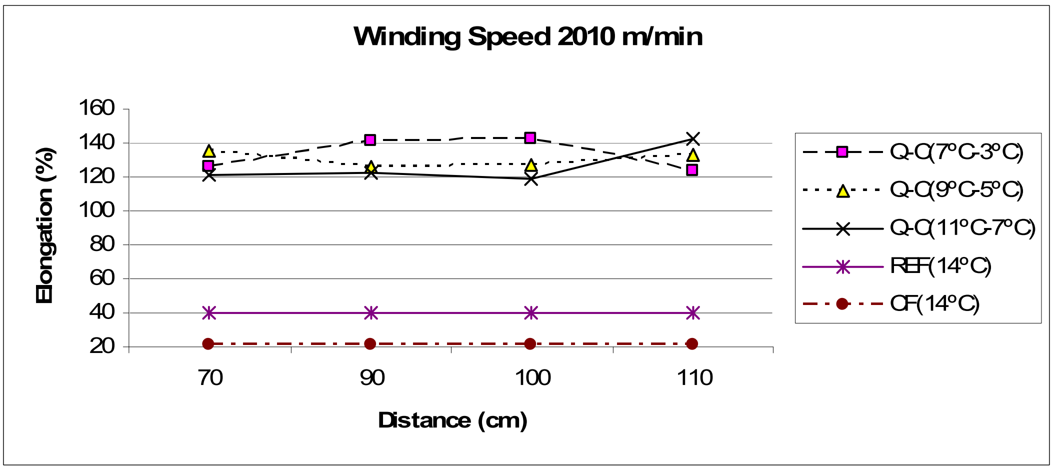


Figure 5.18 Elongation – Distance Effect (2010 m/min winding speed)

The experimental result of the relationship between distance (H) and the elongation percentage at 2010 m/min is shown in Table 5.15 and Figure 5.18. At 2010 m/min speed winding, the closer elongation effect (118,3%) to RF value is seen in Sample 43, with 100 cm distance is and Q-C (11ºC-7ºC).

Table 5.16 Elongation – Distance effect (2020 m/min winding speed)

Winding Speed: 2020 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	107,4	108,8	102,6	39,8	20,88
90	128,7	97	133,4	39,8	20,88
100	123,5	129,2	123,6	39,8	20,88
110	117,8	133,4	102,2	39,8	20,88

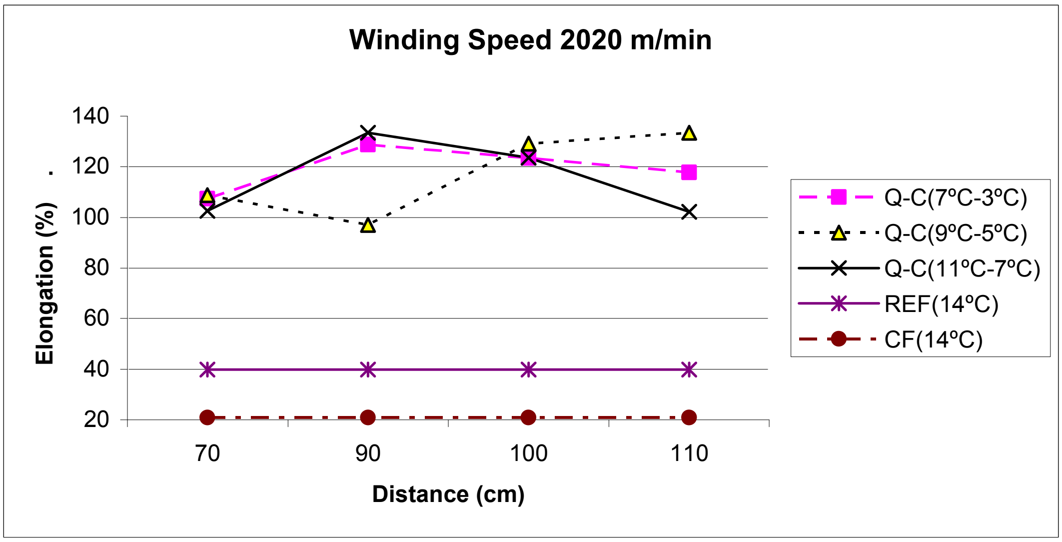


Figure 5.19 Elongation – Distance Effect (2020 m/min winding speed)

The experimental result of the relationship between distance (H) and the elongation percentage at 2020 m/min is shown in Table 5.16 and Figure 5.19. At 2020 m/min speed of winding, the closer elongation effect (97%) to RF value is obtained from Sample 24, at a 90 cm distance and Q-C (9ºC-5ºC).

As seen both from tables and figures, the elongation of self-crimp samples are higher than that of both RF and CF samples. Only, Sample 10 has closer elongation value to the RF value. High elongation stems from spinneret cross section type (circular cross section) and deficient drafting rollers or less drafting percentage on the BCF system.

5.5.4. Yarn Strength of self-Crimp FYS

In Table 5.17, the yarn strength values of self-crimp samples obtained from the strength measurements are given**.**

Table 5.17 Strength values of samples

Sample No	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Strength (%)	2,4	2,2	2,1	2,1	2,4	2,3	2,5	2,3	2,3	2,1
Sample No	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Strength (%)	2,3	2,3	2,2	2,2	2,2	2,1	2,3	2,2	2,3	2,3
Sample No	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Strength (%)	2,3	2,3	2,3	2,1	2,4	2,4	2,2	2,3	2,2	2,4
Sample No	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Strength (%)	2,3	2,2	2,1	2,3	2,2	2,1	2,2	2,2	2,2	2,2
Sample No	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**RF**	**CF**
Strength (%)	2,3	2,2	2,3	2,3	2,3	2,3	2,3	2,1	2,7	4,2

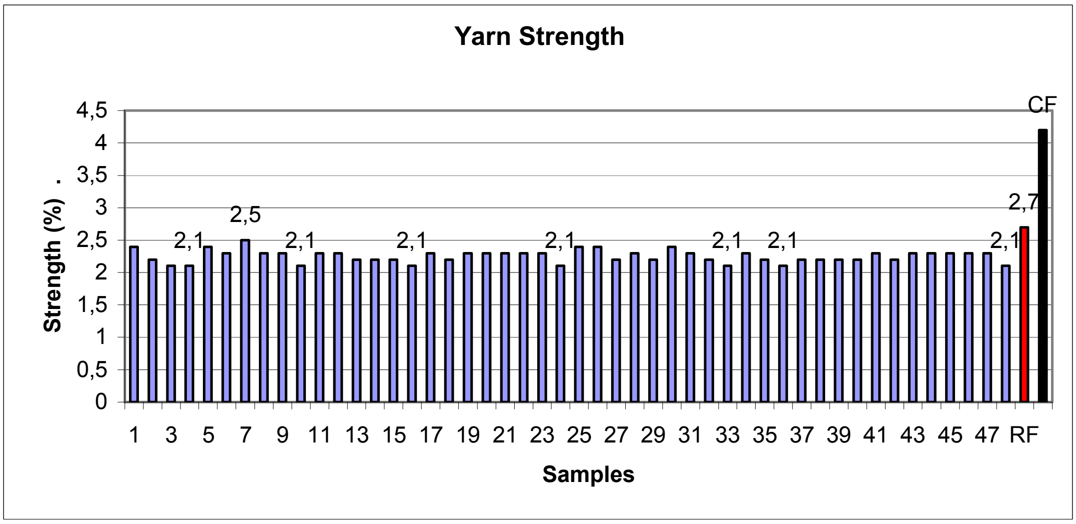


Figure 5.20 Yarn Strength of self-crimp FYS samples

It is obvious from both Figure 5.17 and Table 5.20 that the yarn strength value of RF is 2,7% and that of CF sample is 4,2%. The RF strength value is lesser than the CF strength value. Furthermore, the strength values of the self-crimp samples are nearly same as the strength values of RF.

The maximum value which is closer to RF strength value is the best value among the all self-crimp FYS samples. As shown in Figure 5.17, Table 5.1 and Table 5.20, the Sample 7 has the highest 2,5% strength value. The test parameters for Sample 7 are;

Distance down from spinneret H=90 cm, Q-C (7ºC-3ºC) and the winder speed is 2010 m/min. On the other hand, the lowest strength value 2,1% belongs to the Sample 4, Sample 10, Sample 16, Sample 24, Sample 33, Sample 36 and Sample 48. As shown in Table 5.1, the lowest strength value samples are obtained at the highest winding speed. Except the winding speed of Sample 10 (Winding speed: 2010 m/min), winding speed of all these 2,1% strength value having samples is 2020 m/min. This reason shows that the highest winding speed is caused to decreased yarn strength.

5.5.4.1. Strength – Distance Effect

Table 5.18 Strength – Distance effect (1990 m/min winding speed)

Winding Speed: 1990 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	2,4	2,3	2,1	2,7	4,2
90	2,4	2,3	2,2	2,7	4,2
100	2,3	2,4	2,3	2,7	4,2
110	2,2	2,2	2,3	2,7	4,2

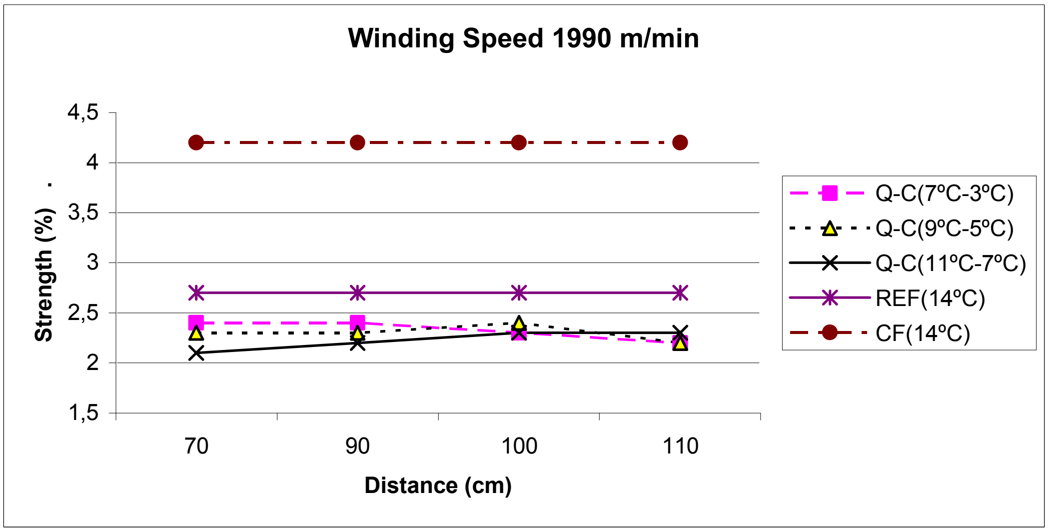


Figure 5.21 Strength – Distance Effect (1990 m/min winding speed)

The experimental result of the relationship between distance (H) and the strength percentage at 1990 m/min is shown in Table 5.18 and Figure 5.21. CF yarns have more strength than BCF yarns. Moreover, as seen in both figures and tables, the self-crimp samples are very closer to the RF samples in the strength percentages. The strength percentage (2,4%) is very closer to RF value at 1990 m/min winding speed, at Q-C (7ºC-3ºC) and at 70 cm and 90 cm distances.

Table 5.19 Strength – Distance effect (2000 m/min winding speed)

Winding Speed: 2000 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	2,2	2,2	2,3	2,7	4,2
90	2,3	2,3	2,2	2,7	4,2
100	2,1	2,4	2,2	2,7	4,2
110	2,2	2,4	2,3	2,7	4,2

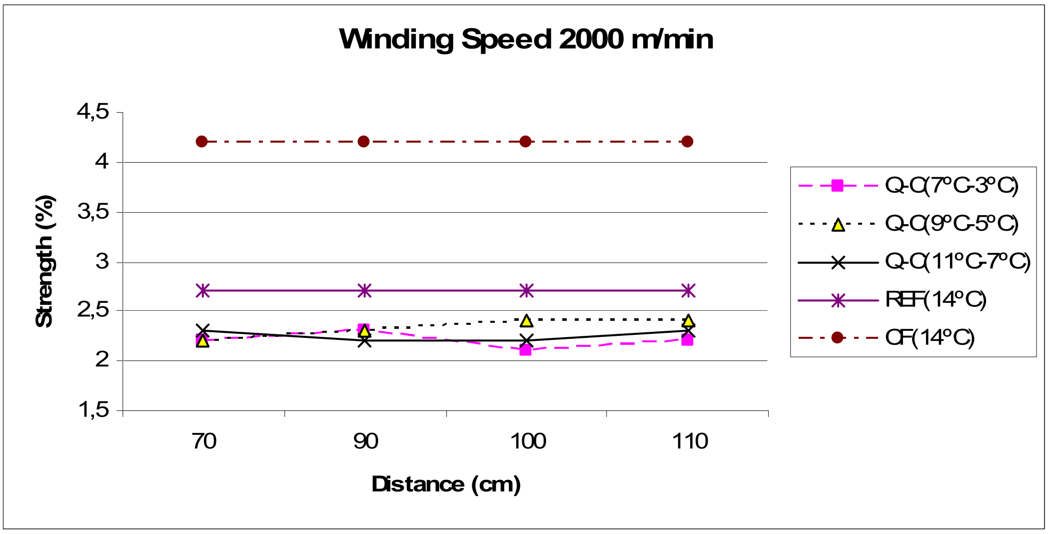


Figure 5.22 Strength – Distance Effect (2000 m/min winding speed)

Table 5.20 Strength – Distance effect (2010 m/min winding speed)

Winding Speed: 2010 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	2,1	2,3	2,2	2,7	4,2
90	2,5	2,4	2,2	2,7	4,2
100	2,3	2,2	2,3	2,7	4,2
110	2,2	2,3	2,3	2,7	4,2

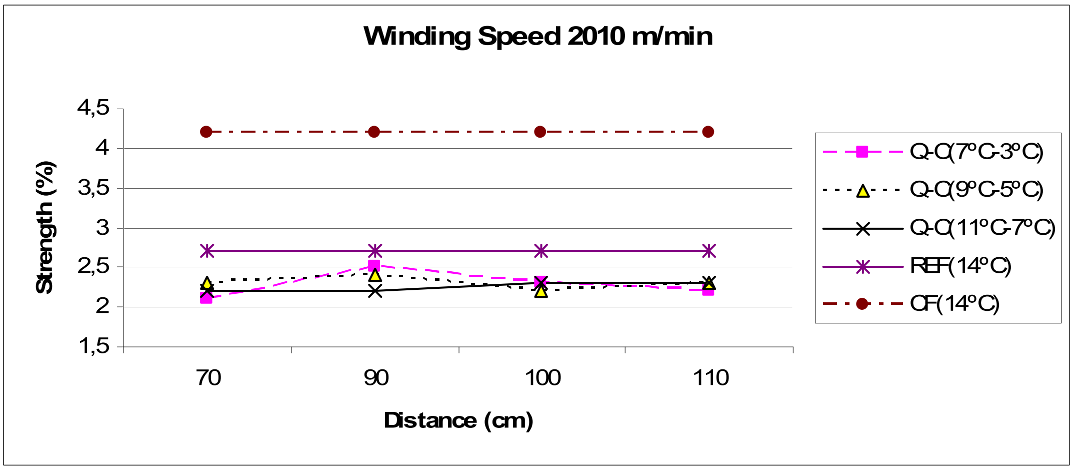


Figure 5.23 Strength – Distance Effect (2010 m/min winding speed)

Table 5.21 Strength – Distance effect (2020 m/min winding speed)

Winding Speed: 2020 m/min					
Distance H (cm)	Q-C (7°C-3°C) (%)	Q-C (9°C-5°C) (%)	Q-C (11°C-7°C) (%)	REF(14°C) (%)	CF(14°C) (%)
70	2,1	2,3	2,1	2,7	4,2
90	2,3	2,1	2,2	2,7	4,2
100	2,3	2,3	2,3	2,7	4,2
110	2,1	2,2	2,1	2,7	4,2

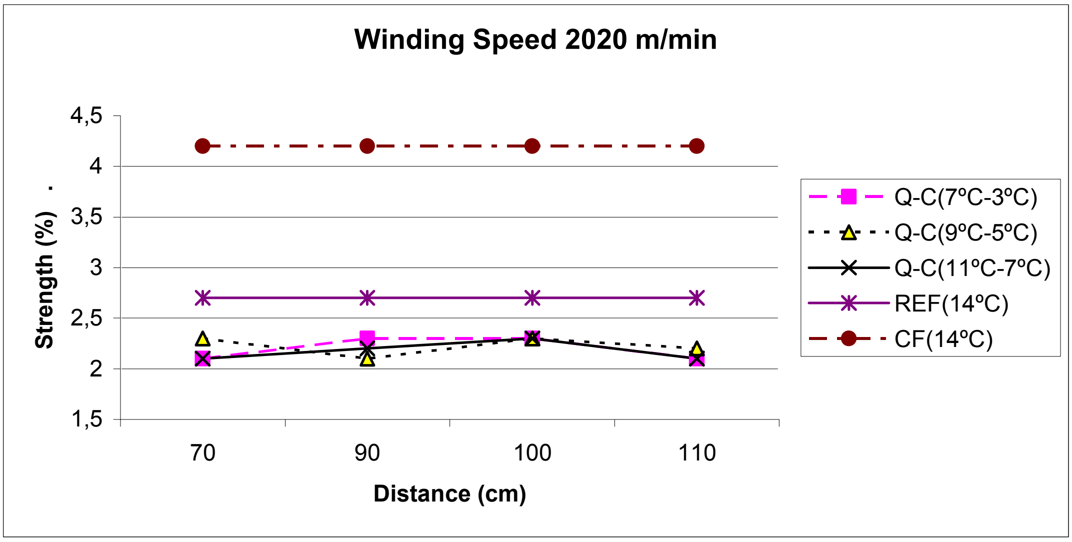


Figure 5.24 Strength – Distance Effect (2020 m/min winding speed)

As seen from whole Tables and Figures, the winding speed 1990 m/min and 2010 m/min have closer strength values to RF strength values. When the strength values of self-crimp samples are checked, they are generally similar to each other despite of Quench temperature differences. The only change is observed when winding speeds are altered. The higher the winding speed, the lower the strength is. In addition, distance alteration has no much effect on the yarn.

5.5.5. Yarn Count (Dtex) of self-Crimp FYS

The yarn count values of self-crimp samples obtained from the count measurements are given in Table 5.22.

Table 5.22 Count Values of samples

Sample No	1	2	3	4	5	6	7	8	9	10
Count (Dtex)	797	792	791	788	791	794	788	787	793	789
Sample No	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Count (Dtex)	791	788	788	791	783	785	790	757	786	788
Sample No	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**
Count (Dtex)	802	783	793	784	782	791	779	780	792	788
Sample No	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
Count (Dtex)	780	790	798	793	800	793	801	785	796	796
Sample No	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**RF**	**CF**
Count (Dtex)	789	796	795	793	797	793	784	791	795	719

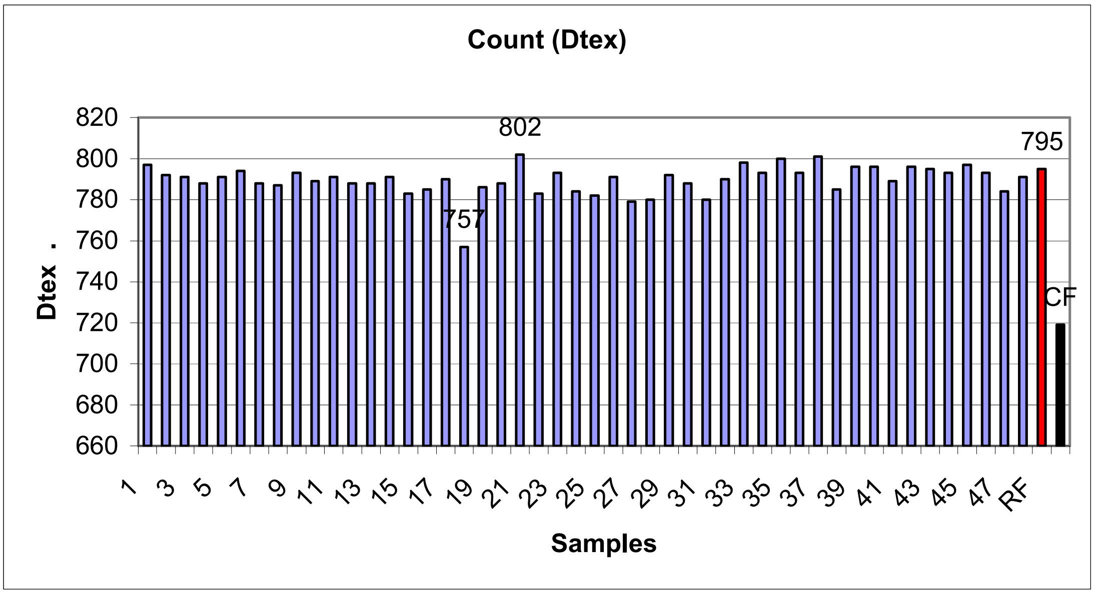


Figure 5.25 Yarn Count of self-crimp FYS samples

It is shown in Figure 5.25 and Table 5.22, the yarn count value of RF is 795 Dtex and that of CF sample is 719 Dtex. The CF count value is lower than the RF count value. However, the count values of the self-crimp samples are nearly same as the count value of RF.

The value which is closer to RF count is the best one among the values of self-crimp FYS samples. As shown in Figure 5.25, Table 5.1 and Table 5.22, Sample 21 has the highest 802 Dtex count value. The test parameters for Sample 21 are; Distance down from the spinneret H=90 cm, Q-C (9ºC-5ºC) and the winder speed is 1990 m/min.

On the other hand, the lowest 757 Dtex count value belongs to the Sample 18. The test parameters for Sample 18 are; Distance down from spinneret H=70 cm, Q-C (9ºC-5ºC) and the winding speed is 2000 m/min. The highest and the lowest count values are found as the same Q-C temperatures, but the winding speeds and distances are dissimilar in these two samples. Sample 43 has the same count level with RF count value. The test parameters for Sample 43 are; Distance down from the spinneret H=100 cm, Q-C (11ºC-7ºC) and the winding speed is 2010 m/min.

5.5.5.1. Count (Dtex) – Distance Effect

Table 5.23 Count – Distance effect (1990 m/min winding speed)

Winding Speed: 1990 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	797	790	798	795	719
90	791	802	801	795	719
100	793	782	789	795	719
110	785	792	797	795	719

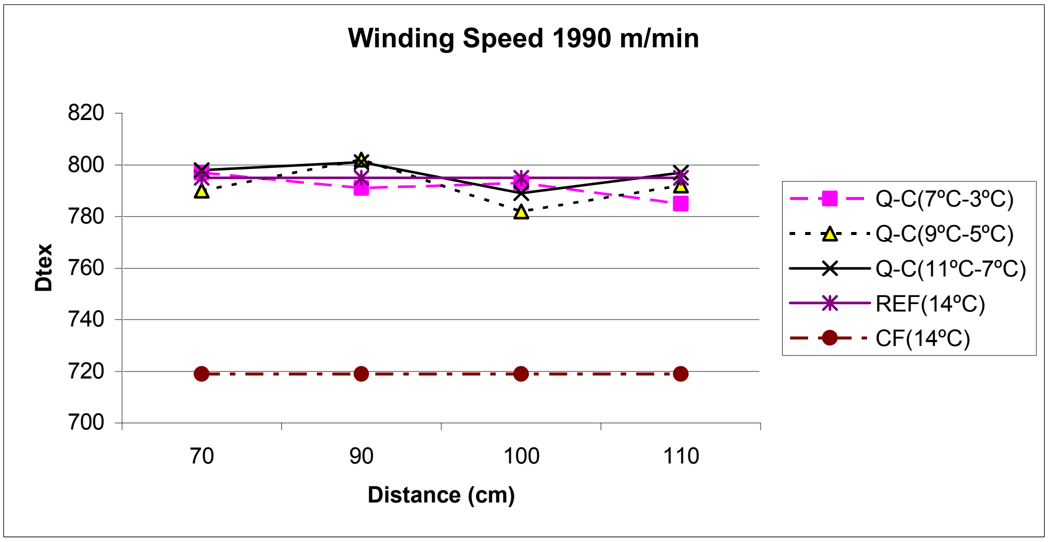


Figure 5.26 Count – Distance Effect (1990 m/min winding speed)

The experimental result of the relationship between distance (H) and the count at 1990 m/min is shown in Table 5.23 and Figure 5.26. The count (dtex) values are affected by the melting pumps speeds, the spinning speed (drafting speed), the drafting ratio and the winding speed. The quench effect is very less in order to determine the count of the yarn in BCF system.

As seen in Table 5.23 and Figure 5.26, at 1990 m/min winding speed, when the quench temperature increases, simultaneously the count of the yarn decreases. Moreover, when the distance H increases, the count of the yarn decreases. The values which are closer to RF values are obtained in Q-C (7ºC-3ºC).

Table 5.24 Count – Distance effect (2000 m/min winding speed)

Winding Speed: 2000 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	792	757	793	795	719
90	794	783	785	795	719
100	789	791	796	795	719
110	791	788	793	795	719

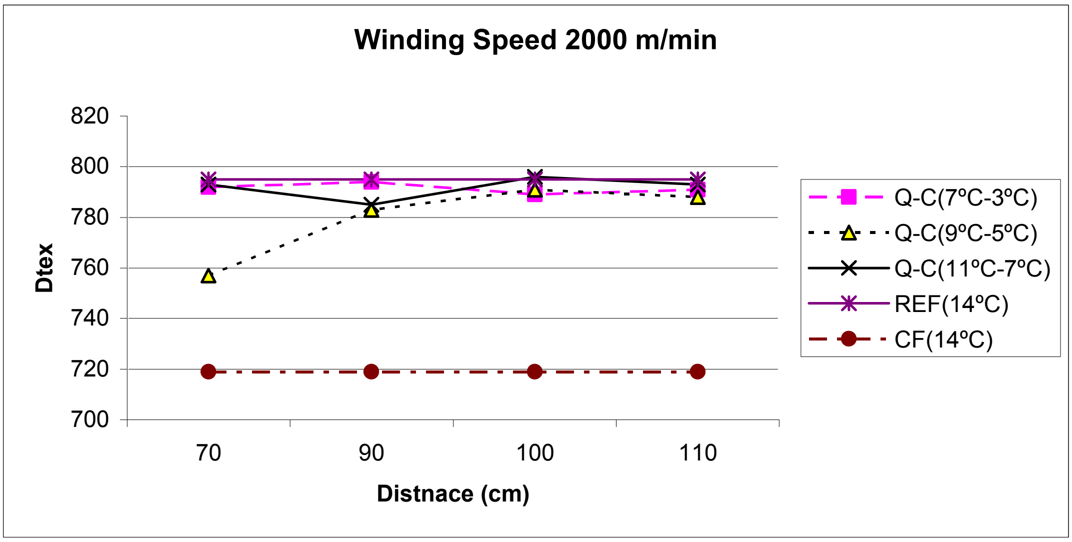


Figure 5.27 Count – Distance Effect (2000 m/min winding speed)

Table 5.25 Count – Distance effect (2010 m/min winding speed)

Winding Speed: 2010 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	791	786	800	795	719
90	788	793	796	795	719
100	791	779	795	795	719
110	783	780	784	795	719

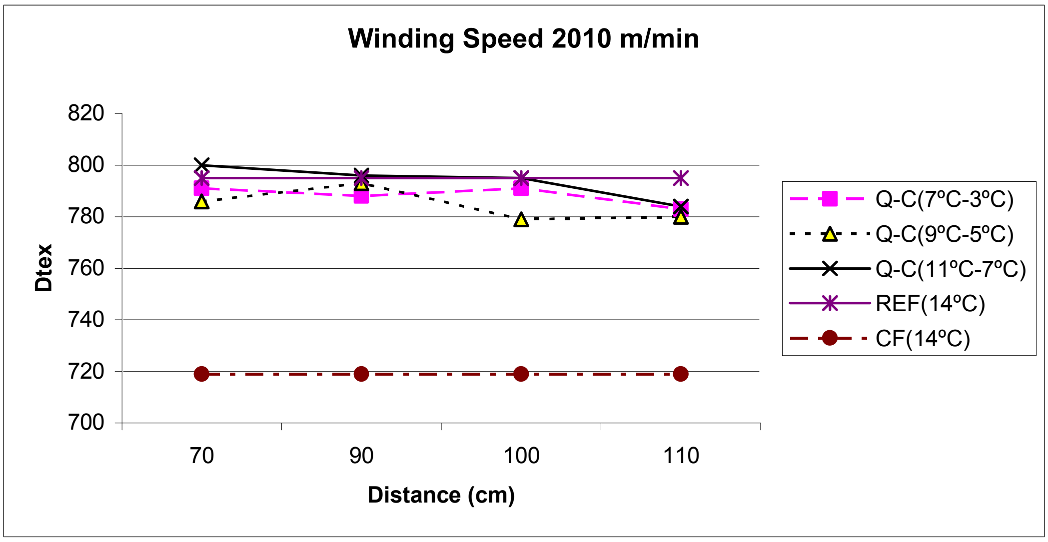


Figure 5.28 Count – Distance Effect (2010 m/min winding speed)

Table 5.26 Count – Distance effect (2020 m/min winding speed)

Winding Speed: 2020 m/min					
Distance H (cm)	Q-C (7ºC-3ºC) (%)	Q-C (9ºC-5ºC) (%)	Q-C (11ºC-7ºC) (%)	REF(14ºC) (%)	CF(14ºC) (%)
70	788	788	793	795	719
90	787	784	796	795	719
100	788	780	793	795	719
110	785	790	791	795	719

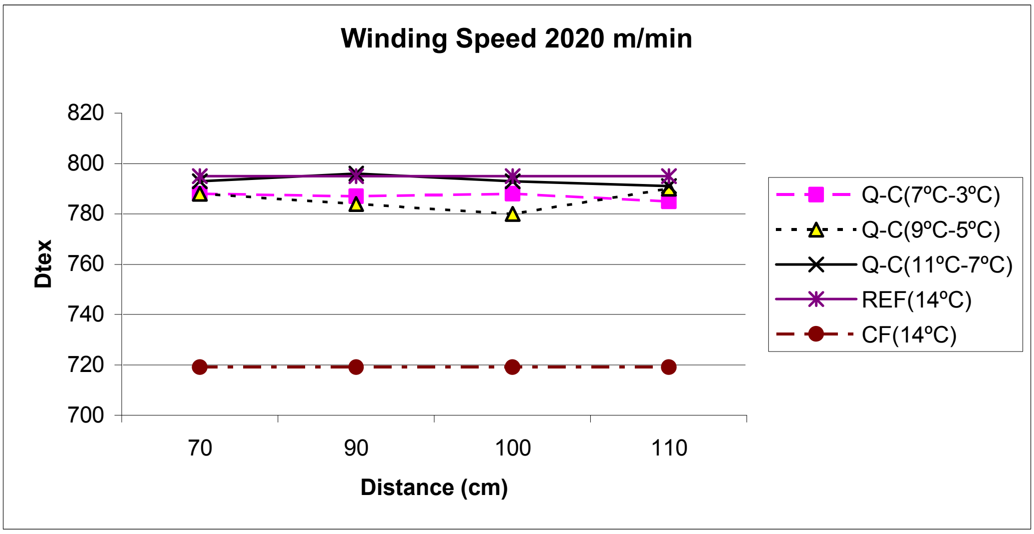


Figure 5.29 Count – Distance Effect (2020 m/min winding speed)

As seen in Figure 5.29 and Table 5.26, the closer RF count appears at 2020 m/min winding speed and Q-C (11ºC-7ºC). The counts of the yarns are nearly same as that of RF.

In general, changes in the quench temperatures have very low effect on the yarn count. Yet, the winding speed has effects on the winding tension of the yarn. Thus, this gives result to different yarn counts in self-crimp FYS. As seen in Figure 5.25, when the winding speed gets higher, the yarn count gets lower. Based on this result, the distance H has no effect on the count of the yarn.

CHAPTER 6

CONCLUSIONS

The Self-Crimp FYS was applied on BCF system to obtain yarn crimp with a new texturing system from % 100 Polypropylene material. The experiments were done on the adapted SML BCF machinery.

In the study of thesis, the new type of spinnerets were designed and manufactured by Özçelik A.Ş. The local cooling unit is designed, developed and manufactured by local turner in Gaziantep. Thereafter, the new designed spinnerets and local cooling apparatus were adapted on SML BCF machine. All the experiments were done in KARAVELİ TEKSTİL.

In the experimental studies, the spinnerets and the local cooling unit were designed and developed two times. The first experiment was done with the first spinneret and the first local cooling apparatus. However, in the first experiment, while the self crimp FYS is tested, some problems are encountered. One of the problems stemed from the melt pump section. Because, there were two spinneret packages and one melt pump. One of them has 14 filament holes and the other has 144 filament holes. As a result, this situation simply caused pressure and flow action problems. The other problem was about winding the yarn onto bobbin. Normally, filaments are respectively followed a route. They are sucked from the suction gun, sent to the draw unit and finally to reached to the winder. Yet, in the test the yarn can not be drawn and can not be winded onto the bobbin. Nevertheless, the result of the first test shows that the self crimped FYS is practically true and workable, but because of the design and production problems, the crimped level can not be obtained.

Second experiment was done with the designed spinnerets and the designed local cooling apparatus. The experiment duration was about 9 hours. In the begining of the second experiment, yarns can not be drafted and wound onto the carton bobbin. Even though the flow of yarn on the cold tube is not regular and smooth, meanwhile, the cold tube can be touched to hot yarn continuously, smoothly and regularly. Thus, the yarn can be drafted and winded onto carton bobbins. Consequently, self-crimp FYS is carried out on the samples obtained from the second experiment.

Winded bobbins are checked and it is figured out that before the yarn is reached to the drafting unit, at the suction gun, a good crimp is attained on waste yarn. However, after the drafting and winding the yarn take a flat shape on the bobbin. It is suspected that pressure on winding roller may be effective on the deformation of the yarn shape. Namely, a flat shape is occurred on the yarn.

As a result of the tests, the crimp level of Self-Crimp FYS is higher than that of the CF yarns, but lower than that of the hot air-jet texturing. The best crimp level closer to crimp level of RF is obtained on Sample 4 with 2020 m/min speed of winding, the distance (H) is 70 cm and Q-C (7ºC-3ºC) at 10,8 % crimp effect. The reference crimp level is 12,1 %. It is observed that crimp level is decreased either when the distance of the local cooling unit is increased or when the Quench temperature is increased. In addition, when the winding speed is increased, the crimp level is increased. As a result, it is obtained that the lowest distance, the lowest quench temperature and the maximum winding speed give the best crimp level.

The shrink levels of Self-Crimp FYS samples are nearly same as those of RF and CF samples. The shrink levels of self-crimp samples are higher than the shrink levels of RF and CF. Overall test results represent that the quench temperatures do not have big effect on the shrink level. Yet, when the winding speed is increased, then the shrink percentage is increased. The winding speed affects the shrink level, because when the speed is increased, tension on the yarn is increased, so the shrink is getting higher. However, shrink levels considerably differ from the shrink values of RF. The best shrink value which is closer to RF shrink value is carried out at 1990 m/min speed.

The elongations of self-crimp samples are greater than that of RF and CF samples. Only values of Sample 10 at 2000 m/min winding speed, with Q-C (7ºC-3ºC), distance 100 cm and the elongation (% 92,8) get closer to RF values. The spinneret cross section type (circular cross section) is effective on shrink level. Moreover, the drafting rollers or drafting percentage on the BCF system affect the elongation of the yarn. In the experiment, the elongation levels of the samples are not well obtained with respect to reference levels.

Strength levels are nearly same as the strength levels of the reference sample. Changes on the quench temperatures have very less effect on the strength of the yarn. Yet, changes on the winding speed affect the yarn in a way that when the winding speed is increased, the strength level decreases.

Count of the yarn is established by the melt pump speed, the feed rolls, the drafting rollers speed and the winding speeds. Sample 43 has the same count level with RF count value among all samples. Test parameters for the sample 43 are; Distance down from the spinneret H=100 cm, Q-C (11ºC-7ºC) and the winding speed is 2010 m/min. The counts of the self-crimped yarn samples are nearly same as the count of reference sample. All the other parameters of self-crimped samples are same as those of RF sample. Therefore, the winding speed affects the count of yarn. Because, when the speed is increased, the count of the yarn decreases.

In conclusion, by the test and results, the theorem of self crimp FYS is proved and it is seen that the method is workable. In addition, the self crimp FYS can be applied on BCF system.

Recommendations

The further study on this subject may be structured as follows:

- The crimp level of self-crimp FYS is lower than that of Hot air-jet texturing method. Therefore, the crimp level is needed to be increased to the crimp levels of hot air-jet texturing. Shrink and elongation values must be reduced to the reference values. These problems can be solved by developing the local cooling unit and adjusting right drafting settings.

- In the experimental study the water is used to get the pipe cold. It could be useful in the next investigations that when much colder materials will be used, the local cooling unit will get colder and the heat exchange on the yarn will be higher. Thus, crimp level will be obtained in high values.

- The friction between the local cooling unit and filaments were occurred the heat on the tube. So, if local cooling unit (tube) designed by turning itself with the help of rollers, then the friction on the local cooling unit gets lower. The molecular orientation will be higher on the filaments and gets more crimp on the filaments.

- On the other hand, SML machine is originally designed for Hot air-jet texturing device. Experiments are done on one section of the SML machine and new designed apparatus is adapted on this section. BCF machine is needed to be new designed for self-crimp apparatus. Yarn flow ways, yarn guides, the position of the drafting godets and winders are designed and set as required in self-crimp FYS. Thus, the crimp levels of self-crimp FYS will be reached to the crimp levels of Hot air-jet texturing.

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