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Linking Yarns from Staple and Filament Fibres by High-Efficiency Pneumatic Interlucing. Part I: Factors Influencing the Linking Effect and Properties of Interlaced Yarns. Analysis of Tensile Strength Parameters

Abstract

The linking of yarns manufactured from staple and filament fibres, as well as only from staple fibres by the technique of high-efficient pneumatic interlucing was the subject of investigations commenced at the Textile Research Institute. This technique, well known and generally used for linking mono- and multifilament yarns, is relatively new considering staple yarns. A broad range of new construction designs and technological investigations allowed the identification of factors influencing the effect of pneumatic interlucing and the properties of the linked yarns obtained by this technique. The influence of the kind of interlucing pneumatic nozzles, as well as of such parameters as the speed and pressure of the air acting in the nozzle, tensions of the linked yarns, and the kind and properties of the component yarns were investigated. Estimation of the existing dependences was carried out on the basis of the following yarn parameters: tensile breaking strength, elongation at break, unevenness of linear density, the number of faults, hairiness, and as well as the estimation of the interlucing cohesiveness, a new parameter which was assessed according to a method elaborated at the Textile Research Institute through innovative investigations. Part I of the article includes analyses of the influence of selected parameters on the tensile strength properties of linked filament – staple yarns, whereas Part II presents an analysis of hairiness, the unevenness of linear density, the number of faults, and the interlucing cohesiveness. The investigation carried out by us indicated the dependencies of all the process parameters tested, such as the speed of air-flow and air pressure, the construction design of the nozzles, and the properties of the component yarns on the linked yarn properties.

Key words: filament yarns, staple yarns, linking, pneumatic interlucing, interlucing nozzle, pneumatically linked yarns, breaking strength, elongation at break, cohesiveness.

Introduction

Linking by the pneumatic interlucing of yarns containing component yarns from staple fibres is a new direction in the techniques and technologies of the formation of doubled yarns, homogeneous as well as composite with new structure and properties, and at the same time a technology allowing high speeds during the process.

In conventional, commonly-used multi-operational techniques of forming linked staple, or staple-filament yarns, the basic operation is twisting, which is made with the use of ringtwisting frames, open-end spinning machines (etage- and double-twist frames) or twisters with a hole spindle. The formation of staple-filament yarns as core yarns is also made with the use of ring-spinning frames. All the above-mentioned ways of linking yarns are characterised by low feeding speeds

within the range of 20 – 60 m/minutes. The low efficiency of these processes results from the limited possibilities of increasing the rotary speeds of the twisting elements of twisting machines.

A significantly higher efficiency, over tenfold, is obtained in pneumatic interlucing technology. This process is well-known and used world wide, as well as being continuously developed in the field of technologies concerning filament-fibre yarns. It is applied to link bundles of elementary fibres into a filament yarn, as well as to link ready-made filament yarns. The linking element used in this technique involves the utilisation of a pneumatic interlucing nozzle in which the connection of different forms of filaments takes place as a result of the compressed air stream action on the guided filament yarns. The process depends on the construction of the nozzle.

The following two basic kinds of pneumatic linking of filament yarns are known:

- pneumatic texturing – forming filament yarns with a characteristic loop-shaped structure along the whole length of the yarn;
- pneumatic interlucing, which gives connections of limited length and different structure, with the joint places distributed at different distances, both depending on the structure of the nozzle and the technological parameters of the linking process.

Pneumatic interlucing was found to be of special importance, which all the time has been continuously developed. This way of linking is used in the world for about 80% of the filament yarns manufactured. It is used in technologies described in [1 - 6, 11 - 15] and mentioned below:

- Manufacturing of single yarns for thickening and strengthen the structure which assures their processing without disturbances immediately after the spinning process and allows to omit mechanical and other kinds of operational preparations before weaving and knitting, for example impart-

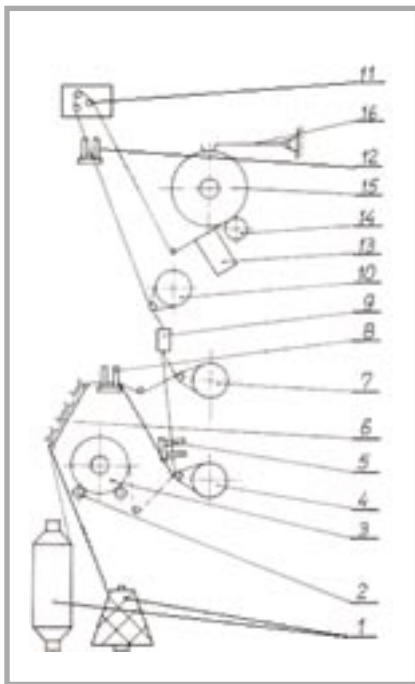


Figure 1. Technological scheme of the experimental machine PY 11; 1 – feeding bobbins, 2 – lap rollers for PU, 3 – feeding bobbin (elastic yarn), 4 and 7 – feeding godets, 5, 8 and 12 – yarn breakage gauges, 6 – tensioners, 9 – interlacing nozzle, 10 – take-up godet, 11 – compensator, 13 – carrier device, 14 – lap roller, 15 – take-up packet, 16 – detector of the packet diameter.

ing additional twist, or twisting and sizing the warp. In this application, linking is realised in a process of forming single yarns with speeds from several hundred to several thousand metres per minute.

- The formation of linked (doubled) yarns from two or more filament components, homo- or heterogeneous,

elastic and inelastic. This process is realised with speeds from several hundred to 1,200 metres per minute with the use of special machines build exclusively for this purpose. They are equipped with necessary godet systems which feed the component yarns and take-up the final linked yarns from the zone of pneumatic interlacing and installations of compressed air together with appropriate kinds of interlacing nozzles.

At present, the nozzles for pneumatic interlacing are produced by some specialised companies which offer a broad assortment of these machine elements with different design solutions for the various technologies of processing filament yarns. The interlacing of components takes place in the nozzle as a result of the air stream action on the guided yarns. Such linking is also known in literature as wrapping, commingling, intermingling, tangling, interlinking, interlacing, and covering.

The common use of pneumatically linking filament yarns by interlacing and the technological development in this field have inspired the commencement of investigations aimed at the use of this highly efficient technique of pneumatically linking yarns formed from filament yarns with the use of staple yarns, and possibly with only staple yarns. This technological direction can also be a way of developing assortments based on yarns dedicated for different applications, as it will create the possibility of forming yarns with various new properties, for example by using sta-

ple natural and filament chemical fibres with their different features.

■ Aim and range of investigation

The aim of our investigations was to manufacture filament – staple yarns and homogeneous staple yarns using the highly efficient technique of pneumatic interlacing.

This problem was connected with multidirectional investigations in the following fields:

- Reconstruction of an experimental machine in order to adapt it to multivariant pneumatic yarn interlacing and creating various assortments of filament – staple yarns or only pure staple yarns.
- Recognition of the factors which limit the linking of components, creation of the effects of these connections, and the obtaining of the properties of the composite yarns interlaced by means of investigating the process parameters, the different kinds of nozzles, and the various raw material systems.
- Recognition and elaboration of estimation methods of new yarns manufactured.
- Recognition of the physical properties and quality features of new yarns pneumatically interlaced.

■ The research stand

In order to carry out the research work, a Polish experimental machine – the PY 11 pneumatically texturing machine of the Majed Company was used. A part of the texturing positions of this machine were modernised and reconstructed in order to perform the pneumatic interlacing with the aim of using two different assortment systems of the component yarns: characterised by equal and differentiated properties. These works included the driving mechanisms of the machine and of the goders, the electronic control systems, the elastomer-feeding rollers, the multiposition creeling frame for bobbins of various shapes and dimensions, the tensioners before the feeding goders, the guiding elements before and after the linking nozzle, as well as the elements for fastening the nozzles and feeding air to them. The scheme of the research stand is presented in Figure 1, and the technological characteristics are in Table 1.

Table 1. Technological characteristic of the stand for pneumatic yarn linking.

Parameter	Value/ kind
Feeding speed	60 – 360 m/min
Air pressure	1 – 6 bar
Speed off-cut of the feeding godets in relation to the take-up godet	up to +25%
Speed off-cut of the take-up godet in relation to the winding lap roller	up to +25%
Drawing ratio of the elastomer	up to 3.5
The kind of the component yarns: - yarns from filament fibres, - yarns from staple fibres	- multifilament even and texturised, monofilament PU, - natural and chemical
Bobbins with component yarns	Cylindrical and conical copses of different dimensions
Linear density of feed yarns	- filament yarns 4 – 17 tex, - staple yarns 15 – 30 tex
Linear density of component yarns (assumed)	Up to 60 tex
Shape and dimensions of the feeding windings	Cross – cylindrical (bi-conical), length of 250 mm, diameter of 245 mm, mass up to 3 kg
Shape and dimensions of the take-up cops	Cylindrical, length of 90 mm, diameter of 83 mm
Pneumatic nozzles	Different construction solutions depending on the investigation works, yarn assortments and effects of linking

Factors influencing the effects of linking and the properties of linked yarns

A great variability of factors occurs in the process of pneumatic interlacing of yarns, which influences the effect of linking the components and properties of the final linked composite yarn. The factors can be divided into the following three groups:

- I group. Parameters of the process including:
 - a) the process speed (the movement of the yarn),
 - b) the pressure of the air fed into the nozzles,
 - c) tensions of the component yarns fed into the pneumatic nozzle, which depend on many controlled parameters acting on the way from the input to the nozzle (the loads of tensioners, the number of feeding godet engirds, and the off-cuts speed of the feeding godets in relation to speed of the take-up godet). All these tensions are controlled individually for yarns with different properties;
 - d) drawing ratio of the elastomer components in the case of manufacturing elastic yarns.
- II group. The types of pneumatic nozzles differentiated by their construction designs. The internal structure of the nozzles, which includes various shapes and dimensions of the air inlet and the yarn guiding canals, as well as their mutual differentiated positions of yarns, result in different air flow parameters occurring, and as a consequence a dissimilarity of the interlaced connections and composite yarn parameters. The external construction of the nozzles is also important. The selection of nozzles and process parameters for different raw material systems yielded the basic factors which conditioned the obtaining of the yarn linkage and the formation of the properties of the interlacing.
- III group. Properties of the component yarns and systems of their interlacing. The physical and quality parameters of the linked yarns also depend on the kind and properties of the components in different linking systems:
 - a) yarn from filament fibres and from staple fibres, and
 - b) yarn doubled from staple fibres.

The effects of linking and the properties of linked yarns depend on all the factors

mentioned above. The dissimilarity of these assortment groups causes that the evaluation of the process and the yarns constitute two independent problems. Recognition of existing dependencies is connected with a very broad range of experimental work. This article includes the results of initial dependencies determined that are related to a limited range of the parameters listed above.

Research material and process conditions

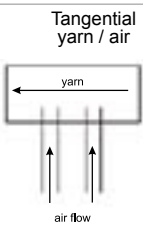
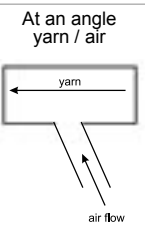
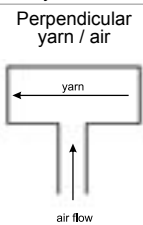
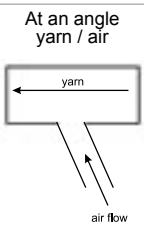
- Process parameters and their ranges:
 - a) yarn take-up speed within the range of 100 – 300 m/minute,
 - b) pressure of the air fed to the nozzle was equal to 0.2 – 0.4 MPa,
 - c) tensions of the component yarns before the nozzle - up to 4.0 cN.
- Interlacing nozzles were supplied by foreign companies. Four kinds of the nozzles tested in this work were selected for our investigation; they were designated as S, K, P, and R. They are characterised by different internal structure and air flow parameters, which are presented in Table 2. The flow test results of the nozzles will be the subject of an independent publication. The nozzles presented are characterised by the following various work principles:
 - S) the circumferential-type with an air canal tangential to the yarn canal; the air flow in this nozzle is typical for rotary chambers;

- K, P and R) oblique nozzles with an air canal situated at a particular angle or perpendicular to the yarn canal axis; measurements of the axial speed of the air stream at the output of both sides of the nozzles indicated the asymmetry of its flow in all nozzles and a different level of the speed between the nozzles. The highest speed occurs in nozzle R, with an air canal area of 2 mm² (situated at a particular angle), whereas the lowest occurs for nozzle P, with a perpendicular canal and an area of 1.6 mm².
- Component yarns devoted to the linking process and their designations:
 - a) yarns from filament fibres – PA_t 7.8tex/68f (polyamide, textured), PA_g 7.8tex/68f (polyamide, even), PE_g 8.4tex/72f (polyester, even);
 - b) yarns from staple fibres: cotton CO of 29 tex (classic ring spun) used for basic tests, whereas for comparison the following yarns were used: cotton CO/B of 20 tex (open-end) and polyacrylonitrile PAN of 1.7 tex – 25 tex (from a converter spinning system, with linear density of fibres equal to 1.7 dtex).

Yarn estimation methods

Pneumatically interlaced yarns, which include yarns from staple fibres in their composition, are new yarn assortments for which no information can be found in literature concerning estimation methods and quality requirements. Therefore, a

Table 2. Characteristic of the interlacing nozzles; *) according to research at IW, **) the nozzle S consists of three identical segments.

Nozzle designation				
S		K	P	R
Situation of air canal in relation to yarn canal				
Tangential yarn / air 		At an angle yarn / air 	Perpendicular yarn / air 	At an angle yarn / air 
Area of the canal × number of canals				
0.8×2		1.6×1	1.6×1	2.0×1
Air speed at the output of yarn canal*, m/s (at pressure)				
Circumferential 57 (0.2 MPa)	Axial 19 (0.2 MPa)	98 (0.2 MPa)	78 (0.2 MPa)	189 (0.2 MPa)
85 (0.4 MPa)	28 (0.4 MPa)	131 (0.4 MPa)	162 (0.4 MPa)	281 (0.4 MPa)
Air consumption for 0.2 and 0.4 MPa, m ³ /h (at pressure)				
2.6×3 (0.2 MPa) 4.4×3 (0.4 MPa)		2.7 (0.2 MPa) 4.6 (0.4 MPa)	2.7 (0.2 MPa) 4.6 (0.4 MPa)	3.2 (0.2 MPa) 5.4 (0.4 MPa)

need arose for the development of new methods of yarn testing, as well as the adaptation or use of methods already existing. At the present stage of investigation, the following methods of yarn testing have been used:

- Organoleptic estimation of yarn appearance – performed on a test stand by means of winding a yarn on colour cartons. Linked places of different compactness, loose state, and parallel positioned components may be observed - which is characteristic for yarns not continuously interluced. The occurrence of long fragments not interluced, which are visible with great frequency, or an excess of one of the components in the form of waves disqualify such composite yarn variants. Special standards have been elaborated for organoleptic estimations. Evaluation of yarn appearance is the first stage of selecting the process parameters for obtaining the correct linking of component yarns.
- Measurement of ‘forced pull-down segments’, a new parameter, which is determined on a test stand for staple-filament yarns in the following way:
 - a) a yarn segment of about 2 cm length is drawn by hand up to the moment of breaking of the component with lower elongation, which is staple yarn;
 - b) the broken yarn, consisting of staple fibres, is pulled-down manually

along the filament yarn up to the moment of blocking, which means the lack of possibility of further pulling-down of the yarn; during the pulling down of the broken component yarn, subsequent resistances are forced, and the weakest interlucings are broken;

- c) the length of the uncovered filament yarn segment is measured.

This parameter, notwithstanding its subjectivity, gives a general view of the linking effect. An assumption was accepted that the longer the forced pull-down segment is, the weaker the linkage and the lower the frequency of the interluced places are (yarn segments).

- Tests of the tensile strength parameters. The tests were carried out with the use of an automatic tensile tester dedicated for yarns [7]. Pneumatically interluced yarns are characterised by different shapes of yarn breaking runs, by single-, double-, and multi-stage runs. On the basis of the shape of the stress-strain curves, we draw conclusions about the effect of the linking of component yarns. By analysis of the stress-strain curves, we estimated:
 - a) the breaking force and elongation at the moment of the first force peak, at which the destruction of yarn begins,
 - b) the breaking force and elongation at the moment of the final force peak at which yarn breaks.

The values of breaking forces and elongations recorded were compared to the level of the parameters of the component yarns.

- Measurement of the cohesion forces of component yarns (which means the forces which are needed to divide yarns interluced pneumatically). The method of assessing this parameter was elaborated at the Textile Research Institute [8]. The measurements are performed with the use of an automatic tensile tester dedicated for yarns, equipped with a specially designed adapter devoted to feeding and transporting the yarn, together with changing the position of the tensile tester’s jaws. When the tester is switched on, the movement of the jaws to their upper position, with a speed of 100 mm/minute, divides the component yarns. The forces which occur while dividing the components are identified from the stress-strain curve recorded.
- Measurement of yarn hairiness. This parameter was estimated with use of a Shirley Yarn Hairiness Tester [9]. The level of hairiness was compared to that of the staple component yarn.
- Measurements of the yarn linear density unevenness and the number of faults were performed with use of an Uster apparatus [10]. These parameters were analysed in relation to those of the staple yarn component

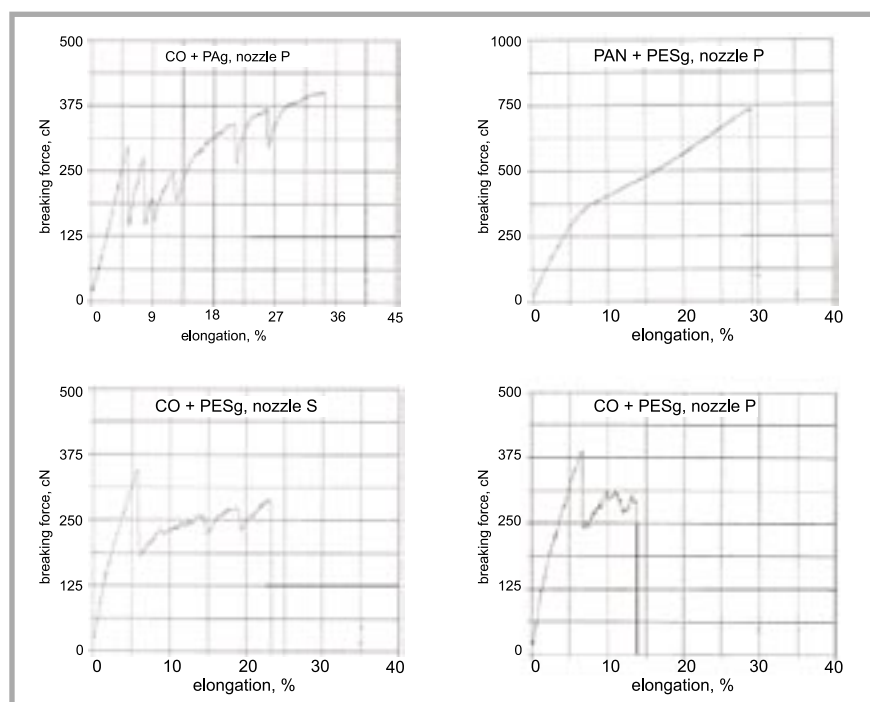


Figure 2. Examples of the breaking force in dependence of elongation for various raw material variants and different pneumatic nozzles.

Research results and discussion

An analysis of the parameters of new staple-filament composite yarns formed by the process of pneumatic interlucing was carried out, especially the features of linking cotton staple yarns (CO) with chemical fibre filament yarns (PA, PAg and PESg) in this way. The influence of the interlucing process parameters, the interlucing nozzles, and the raw materials used on the linking effect of component yarns was analysed. The analysis also included the aspect of physical and quality properties of the new yarns.

The linking of components in the yarns discussed occurs as a result of the interlacing and/or wrapping of external fibres of staple yarns with/around filament yarns.

Tensile strength parameters of yarns

Tests of the mechanical parameters of the yarns indicated a different character

of yarn breaking curves with dependence on the process parameters and nozzles used, as well as the raw material composition. On the basis of the shape of the stress-strain curves, breaking forces and elongations determined on the basis of these curves, we can draw conclusions about the linking performance of both component yarns. Examples of stress-strain curves are presented in Figure 2, which demonstrate their different shapes, characterised by single-, double-, and multi-stage runs.

A multistage run of breaking force dependencies is a phenomenon, which is completely clear taking into consideration the use of components which are characterised by extremely different elongations at break, for example the cotton staple yarn CO with an elongation at break of about 5%, and the filament yarns PAT, PAG, and PEG with an elongation at break of 28 – 38%. Interesting results occur due to the determination of breaking forces and elongations during the initial and final yarn breaking phases, which means at the moments of:

- the first breaking force peak – the beginning of yarn destruction when the component yarn with lower elongation at break, which is the cotton staple yarn CO, breaks,
- the final peak, which means the breaking of the second component, is filament yarn composed of chemical fibres, and at the same time the whole composite yarn.

The relation of these parameters to the breaking forces and elongations at break of component yarns indicate the performance of linking and the action effects of compressed air on component yarns. We aimed at obtaining linkings for which the forces at the first peak would be greater than the breaking force of the component yarn with lower elongation at break, which is that of the cotton yarn. The results of investigation by changing the process speed, air pressure, the kind of nozzle (S, K, or P) and the breaking force of the component yarns of the composite yarn CO+PAT (textured filament yarn) are presented in Figures 3 and 4.

The analysis of yarn test results indicated many significant dependencies which were differentiated with dependence on the nozzles characterised by different kinds of air stream action on the yarn linking:

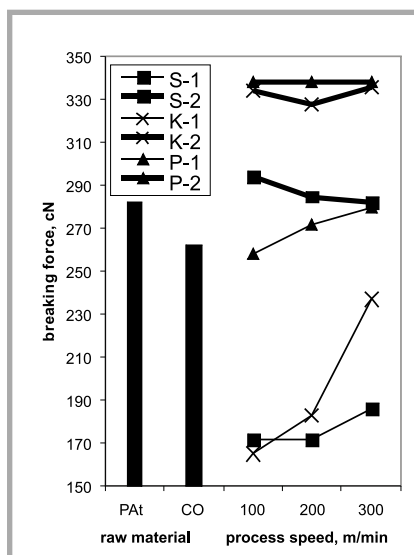


Figure 3. Influence of the process speed on the breaking forces of pneumatically interlaced yarns; 1 – first peak, 2 – final peak; nozzles: S – 0.4 MPa, K, P – 0.2 MPa.

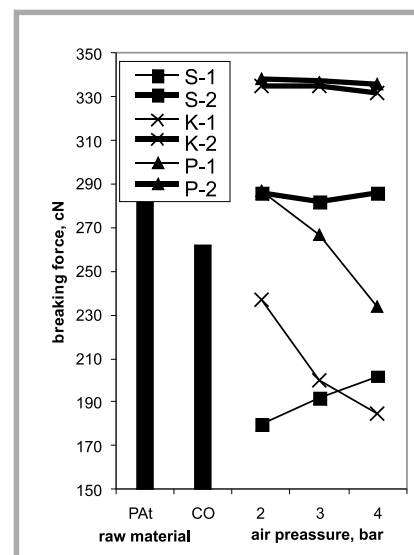


Figure 4. Influence of the air pressure on the breaking forces of pneumatically interlaced yarns; 1 – first peak, 2 – final peak; nozzles: S – 0.4 MPa, K, P – 0.2 MPa, process speed 300 m/min.

- In the case of nozzle K (the air stream at a particular angle) and nozzle P (perpendicular air stream), an increase in the breaking force appears at the first peak (positive effect) with an increase in the process speed and a lowering of the air pressure. Higher values of breaking force were obtained for yarns linked by nozzle P compared to those linked by nozzle K. These forces, in comparison to the breaking forces of the initial cotton yarn CO, are at a similar level for nozzle P, whereas for nozzle K they are significantly lower. The breaking forces at the final peak are at a similar level for both nozzles, which are higher than that of the filament component PAT by about 20%. These dependencies brought to light that nozzle P is

characterised by better performance and smaller destructivity of action.

- In the case of nozzle S (the circumference-type), the yarn breaking forces at the first peak increases with an increase in air pressure. The level of these forces is considerably lower than the initial breaking force of the yarn CO. At the final peak, the breaking forces achieved a level a little higher than the value of the filament yarn PAT (by about 4%). These results indicate nozzle S has a lower linking performance in comparison to nozzles K and P.

Investigations with use of various filament yarns in the linking systems CO+PAT, CO+PAG, CO+PEG and different interlacing nozzles designated as

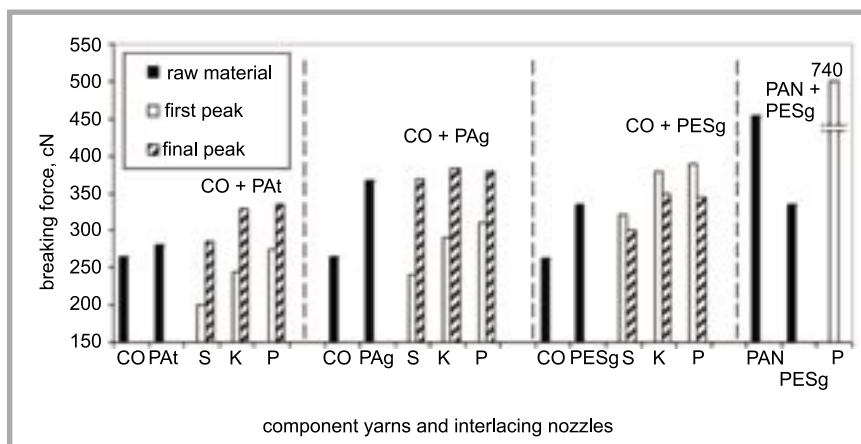


Figure 5. Influence of multifilament degree of the filament yarns and kind of nozzle on the breaking force of yarns linked by pneumatical interlacing; nozzles: S – 0.4 MPa, K, P – 0.2 MPa; process speed 300 m/min.

S, K, and P indicated a great influence of the filament component on the tensile strength parameter distribution among the interlaced yarn segments. The results of these investigations are illustrated in Figure 5. The filament yarns differ in their strength parameters, structure (textured or even) and surface properties.

The most advantageous results of this series of tests were obtained for CO+PEg composite yarns, which were characterised by the following relations: the force of the first peak is greater than the force of the final peak, and the force of the first peak is greater than the breaking force of the yarn CO for all the nozzles used. The increase in the breaking force at the first peak in relation to the yarn CO was within the range of 40% - 60%. This effect confirms a good interlacing of the component yarns and good transition of the breaking forces by both components. In the case of CO+PAg yarns, other relations were obtained: the forces at the first peak were lower than those of the final peak, but at the same time, while testing the nozzles K and P, the forces of the first peak were greater than the breaking force of the CO component by up to 40%. In the case of the yarn CO+PAT, for the majority of variants, the forces at the final peak were lower than the breaking force of CO. However, for all the assortments there exists a possibility of obtaining a positive dependency, which means that the force at the first peak is greater than the breaking force of CO. This dependency is important from the point of view of processing composite yarn through further technological processes. A greater increase in the force at the first peak in relation to/compared to that of the staple fibre used indicates a higher performance of linking with multifilaments.

Figure 6 presents summarising information concerning the whole range of experiments which are related to the area in which there occurred percentage changes (an increase or decrease) in the breaking forces of the component yarns interlaced in relation to the breaking force of the initial yarns. This data includes all the results of investigation involving the nozzles, process speed, air pressure, yarn tension, and different raw material systems. Figure 6 indicates the possibility of creating the mechanical properties of interlaced yarns, which depend on suitable selection of different parameters.

An analysis of yarn elongation at the moment of the beginning of the break, and during the final phase, which is

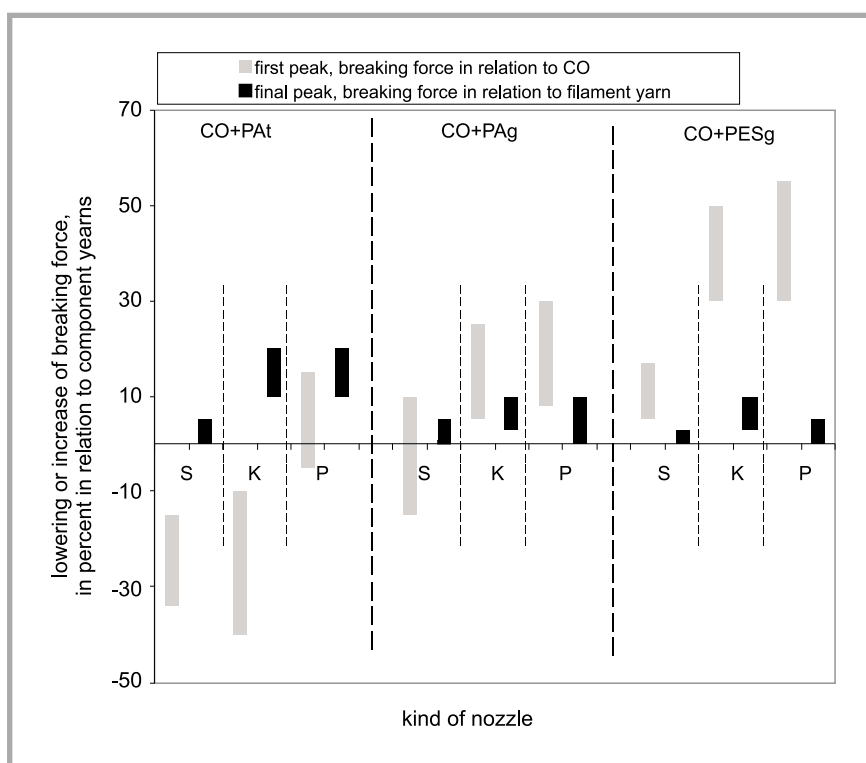


Figure 6. Percentage areas of changes (increase, lowering) of breaking forces of the interlaced yarn's components in relation to initial yarn values for the whole range of experiments carried out by us; nozzles: S 0.4 MPa, K, P – 0.2 MPa; process speed 300 m/min.

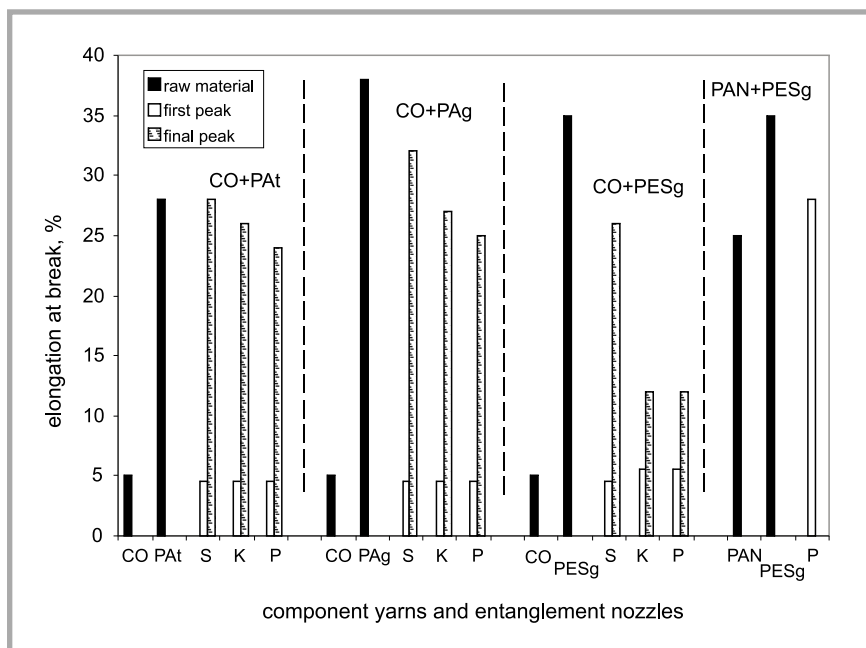


Figure 7. Influence of multifilament degree of the filament yarns and kind of nozzle on the elongation at break of yarns linked by pneumatical interlacing; nozzles: S 0.4 MPa, K, P – 0.2 MPa; process speed 300 m/min.

illustrated in Figure 7, indicates that the destruction of yarn interlaced with a content of the staple yarn CO is initiated at an elongation of about 5%, typical for the elongation at break of cotton yarn. The elongation W_k at the final break of the interlaced composite yarn (final peak) is within the range of 12% - 32%

(for initial yarn with elongation at break within the range of 26% - 36%). The final elongation W_k of the/an interlaced yarn depends on the kind of filament component and is always lower than its elongation at break, which may be illustrated by the following data: For the composite yarn CO+PESg, the final elongation W_k

is smaller than (by 30 – 70)% in relation to that of the filament yarn PAg (a greater decrease in yarns interluced by nozzles P and K, but smaller for those linked by nozzle S); for yarns CO+PAg the final elongation is lower (15 – 35)% in comparison with yarn PAG; and for yarn CO+PAT the final elongation is lower by up to 15% of the PAT yarn elongation or it is at the same level. Generally, we can state that yarns interluced by nozzles K and P are characterised by lower elongations at break, and at the same time by a greater decrease in these elongations in relation to what of the initial filament yarns than the yarns interluced by nozzle S. This behaviour signifies the better performance of nozzles P and K with regard to the linking of components than that of nozzle S. Investigations of interluced yarn from polyacrylonitrile (PAN) staple yarn and PEG filament yarn showed a single-stage run of the breaking force curve. This was the result of the mutual relation of the tensile strength properties of these yarns, where the breaking force of PAN yarn was higher than that of PEG yarn, whereas the elongation of PAN yarn was about 30% lower than that of PEG yarn. In this case the breaking force of the interluced yarn is about 60% higher in comparison with the breaking force of the PAN component, which proves a high performance of interlucing. This latter assortment will be the subject of our further detailed investigations. The analysis of breaking forces and elongations at break confirms the influence of different parameters on the linking effects and mechanical properties of interluced yarns.

Summary

The pneumatic interlucing of yarns containing staple fibres is a new direction in the development of techniques and technologies for the formation of linked homogeneous and composite yarns. The action of a stream of compressed air on the yarns containing staple fibres causes differentiated changes in their mechanical parameters and surface appearance, as well as in the mutual connection of the component yarns. A broad knowledge was obtained about the structural and quality features of the new kinds of yarns and about the directions of their changes as a result of the direction of action of the air stream and its intensity on the yarns being interluced (different construction designs of the nozzles, air pressure, and the tension of the linked yarns), as well as different features of the components used. The evaluation of the interlucing

process and the properties of the composite yarns formed were based on differentiated yarn factors including tensile strength parameters, among others. In order to better recognise the influence of the particular parameters, which are responsible for the final effect of linking and the properties of linked yarns, a need arose for a detailed analysis of the dependencies of breaking strength vs. elongation. These stress-strain curves of filament – staple yarns linked by pneumatic interlucing are characterised by differentiated runs (single-, double-, and multi-runs) and allow to determine the level of breaking strength at different stages of the stretching process (from the beginning of yarn destruction to the final break). Analyses of these forces with regard to the breaking forces of component yarns allowed to obtain an overview of the linking performance, which depends on the process parameters and the kind of pneumatic nozzles used, as well as on the features of component yarns, which can be described by the following statements:

- Each of the assortment systems are characterised by a different shape of the breaking force curves and the level of forces during different stages of the yarn stretching process, which results from different tensile strength properties (breaking strength at elongation at break) and surface features of the component yarns.
- Significant differences occur in the distribution of tensile strength parameters of yarns interluced in through-way type nozzles (K, P, and R) and the circumference-type nozzle S. Such differences also occur for yarns interluced in the same kind of nozzle, but of different designs (K, P, and R). This is caused by different directions of action and the intensity of pressed air on the linked yarns.
- While linking staple yarns with filament yarns of significant difference in their elongation, the resulting elongation of the interluced yarn is lower than that of the filament component yarn. An elongation decrease also takes place with an increase in the performance of the linked components.

For an entire evaluation of the influence of the interlucing process on the properties of composite yarns and the linking effect, a complex estimation of yarn parameters is necessary. Taking this into account, not only the tensile strength parameters of the composite yarns were investigated and analysed, but also the

surface features (hairiness and number of faults) and the unevenness of linear density, as well as new parameters dedicated to the estimation of linking effects, such as the segments of the forced pull-down of the weaker component and the cohesiveness forces. The results of these investigations will be described in the second part of this article published in the next issue of *Fibres & Textiles in Eastern Europe*,

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References

1. W. Ankudowicz, H. Dopierała: „Pneumatic interlacing in manufacturing filament – staple yarns”, *Przegląd włókienniczy* nr 1, 2005r. p. 37-41.
2. E. Schwarz, L. Lacher, Heberlein: „Air Covering: a process with great potential”. *IFJ Oktober 2001r.* p.62-66.
3. <http://www.heberlein.com>
4. <http://www.temco.com>
5. <http://www.ssm-airtex.com>
6. H-D. Scherpt, Marc A. Zenses „Advanced Air Jets to Meet Higher Performance Yarn Requirements. *IFJ, February 2004*, pp. 60-61.
7. PN-EN ISO 2062: 1997 „Tekstylija. Nitki w nawojach. Wyznaczanie siły zrywającej i wydłużenia przy zerwaniu odcinków nitki”.
8. H. Królikowska, W. Ankudowicz, H. Dopierała: „Some aspects of evaluation pneumatic interlaced filament – staple yarns”, *Przegląd włókienniczy* nr 12, 2005.
9. PN-91/P-04685 „Tekstylija. Przędza, włóczka. Wyznaczanie włóchatości metodą fotoelektryczną”.
10. PN-76/P-04804 „Metody badań wyrobów włókienniczych. Przędza i półprodukty przędzenia. Wyznaczanie nierównomierności masy liniowej metodą elektro-pojemnościową”.
11. M. Keulen: “Advanced Ceramics Techniques for Refinements in Air Jet Technology”. *IFJ. October 2001*.
12. W. Ankudowicz, H. Dopierała, P. Swaczyna: „The technique of pneumatic linking filament yarns and its application for linking yarns from staple yarns”, *Przegląd włókienniczy*, 8/2007, pp. 58-62.
13. R. Machatschke, H.-D. Scherpf: “Controlled interlacing with Temco Air-jet in texturing” *Chemical Fibers International* 4/2001, pp.144-145.
14. H. Weinsdorfer, H. Artunc, B. Cui: „Verwirbelung von glatten und texturierten Mikrofilamentgarnen” *Melliand Textilberichte* 2/1993, pp. 111-115.
15. H. Weinsdorfer, „Improved Consistency in Flat Yarn Interlacing”, *IFJ 12/2001*, pp. 80-82.

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