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Review Article

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A review on Air-Jet Textured Yarn Spinning Technology (ATY) in the global textile industry

Abstract

In this theoretical review study included Air-Jet Textured Yarn spinning technology (ATY); its importance, formation mechanism principle, yarns used, and general properties were explained in detail, supported by images and tables from various sources. Moreover, the specific ATY yarn process parameters required for ATY yarn production and the quantitative values of these process parameters were presented. Finally, the effects of ATY yarn types, and various ATY yarn process parameters on the thermal comfort, physical, and mechanical properties of textile-based woven, and knitted fabrics were explained. According to the results included ATY yarn production machines produced by DuPont and Heberlain Companies have generally used for the production of ATY yarns nowadays. Moreover, multi-jet systems (4 jets) called the Taslan have widely used because they affect the air pressure values, and air-flow regime more homogeneously in various yarn formation axes. Effective technical parameters for ATY yarn production are jet (nozzle) type, jet (nozzle) angle (°), overfeed ratio, amount of compressed air-flow (volumetric air-flow ratio), number of air-jets (nozzles), air-jet inner diameter (mm), production speed (m/min), heater and cooling plate temperatures (°C), times, lengths (mm), inner diameters, pre-tension values, types, and cross-sections of yarns and filaments, wetting of the yarn and the elasticity modulus of the deflection ball of the yarn (N/mm^2). Additionally, FDY structure, yarn count (dtex)/filament count from 80/24 to 1666/1000, overfeed ratio value from 5.5 to 36, air pressure value from 7 bar to 10 bar, production speeds from 300 m/min to 500 m/min, a draft ratio value of between 1.75 and 2.19, and a temperature value of 180 °C to 200 °C are generally used in the production of ATY yarns. Texturing property (bulky volume), instability, and mass loss increase, but tensile strength decreases as air pressure increases. These effects are more evident in fine yarn counts (dtex). Tensile strength increases, but instability, and mass loss decrease as the texturing speed increases. Water consumption has no effect on the physical, mechanical, and thermal comfort properties of both woven, and knitted fabrics with ATY yarn structures. POY and FDY structured PET, PA 6, PA 6.6, PP, PI, CV, CO, CMD, PPD-T, and EA yarns are used in the production of ATY yarns. ATY yarns are widely used in home textiles, clothing, airbags, carpets, and upholstery fabrics. The multi-lobed section PET ratio should be high for high bursting strength, tensile strength, air permeability, maximum breaking force, texturing property (bulky volume) and linear density of the yarn values, high shear strength, maximum percent elongation at break, thermal conductivity, pilling resistance. The ratio of CMD, CV, PA 6, or PA 6.6 should be high for water vapor permeability values. The CO ratio should be high for high thermal resistance. The PET ratio should be high for high abrasion resistance values. Shear strength, maximum percent elongation at break, elastic recovery behavior, and abrasion resistance increase as the EA ratio increases. ATY yarns have lower tensile strength, maximum breaking force, maximum percent breaking elongation, breaking work, and abrasion resistance values compared to ring, and OE rotor yarns (except DTY), respectively. The issue of recycling is extremely important for the sustainability of the global textile industry in the future. For this important issue, textile waste must be classified, collected, and evaluated. Moreover, optimization of various experimental production process parameters should be ensured in order to preserve the mechanical properties of blended yarns, especially CO/PET, and CO/PA yarn structures, by reducing chemical, water, energy, and labor costs.

Keywords: Air-Jet Textured Yarn Spinning Technology (ATY), process parameters, yarns, fabrics, general properties

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Introduction

In this theoretical review study included Air-Jet Textured Yarn spinning technology (ATY); its importance, formation mechanism principle, yarns used, and general properties were explained in detail, supported by images and tables from various sources. Moreover, the specific ATY yarn process parameters required for ATY yarn production and the quantitative values of these process parameters were presented. Finally, the effects of ATY yarn types, and various ATY yarn process parameters on the thermal comfort, physical, and mechanical properties of textile-based woven, and knitted fabrics were explained. This study aimed to summarize the information of various experimental studies on Air-Jet Textured yarn spinning technology (ATY), to ensure the optimization of the production process parameters of ATY yarn production according to yarn types, and to produce home textiles such as casual clothes, airbags, and upholstery fabrics where thermal comfort will be at the forefront. It has been prepared for the technical optimization of its effects on various structural, physical, and mechanical properties of woven or knitted fabrics to be produced for their applications.

Importance, formation mechanism principle, yarns used, and general properties for Air-Jet Textured Yarn Spinning Technology (ATY)

Air-Jet Textured Yarn spinning technology (ATY) was produced with using various nozzle profiles that create a supersonic, turbulent, and non-uniform air environment, the yarn is used in the heater and cooling plates by entangling and twisting it (with the vortex effect) thanks to the air-flow (water vapor - wetting) applied to the fibers that form the Air-Jet Textured yarn and turning it into a looped structure (with the vortex effect). It is the formation of a stable yarn by drawing it within a certain temperature range (first heating, and after cooling (fixing)) depending on the yarn type.[1,2,4–7,9,14,15] ATY started with the patent of the DuPont company in 1951 and was also developed by Mirlan in Czechoslovakia. It started with the development of Jet. After the 2000s, it has continued to develop until today with significant technological developments especially in jet (nozzle) profiles. The most important design criterion in ATY is jet. (it is number of jet (nozzle)). Air pressure is created thanks to the jet (nozzle) profile. The developments in ATY technology actually depend on the jet profile due to this situation. The first ATY technology developed by DuPont had a production speed of 50 m/min and compressed air with an air-flow of over 20 m^3/hour.

Although the DuPont company increased the production speed up to 350 m/min over time with the ATY technology it developed, in 1978 the Heberlain company introduced a new product, called the T series, with a completely unique jet (nozzle) design, at a production speed of 500 m/min and consuming less air compared to the DuPont company. It developed the jet (nozzle). Later, in 1997, the Heberlain company introduced a new jet called the S series, and the production speed of this jet was 800 m/min. The reason for this high production ratio was that the jet design had multiple number of jets (nozzles). Thus, ATY yarns are exposed to more and higher velocity turbulent air-flows. This increases the looped structure of ATY yarn. So, it ensures that it is a textured (bulky volume) yarn. Moreover, this new multiple jet (nozzle) is known as Taslan. This new jet with a multiple jet (nozzle) structure developed by the Heberlain company had higher performance compared to the jet structure called Taslan, which DuPont, and Hemajet also developed over time.[1] The effective technical parameters for the developed ATY yarn production are jet (nozzle) type, jet (nozzle) angle (°), overfeed ratio, amount of compressed air-flow (volumetric air-flow ratio), number of air-jet (nozzle), air-jet (nozzle) inner diameter (mm), production speed (m/min), heater and cooling plate temperatures (°C), times, lengths (mm), inner diameters, pre-tension values, types and cross-sections of yarns and filaments, wetting of the yarn and the elastic modulus of the deflection ball of the yarn (N/mm^2), tensile strength of the yarn (MPa), number of the yarn (dtex), and its effects on the dimensional stability of the yarn.[1–18,22] Even though the entanglement behavior of the fibers forming ATY yarn in the supersonic air-flow environment has been examined by various scientists, a complete technical explanation has not been found. When the jets (nozzles) of DuPont and Heberlain companies, which are the jet (nozzle) manufacturers that they generally provide the production of the most commonly used commercial ATY yarns today. It has been determined that bar compressed air is used, the air-flow regime is supersonic, turbulent, and asymmetric, the air-flow speed is non-uniform and creates shock waves.[8] It has been observed that these shock waves first cause the separation of the fibers from each other in the fibers forming the ATY yarn, and after their displacement in the longitudinal direction (deviation from the fiber axis). Thus, ensuring the ATY yarns have a looped structure (Air-Jet Texturing).[1] The properties of ATY yarns are higher texture properties (bulky volume) in woven and knitted fabrics, it provides better touch and comfort properties in the fabrics, and provides higher rubbing fastness, elasticity modulus, pilling resistance, a rough surface, and lower tensile strength values thanks to their friction coefficients.[2,4,14–18] Porosity and cover factor are the most important factors affecting the moisture and thermal properties of woven and knitted fabrics.[10,11] ATY yarns with hollow filaments are widely used thanks to their permeability adsorption, and fast-drying properties especially in sportswear applications. In addition; DTY, ATY, ITY, and BCY yarns are widely used in sportswear applications thanks to their high texturing properties (bulky volume). Moreover; factors such as yarn type, yarn structure, yarn filament count, yarn and filament cross-sections, yarn count, pore size and number, warp density, weft density, thickness, weight, fabric construction are also effective factors on the moisture and thermal properties for their fabrics.[10–18] As the fixation temperature of a twisted ATY yarn used as a carpet yarn increases, its static recycling also increases in the autoclave process.[12] The loop size, instability, and loop structure increase in ATY yarns as the pressure value of the applied air pressure increases. Thus, it means a higher amount of textured ATY yarn. Moreover, the tensile strength, and maximum percent elongation of ATY yarns decrease as the air pressure increases.[1,2] Another observation on this subject is about the relationship between the migration movements of the fibers and air pressure. According to this view that as the air pressure increases, the number of fibers with large loop sizes forming the ATY yarn decreases, the irregularity of the fibers decreases, and the dimensional stability of the ATY yarn is better.[1] POY and FDY structured PET, PA 6, PA 6.6, PP, PI, CV, CO, CMD, PPD-T, and EA yarns are used in the production of ATY yarns.[1,2,4–18] The water consumption amount of the jet (nozzle) is 1 liter/hour for 1 bar pressure.[6,7] Jet (nozzle) geometry, yarns, and filaments; geometry, diameter, and number of jets (nozzles) were simulated and proven to be the most effective design criteria on hairiness, loop size and number, instability, tensile strength, maximum breaking force and maximum percent elongation at break.[3] The ATY Yarn production theoretical view was presented in Figure 1.[7]

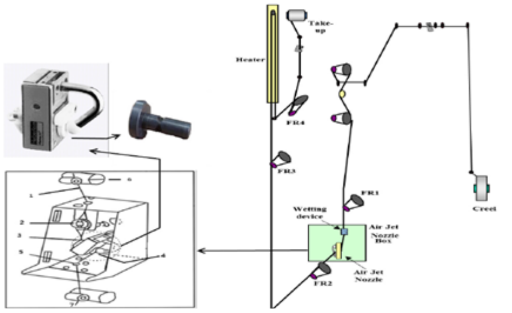

Figure 1 The ATY yarn production theoretical view.[7]

The technical internal structure of the single jet (nozzle) used in ATY yarn production was presented in Figure 2.[5]

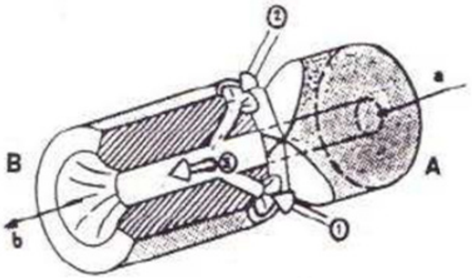

Figure 2 The technical internal structure of the single jet (nozzle) used in ATY yarn production.[5]

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The real views of the single jet (nozzle) used in ATY yarn production were presented in Figure 3.[8]

Figure 3 The real views of the single jet (nozzle) used in ATY yarn production.[8]

Rice, trilobal, and circular, respectively (from top to bottom) for the cross-sectional views of ATY yarns were presented in Figure 4.[2]

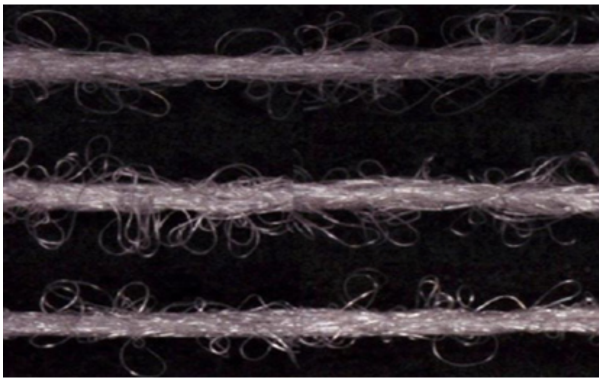

Figure 4 Rice, trilobal, and circular, respectively (from top to bottom) for the cross-sectional views of ATY yarns.[2]

Proses production parameters for yarn production of Air-Jet Textured Yarn Spinning Technology (ATY)

Various yarn types, yarn structures (POY or FDY), yarn counts (dtex), filament numbers, overfeed ratios (%), air pressure values (bar), texturing speeds (m/min), drawing ratios, and heating plate temperatures (°C) are important for ATY yarn production as their process production parameters.

Technical summary information of various experimental studies on the production process parameters of ATY yarns produced with Air-Jet Textured Yarn spinning technology (ATY) was presented in Table 1.[1,2,4–10,13,15,16]

Table 1 Technical summary information of various experimental studies on the production process parameters of ATY yarns produced with Air-Jet Textured Yarn spinning technology (ATY)[1,2,4–10,13,15,16]

Yarn types (core and effect)	Yarn constructions (core and effect)	Yarn counts/ filament numbers (core and effect) (dtex)	Overfeeds (core and effect) (%)	Air pressures (core and effect) (bar)	Texturing speeds (core and effect) (m/min)	Drawing ratios (core and effect)	Heater temperatures (core and effect) (°C)	Sources
PET/PET	POY/POY	415/48/86/36	5.5/37.9	8-Aug	275	2.19/1.75	110/70	1
PET/PET	FDY/FDY	169/X/83/36/ 111/Z	14/36	10-Jul	300-500	None	180/180	2
PET/PET	FDY/FDY	166/144	18/27/36	7,8.5,10	300-500	None	180/180	4
PET/PET	FDY/FDY	167/72	25-50/25-50	8.5	300	None	None	5
PET/CV	FDY/FDY	80/75/80/24	14.7	7	300	None	200	6
PET/CV	FDY/FDY	80/75/80/24	24	8.5	400	None	200	6
PET/CV	FDY/FDY	80/75/80/24	33.3	10	500	None	200	6
PPD-T/PPD-T	None	1666/1000	4.2/6.4/8.7/11.1/13.6	10	200/220/250	None	150/170/190/210/230	7
PPD-T/PPD-T	None	933/X/111/Y/1666/Z	8.7/16.7	10/10/2010	220/220/220	None	None	8
PPD-T/PP	None	1666/1000/389/72	1:2-57/43	3	300	None	None	9
PPD-T/PP	None	1666/1000/389/72	1:4-41/59	6	400	None	None	9
PPD-T/PP	None	1666/1000/389/72	1:6-31/69	10	500	None	None	9
PET/PET	POY/POY	75/48/95/72/105/96	None	7	300	10.4	180	10
PET/PET	POY/POY							
PET/PET	POY/POY							
PA 6.6	None	210/34	10	7	300	None	150	13
LT PET/PA 6.6	None	180/72/210/34	10	7	300	None	150	13
LT PET	None	180/72	10	7	300	None	150	13
HT PET/PA 6.6	None	210/34/210/34	10	7	300	None	150	13
HT PET	None	210/34	10	7	300	None	150	13
PET/CV	FDY/FDY	80/75/80/24	14.7/20.3/24.0/33.3	7/7.3/9.7	300-500	None	200	15
PI/PI	FDY/FDY	475/160	0.5/2.2	7	280	None	None	16
PI/PI	FDY/FDY	495/160	8-Aug	9	300	None	None	16

Structural, physical, and mechanical properties for fabric forms of Air-Jet Textured Yarn Spinning Technology (ATY)

ATY yarn process production parameters such as various yarn types, yarn structures (POY or FDY), yarn counts (dtex), filament numbers, overfeed ratios (%), air pressure values (bar), texturing speeds (m/min), drawing ratios, and heating plate temperatures (° C) effect on various physical, mechanical, and thermal comfort properties of woven and knitted fabrics produced from DTY, ring, and OE rotor yarns, mostly ATY yarns were interpreted comparatively and technically in Table 2.

Table 2 Technical summary information of various experimental studies on general technical conclusions for various experimental studies of ATY yarns, and fabrics produced with Air-Jet Textured Yarn spinning technology (ATY)[1,2,4–13,16–18]

General technical conclusions for various experimental studies	Sources
As the jet (nozzle) diameter increased, the texturing properties (bulky volume), and loop size of ATY yarn increased, but the tensile strength, maximum breaking force (N), and maximum percent breaking elongation (%) decreased. Jet (nozzle) inner diameter must be minimum.	1
Yarns with thicker filament diameter compared to yarns with thinner filament diameter had lower physical mass loss, and tensile strength reduction but higher instability. Moreover, filaments with round cross-sections had higher instability compared to filaments with trilobal, and rice cross-sections. As the yarn count (dtex) got thicker, the texturing property (bulky volume) and instability increased, but it had lower tensile strength.	2
As air pressure increased, texturing property (bulky volume), instability, and mass loss increased, but tensile strength decreased. As texturing speed increased for the same yarn count and filament count, texturing properties (bulky volume), and tensile strength increased, but instability, and mass loss decreased.	4
As all overfeed ratio, and yarn tension in parallel, or center-shell types increased, yarn count (dex), maximum breaking elongation, and hairiness decreased, but tensile strength, maximum breaking force, and breaking work increased. Moreover, the center-to-shell overfeed ratio (50/50) had a much sharper impact on all results.	5
As air pressure, and overfeed ratio increased, texturing property (bulky volume), and instability increased, but tensile strength decreased. As the PET ratio increased, tensile strength increased. Maximum tensile strength existed for PET/CV ratio 100/0, while minimum tensile strength existed for PET/CV ratio 0/100. Maximum loop instability existed for PET/CV ratio 16.67/83.33, while minimum loop instability existed for PET/CV ratio 100/0. Maximum texturing properties (bulky volume) was available for PET/CV ratio 16.67/83.33, while minimum texturing properties (bulky volume) was available for PET/CV ratio 83.33/16.67. Low instability, high texturing properties (bulky volume), and tensile strength were observed at low production ratio.	6
As the production speed increased, the yarn count (dtex) decreased, tensile strength increased, maximum percent breaking elongation, modulus of elasticity, instability, dry shrinkage, and wet shrinkage did not change. As the overfeed ratio increased, tensile strength, and instability decreased, yarn count (dtex), and maximum percent elongation at break increased, and modulus of elasticity, dry shrinkage, and wet shrinkage did not change. As air pressure increased, instability, yarn count (dtex), and maximum percent elongation at break increased, modulus of elasticity, and tensile strength decreased, and dry shrinkage and wet shrinkage did not change. As the temperature increased, yarn count (dtex), and instability decreased, and the modulus of elasticity, tensile strength, maximum percent elongation at break, dry shrinkage, and wet shrinkage did not change. As water consumption (wetting) increased, instability, yarn count (dtex), maximum percent elongation at break, modulus of elasticity, tensile strength, dry shrinkage, and wet shrinkage did not change.	7
As the inner diameter of the jet (nozzle) increased, the yarn count (dtex), and maximum percent breaking elongation increased, but elasticity modulus, and tensile strength decreased. Dry shrinkage and wet shrinkage varied. The instability did not change, but as the yarn count (dtex) increased, the instability increased.	8
A production speed of 300 m/min and 10 bar air pressure should be applied for the most uniform PPD-T/PP blend yarn ratio (1:6-31/69).	9
POY PET DTY yarns compared to POY PET ATY yarns had higher porosity, and lower cover factor. However, both DTY, and ATY yarns generally had a high covering factor. Moreover, yarns with hollow filaments had higher porosity. As the yarn count (dtex), and the texturing properties (bulky volume) increased, the absorbency values increased. Because, the capillarity area required for absorbency increased, but thermal conductivity decreased. Thermal insulation values of yarns with air gaps, and hollow filaments in textured (bulky volume) yarns were higher. Because air was one of the best insulating materials. As the pore size increased, and the covering factor decreased, water vapor permeability, air permeability, drying ratio, drying speed, and drying duration increased.	10
Depending on the density, construction, and geometry of the fabric, as the volume of filaments in the yarn increased, and the cross-sectional shape of the filaments flattens, the drying ratio decreased with moisture diffusion, and transfer to the textile material. The yarns with high textural properties (bulky volume) compared to plain (non-textured) yarns had lower performance in terms of moisture transfer, drying ratio, thermal comfort, water vapor, and air permeability values. In terms of their effects on the absorbency values of woven fabric constructions woven from yarns with textured properties (bulky volume), from highest to lowest were ribstop, warp rib, and weft rib, respectively. In terms of their effects on the absorbency values of woven fabric constructions woven from yarns with straight filaments, from highest to lowest were ribstop, weft rib, and warp rib, respectively. All the moisture in a woven fabric woven from a PET yarn with average warp, and weft density values (16 to 26), and fine yarn counts (166.67 dtex), and a 350 t/m twist structure was completely removed from the woven fabric after 90 minutes under standard atmospheric conditions. Although yarns with filaments with textural properties (bulky volume) were not effective in the warp direction in terms of absorbency values compared to yarns with straight filaments, they were effective in the weft direction, and were higher, but the drying ratio was lower.	11
Woven fabric carpets were produced with 165 dtex yarn count and untwisted PET ATY yarns (with warp yarn and cotton addition (20%)) and jute (weft yarn) in various pile heights and various warp and weft density values. As pile height, warp, and weft density increased, bending stiffness increased. Dry bending stiffness was 8 times higher than wet bending stiffness. Moreover, especially as the weft density increased, the bending length (cm) increased. The dry bending length (cm) increased and was higher as the pile height increased compared to the wet bending length (cm). As the density of pile increased, thickness loss, and resilience properties generally decreased. As the applied force value and number of cycles in wear resistance increased, mass loss and resilience increased. Moreover, as pile height increased at the same pile density, a small amount of mass loss increased. As the pile height increased at high pile density, the critical friction stroke number required to completely break the pile yarns was determined by the friction effect in the friction fastness test.	12

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Table 2 Continued...

General technical conclusions for various experimental studies	Sources
Woven fabric airbags with various warp and weft density values were produced for automotive applications and subsequently were coated. According to the results that for woven fabric structures, the highest tensile strength was observed in HT PET yarn structures in both warp and weft directions, while the lowest tensile strength was observed in LT PET yarn structures. For woven fabric structures, the highest shear strength was observed in LT PET yarn structures in both warp and weft directions, while the lowest shear strength was observed in LT PET/PA 6.6 yarn structures. For woven fabric structures, the highest maximum percent elongation at break was observed in LT PET/PA 6.6 yarn structures in both warp and weft directions, while the lowest tensile strength was observed in HT PET/PA 6.6 yarn structures. For woven fabric structures, the highest bursting strength was observed in LT PET yarn structures in both warp and weft directions, while the lowest bursting strength was observed in LT PET/LT PET yarn structures. For woven fabric structures, the highest air permeability was observed in LT PET/LT PET yarn structures in both warp and weft directions, while the lowest air permeability was observed in LT PET yarn structures.	13
Woven fabrics of various densities of warp, and weft yarns from CO ring, CO/PA ATY, and CO/PET ATY yarns were produced. According to the results that for woven fabric structures, the highest tensile strength was observed in CO ring yarn woven fabric structures in both warp and weft directions, while the lowest tensile strength was observed in CO/PA yarn woven fabric structures. For woven fabric structures, the highest maximum percentage elongation at break was observed in CO/PA ATY yarn woven fabric structures in both warp and weft directions, while the lowest maximum percentage breaking elongation was observed in CO ring yarn woven fabric structures. For woven fabric structures, the highest thermal conductivity was observed in CO/PA ATY yarn woven fabric structures in both warp and weft directions, while the lowest thermal conductivity was observed in CO ring yarn woven fabric structures. For woven fabric structures, the highest water vapor permeability was observed in CO/PET ATY yarn woven fabric structures in both warp and weft directions, while the lowest water vapor permeability was observed in CO ring yarn woven fabric structures. For woven fabric structures, the highest air permeability was observed in CO ring yarn woven fabric structures in both warp and weft directions, while the lowest air permeability was observed in CO/PA ATY yarn woven fabric structures.	14
Ring, and ATY yarns with FDY PET, and FDY CV yarn structures and their mixtures in various proportions were produced as yarn forms. Then, woven fabrics were produced at various densities of warp and weft yarns. According to the results that in woven fabrics woven from 67/33, and 83/17 PET/CV blended yarns, instability, and texturing properties (bulky volume) were observed for their highest values. As the PET ratio increased in woven fabrics woven from FDY PET/FDY CV ATY blended yarns, tensile strength values increased. As the PET ratio increased in both ring and ATY structured woven fabrics woven from FDY PET/FDY CV ATY blended yarns, air permeability, texturing property (bulky volume), and linear density of the yarn increased, but water vapor permeability decreased. FDY PET/FDY CV ATY structured woven fabrics had lower handle (softness), lower air permeability values, and higher water vapor permeability, absorbency, diameter, and thickness values compared to FDY PET/FDY CV ring structured woven fabrics.	15
Woven fabrics were produced from FDY PI and PI ATY blended yarns in 475 and 495 dtex yarn counts in 2x2 basket woven fabric construction. According to the results that tensile strength values were variable. The tensile strength values in the warp direction, from highest to lowest were observed FDY PI/PI ATY with thicker yarn count, FDY PI/PI ATY, and FDY PI/FDY PI with higher weft density, respectively. The tensile strength values in the weft direction, from highest to lowest were observed FDY PI/FDY PI, FDY PI/PI ATY with higher weft density, and FDY PI/PI ATY with thicker yarn count respectively. The shear strength values in both warp and weft directions, from highest to lowest were observed FDY PI/FDY PI, FDY/PI/PI ATY with higher weft density, and FDY PI/PI ATY with thicker yarn count, respectively. The thermal resistance values, from highest to lowest were FDY PI/PI ATY with thicker yarn count, FDY PI/PI ATY with higher weft density, and FDY PI/FDY PI with higher weft density, respectively. The air permeability, and moisture permeability values, from highest to lowest were observed FDY PI/PI ATY with thicker yarn count, FDY PI/PI ATY, and FDY PI/FDY PI with higher weft density, respectively. The absorbency values in both warp and weft directions, from highest to lowest were observed FDY PI/PI ATY with thicker yarn count, FDY PI/PI ATY, and FDY PI/FDY PI with higher weft density, respectively. The contact angle values, from highest to lowest were observed FDY PI/PI ATY with thicker yarn count, FDY PI/PI ATY with higher weft density, and FDY PI/FDY PI with higher weft density, respectively.	16
Ring, OE rotor, and ATY yarns with CO, PA 6.6+EA, and CMD yarn structures were produced. Then, knitted fabrics were produced in 1x1 rib knitted fabric construction. According to the results that the tensile strength, maximum breaking force, maximum percent elongation at break, work at break, and abrasion resistance values, from highest to lowest were ring, OE rotor, and ATY, respectively. As the PA+EA ratio increased, the wear resistance values increased, but as the CMD ratio increased, the wear resistance values decreased. As the CO ratio increased, the abrasion resistance values were not affected. For the pilling resistance values, from highest to lowest were the CMD structured ATY, ring, and OE rotors, respectively. Knitted fabrics knitted from all CO structured yarns had the lowest pilling resistance values. For the pilling resistance values, from highest to lowest were the CMD structured ATY, ring, and OE rotors, respectively. Knitted fabrics knitted from all CO structured yarns had the lowest pilling resistance values. Air permeability, and moisture permeability values for CMD structured knitted fabrics, from highest to lowest were OE rotor, ATY, and ring, respectively. Knitted fabrics knitted from all CO structured yarns had the lowest air permeability, and moisture permeability values. For thermal resistance values, from highest to lowest were OE rotor, ring, and ATY, respectively. While knitted fabrics knitted from CO structured ring yarn had the highest thermal resistance values, knitted fabrics knitted from CMD structured ring yarn had the lowest thermal resistance values.	17
Woven fabrics were produced in 3x1 twill woven fabric construction, with equal warp, and weft density values, from ATY, and DTY yarns produced by adding (0%, 2.5%, 3%, 3.5%, and 4.0% EA yarns to PET structured yarns. Their yarn counts (dtex) were 244 dtex. According to the results that as the EA ratio increased, the shear strength value, maximum percent elongation at break value, and elastic recovery behavior increased in all woven fabrics. Moreover, ATY yarns had higher shear strength values, maximum percent elongation at break values, and elastic recovery behaviors compared to DTY yarns. PET structured woven fabrics without EA had the lowest shear strength values, had the highest percent elongation at break values, and elastic recovery behaviors.	18

Technical summary information of various experimental studies on general technical conclusions for various experimental studies of ATY yarns, and fabrics produced with Air-Jet Textured Yarn spinning technology (ATY) was presented in Table 2.[1,2,4–13,16–18]

Sustainability, and future trends of Air-Jet Textured Yarn Spinning Technology (ATY)

Raw materials (especially natural, regenerated, or synthetic-based yarns) go through many long-term production processes to be transformed into final products (non-woven, woven, or knitted fabrics) in the global textile industry. While raw materials (especially for yarns) are used in high quantities in these production processes, they can be produced with high chemical, water, energy (such as washing, drying, and ironing), and labor costs.[19–21] Environmental interactions, and recycling of products due to climate change the importance of transformation is high and varies depending on the raw material in these production processes. This has led to various theoretical, and experimental studies on the subject of recycling.[19–23] Because sustainability can be achieved as long as recycling can be achieved.[20] In addition, textile waste must be classified, collected, and evaluated. Production efficiency should be kept maximum by ensuring that natural raw materials (especially natural-based yarns) can be reproduced with clean technologies, and the process parameters in the production processes are optimized. Moreover, the amount of waste losses should also be noted.[19] For this purpose, high-level and multiple repetition filtration methods should be applied in the production processes of final products. Moreover, the use of biological, and environmentally friendly auxiliary chemicals, which require low production time, water, and energy consumption, needs to be increased.[20] Process parameters such as yarn type, yarn count (dtex), drawing system, drawing roller number, geometry, drawing ratio, and production speed are extremely effective in recycling processes for yarns.[14,19,21–23] They have been carried out on both pure, and blended yarn structures of CO, RA, Malina, PA, and PET yarns for their experimental studies on recycling.[14,19–23] Especially, the mechanical properties of ATY, OE rotor, and ring spinning technologies are studied.[14,19,21–23] According to the Sustainable Development Goals (SDG) aims that they can be to transform natural-based raw materials into very high amounts of final products by 2030 in the global textile industry.[20] The mechanical properties of CO/PET blended ring yarns were at lower values. In addition, the least impact on the mechanical properties of CO ring yarn was observed at the Ne 10 yarn count. Moreover, as the amount of waste increased, the mechanical properties of the yarn decreased.[19] The mechanical properties of PET ring yarns were decreased.[23] There was a minimum loss in mechanical properties when OE rotor yarns with CO yarn structure were recycled at a ratio of 80% but as the recycling rate increased, the quality, cost, and mechanical properties of the yarn decreased. Moreover, yarn defects were increased.[21]

Conclusion

According to the results included ATY yarn production machines produced by DuPont and Heberlain Companies have generally used for the production of ATY yarns nowadays. Moreover, multi-jet systems (4 jets) called the Taslan have widely used because they affect the air pressure values, and air-flow regime more homogeneously in various yarn formation axes. Effective technical parameters for ATY yarn production are jet (nozzle) type, jet (nozzle) angle (°), overfeed ratio, amount of compressed air-flow (volumetric air-flow ratio), number of air-jets (nozzles), air-jet inner diameter (mm), production speed (m/min), heater and cooling plate temperatures (°C), times, lengths (mm), inner diameters, pre-tension values, types, and cross-sections of yarns and filaments, wetting of the yarn and the elasticity modulus of the deflection ball of the yarn (N/mm^2). Additionally, FDY structure, yarn count (dtex)/filament count from 80/24 to 1666/1000, overfeed ratio value from 5.5 to 36, air pressure value from 7 bar to 10 bar, production speeds from 300 m/min to 500 m/min, a draft ratio value of between 1.75 and 2.19, and a temperature value of 180 °C to 200 °C are generally used in the production of ATY yarns. Texturing property (bulky volume), instability, and mass loss increase, but tensile strength decreases as air pressure increases. These effects are more evident in fine yarn counts (dtex). Tensile strength increases, but instability, and mass loss decrease as the texturing speed increases. Water consumption has no effect on the physical, mechanical, and thermal comfort properties of both woven, and knitted fabrics with ATY yarn structures. POY and FDY structured PET, PA 6, PA 6.6, PP, PI, CV, CO, CMD, PPD-T, and EA yarns are used in the production of ATY yarns. ATY yarns are widely used in home textiles, clothing, airbags, carpets, and upholstery fabrics. The multi-lobed section PET ratio should be high for high bursting strength, tensile strength, air permeability, maximum breaking force, texturing property (bulky volume) and linear density of the yarn values, high shear strength, maximum percent elongation at break, thermal conductivity, pilling resistance. The ratio of CMD, CV, PA 6, or PA 6.6 should be high for water vapor permeability values. The CO ratio should be high for high thermal resistance. The PET ratio should be high for high abrasion resistance values. Shear strength, maximum percent elongation at break, elastic recovery behavior, and abrasion resistance increase as the EA ratio increases. ATY yarns have lower tensile strength, maximum breaking force, maximum percent breaking elongation, breaking work, and abrasion resistance values compared to ring, and OE rotor yarns (except DTY), respectively. The issue of recycling is extremely important for the sustainability of the global textile industry in the future. For this important issue, textile waste must be classified, collected, and evaluated. Moreover, optimization of various experimental production process parameters should be ensured in order to preserve the mechanical properties of blended yarns, especially CO/PET, and CO/PA yarn structures, by reducing chemical, water, energy, and labor costs.

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Conflicts of interest

The author declares that there is no conflict of interest.

References

1. Wickramasinghe GLD, Foster PW. Effect of nozzle size on texturing performance: comparison between air-jet and steam-jet texturing. *The Journal of the Textile Institute.* 2015;106(10):1051–1058.
2. Baldua RK, Rengasamy RS, Kothari VK. Effect of feed yarn parameters on air-jet textured yarn properties. *Fibers and Polymers.* 2015;16(2):463–470.
3. Delcour L, Peeters J, Degroote J. Development of an iterative procedure with a flow solver for optimizing the yarn speed in a main nozzle of an air jet loom. *The Journal of the Textile Institute.* 2019;110(6):859–872.
4. Baldua RK, Rengasamy RS, Kothari VK. Effect of linear density of feed yarn filaments and air-jet texturing process variables on compressional properties of fabrics. *Indian Journal of Fibre & Textile Research (IJFTR).* 2017;42(1):9–16.

5. Iliya EB. Effect of process variables on the physical properties of air-textured yarns. *Nigerian Journal of Textiles.* 2017;3(1):15–22.
6. Mahish SS, Punj SK. Optimization of process parameters in air-jet texturing of polyester/viscose blended yarns. *Indian Journal of Fibre & Textile Research (IJFTR).* 2010;35(3):213–221.
7. Kim HA, Kim SJ. Effects of processing parameters on the mechanical properties of aramid air textured yarns for protective clothing. *Autex Research Journal*. 2018;18(2):149–159.
8. Choi LH, Kim HA, Kim SJ. Physical properties of aramid and aramid/nylon hybrid ATY for protective garments relative to ATY nozzle diameter. *Fashion & Textile Research Journal.* 2013;15(3):437–443.
9. Hosseinalizadeh M, Dolatabadi MK, Najar SS, et al. Blending quality of co-air-textured yarn: Optimization parameters of Kevlar/polypropylene applicable for thermoplastic composites. *Journal of Composite Materials.* 2019;53(13):1791–1802.
10. Kim HA, Kim SJ. Moisture and thermal permeability of the hollow textured PET imbedded woven fabrics for high emotional garments. *Fibers and Polymers.* 2016;17(3):427–438.
11. Saricam C, Kalaoğlu F. Investigation of the wicking and drying behaviour of polyester woven fabrics. *Fibres & Textiles in Eastern Europe.* 2014;22-3(105):73–78.
12. Erdogan G, Yucel S, Bilisik K. Textured polyester fiber in three-dimensional (3D) carpet structure application: experimental characterizations under compression–bending–abrasion–rubbing loading. *Polymers.* 2023;3006-15(14):1–26.
13. Mankodi H, Kodinaria B. Airjet textured yarn fabrics for airbag: an innovative approach. *Journal of Textile Science & Engineering.* 2020;10(6):1–5.
14. Gorjanc DS. The functionality of woven fabric from air-jet yarn from the mixture of CO/PA and CO/PES fibres in the weft direction. *The Journal of the Textile Institute.* 2019;110(5):680–689.
15. Mahish SS, Punj SKK, Kothari VK. Comfort and handle related properties of P/V blended air-jet textured yarn fabrics. *Fibers and Polymers.* 2010;11(6):932–940.
16. Huang S, Sun L, He M, et al. Preparation and properties of polyimide air-jet textured yarns and their woven fabrics. *Textile Research Journal.* 2020;90(13-14):1507–1516.
17. Tomljenović A, Živičnjak J, Mihaljević I. Usage durability and comfort properties of socks made from differently spun modal and micro modal yarns. *Materials.* 2023;1684-16(4):1–27.
18. Thakkar A, Shah VD, Bhatia M. Studies of stretchable airjet textured yarn–a experimental review. *International Journal for Scientific Research & Development (IJSRD).* 2015;3(9):83–86.
19. Kodaloğlu M. Sustainability through textiles recycling: yarn reuse, environmental and human health impact. *International Journal of Engineering and Innovative Research*. 2024;6(2):98–105.
20. Felgueiras C, Azoia NG, Gonçalves C, et al. Trends on the cellulose-based textiles: raw materials and technologies. *Frontiers in Bioengineering and Biotechnology*. 2021;608826-9(1):1–20.
21. Wanassi B, Azzouz B, Ben Hassen M. Sustainable denim yarn: quality-cost analysis and analytic hierarchy process (AHP) optimization. *AATCC Journal of Research*. 2018;5(4):17–24.
22. Xia Z, Xu W. A review of ring staple yarn spinning method development and its trend prediction. *Journal of Natural Fibers*. 2013;10(1):62–81.
23. Sarıoğlu E. Ecological approaches in textile sector: The effect of r-pet blend ratio on ring spun yarn tenacity. *Periodicals of Engineering and Natural Sciences*. 2017;5(2):176–180.

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