

Measurement of the Adhesive Force for Selected Yarns Joined with the Use of the Pneumatic Linking Technique

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Abstract

The article presents an idea of measuring the adhesive force – a force binding together the components of yarn pneumatically linked, describes the measuring system designed and partially constructed at the Textile Research Institute (IW), discusses the conditions of the measurement and presents exemplary results of the adhesive force indicator, determined specially for studies on the structure and properties of yarns pneumatically linked, composed of staple fibres.

Key words: pneumatic linking, pneumatically linked yarns, adhesive force.

Introduction

The technique of pneumatically linking yarns is well known only with reference to those made of filament fibres and is used in order to improve the quality and processing of yarns as well as to enlarge the number of linear textile products [1, 6, 7]. The Textile Research Institute in Lodz (IW) conducts studies on the application of the pneumatic linking method by forming linked yarns composed of staple fibres [4, 2]. The effect of pneumatically linking two yarns made of staple fibres or yarn made of staple fibres with yarn made of filament fibres is controlled by the braiding and wrapping of both component yarns with fibres from external layers made of staple fibres. These fibres form the hairiness of yarn – determined as the amount of fibres protruding from the surface of yarn for a unit of length (1 m). Thus the higher the value of hairiness of linked yarns, the better the effect of linking the components and the bigger the force required to separate them. There are many different factors and parameters shaping the general quality of yarn, such as the parameters of fibres (length, amount of neps, amount of impurities, non-uniformity of linear mass etc.), which create the yarn and technological factors influencing the

values of particular qualitative and physical parameters [9, 10]. However, from the point of view of this publication, the most important parameter influencing the linking of component yarns is their hairiness and the number of fibres participating in the linking process – creating the linking area [11, 12]. Therefore it is important to find an indicator and measuring method for determining the forces linking both of the component yarns [2, 3, 5 – 8], which was done at the Textile Research Institute (IW) as research project No. 4T08E08224 in the following dates: 4.2003 – 12.2004.

Idea of measurement and devices

The principle of measuring the adhesive force assumed consists in the separation of components of the pneumatically linked yarn with the use of a standard tensile testing machine for yarns.

The ends of component yarns are placed in two grips of a tensile tester. Next, after starting the tester, the linked yarn is separated, which is presented on the graph of forces linking both of the yarns. **Figure 1** presents a linked yarn, as well as a yarn separated and its components in the following stages of the separating process.

Figure 1 presents characteristic groups of fibres linking the component yarns.

The measurement consists in determining the forces during the tensile process of fibres forming the connection and accompanying forces of unwrapping and unwinding. An additional element used was a yarn guide, thanks to which the yarn changed direction from vertical to horizontal. The tensile tester made by Hounsfield was used in this research. The yarn guide, fixed on a stand, was placed at a previously set distance and at a previously set height. **Figure 2** presents the measurement of the adhesive force.

Conditions of measurement:

- initial distance between grips 1 and 2 : 200 mm (distance allowed for the separation of yarn and placing its components in the grips in order to start the measurement);
- stationary yarn guide is fixed half way from the grips in their initial position (100 mm above the position of the bottom grip) to a distance of 1500 mm from the tensile machine;
- travelling speed of the grip 2 – 150 mm/min; the speed is lower than that used for breaking yarn. The speed of unwinding was decreased for better observations;
- the maximum distance of travelling for grip 2 – 500 mm.

The operation of the measuring stand was evaluated on the basis of a study on pneumatically linked yarns contain-

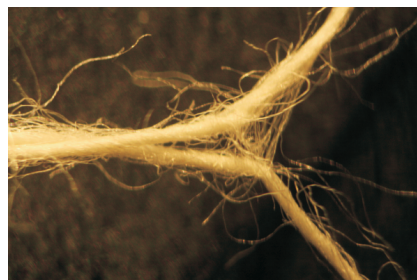


Figure 1. Process of separating of linked yarn.

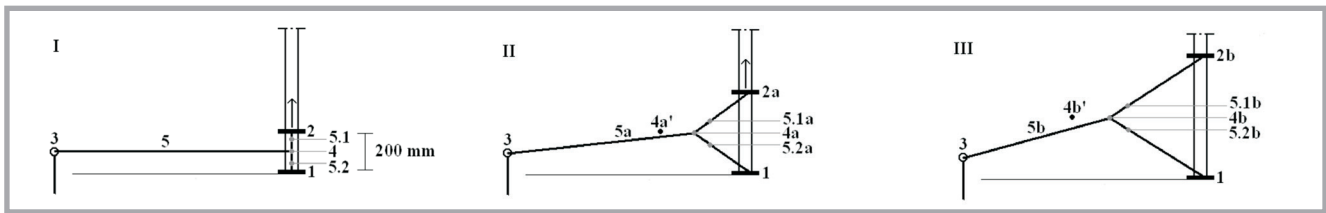


Figure 2. Scheme of fixing and guiding the yarn during adhesive force tests at subsequent stages of the measurement; Description of the scheme: 1) Stationary grip of the tensile machine, 2) Movable grip of the tensile machine, 2a and 2b – subsequent positions of the movable grip; 3) Guides of linked yarn, 4a and 4b – subsequent positions of the point of separating yarn with the increasing distance between the grips (4a' and 4b' – position of the point of yarn separation for yarns loosely linked); 5) Linked yarn in the initial position; 5.1 and 5.2 – components of the linked yarn; 5a and 5b – linked yarn in subsequent positions of grip 2; 5.1a, 5.2a and 5.1b, 5.2b – components of linked yarns in subsequent positions of grip 2 (2a, 2b).

ing two cotton yarns (CO+CO) from a carded system. After starting the tensile machine, as a result of raising grip 2, one of the component yarns is lifted up, causing as follows:

- the point of separating yarns (4) changes its position with respect to point (3) as far as to point (4b) through point (4a). Point (4) also changes its position horizontally, depending on the adhesive force; for tighter connections it is placed closer to the tensile machine, while for loose connections it is moved away from the tensile machine (4a' and 4b');
- linked yarn changes its position toward point (3): from point 5 (angle of 90°) to point 5b through point 5a.

Separation curves that are registered during the tests performed according to the method mentioned above show a tendency towards an increase in the value of the adhesive force with an increasing distance between the grips. Examples of such courses of separation forces in cN for the tested component yarn comprising two pneumatically linked cotton yarns (CO+CO) are presented in **Figure 3**, where the values of adhesive forces are registered as a function of elongation.

During the tests, an increasing irregularity of distribution of separating forces carried by both of the components (arms 5.1a and 5.2a as well as 5.1b and 5.2b) was noticed, that is a change in the forces and shape of the isosceles triangle formed by the components of yarn in the separating process. In order to eliminate irregularities in the separating process, a modification of the measuring method was done that enabled to keep the form of an isosceles triangle during the whole process of separating the components of yarn. The idea of this new solution consists in the introduction of an additional element guiding the yarn, thus the uniform distribution of forces in the components of yarn is maintained and an isosceles triangle is formed by arms 5.1a, 5.2a and arms 5.1b, 5.2b throughout the whole measuring process. An additional element, presented in **Figure 4**, was de-

signed and constructed at IW in the form of an attachment to the tensile machine.

Principle of operation

The motor of the device placed inside the unit case (1) drives the leading screw (2) through the jaw clutch (3). The leading screw (2) is fixed in the ball bearings (4). Between the casings of the ball bearing (4) there is a guide (5) on which a slide

with a nut (6) runs. A bar (7) with yarn guides (8, 9) is fixed to the slide and runs upright with steady speed – twice lower than that of the top grip of the tensile machine. By pulling the nut (6) off the leading screw (2), the drive becomes disconnected and the slide (6) can be lowered to the bottom position, enabling to restart the device. The speed of the slide is determined experimentally and is within

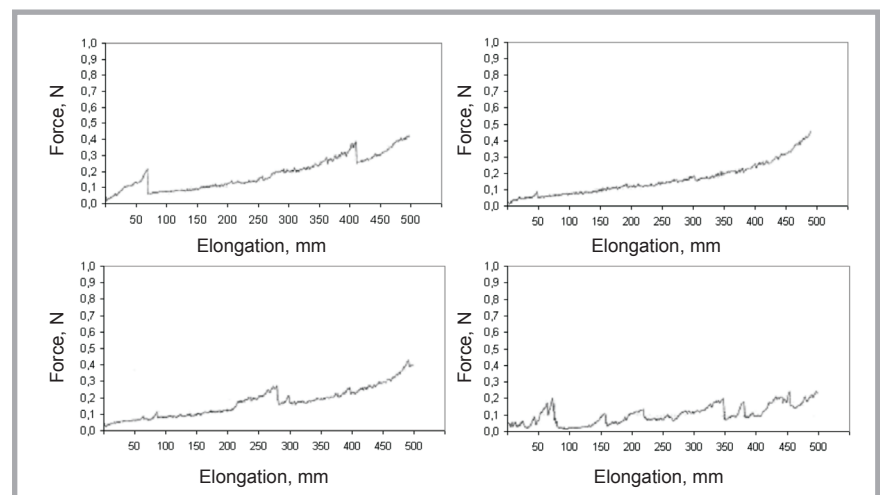


Figure 3. Exemplary curves of the adhesive force.

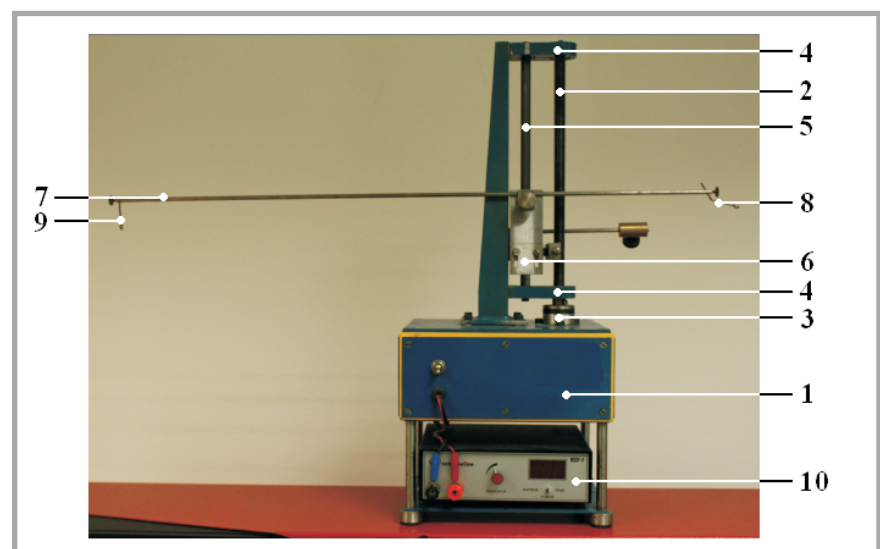


Figure 4. Device guiding the yarn to the separating zone.

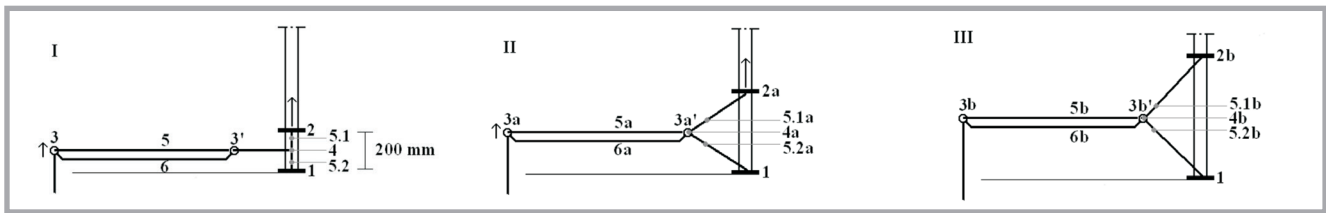


Figure 5. Scheme of fixing and guiding the yarn during tests on adhesive force using an additional device guiding yarn to the separating zone in subsequent stages of measurement; Description of the scheme: 1) Stationary grip of the tensile machine; 2) Movable grip of the tensile machine 2a and 2b – subsequent positions of the movable grip; 3) 3' – guides of linked yarn; 3a, 3a' and 3b, 3b' – subsequent positions of yarn guides; 4) 4a and 4b – subsequent positions of the point of separating yarn with increasing distance between the grips; 5) Linked yarn in the initial position; 5.1 and 5.2 – components of the linked yarn; 5a and 5b – linked yarn in subsequent positions of grip 2; 5.1a and 5.2a as well as 5.1b and 5.2b – components of linked yarns in subsequent positions of grip 2 (2a, 2b); 6) Guiding bar – initial position; 6a and 6b – subsequent positions of the bar guiding yarn during the measurement.

the range 50 – 100 mm/min, which can be regulated by the stabilised feed mechanism RZS – 1 (10) of controllable voltage 0 – 30 V/3A.

A scheme of measuring forces with the use of the attachment for parallel feeding of yarn is presented in **Figure 5**.

The device designed and constructed enables to feed the components of linked yarn to the grips of the tensile machine under stabilised conditions. Using the yarn guides, especially at the point of separating the components, provides the

form of an isosceles triangle (of the following vertexes: 1-4a-2a and 1-4b-2b), formed from the components of yarn during the measurement. The separating point is placed at the same distance from the tensile machine throughout the whole measurement (on the vertical line of travelling yarn guide 3). Exemplary graphs of adhesive forces registered with the use of the modified measuring set are presented in **Figure 6**.

For each graph of the adhesive force separate peaks and corresponding values of forces were determined (few values de-

pending on the character of the graph). On the basis of the values obtained, an average value for the sample tested was calculated.

Study on the adhesive forces for various component yarns formed by the technique of pneumatic linking

During the tests, the correctness of separating component yarns was recorded for each sample, conducting 50 measurements for each sample and obtaining 50 graphs of adhesive force for each variant.

Taking into consideration the aspects mentioned above and test results according to method I and II (character of graphs for adhesive forces), it was decided that method II will be used in further research using the attachment constructed at the IW, providing parallel feeding of yarn during measurement of the adhesive force.

An analysis of adhesive forces was made on the basis of the results of 20 variants of pneumatically linked component yarns. In the research the following component yarns were used:
CO/O – carded cotton yarn,
CO/B – open-end rotor cotton yarn,
WO – worsted woollen yarn,
PAN 3.3 – polyacrylonitrile yarn from the converter system of the linear mass of 3.3 dtex fibres,
PAN 1.7 – polyacrylonitrile yarn from the converter system of the linear mass of 1.7 dtex fibres,
PES – polyester yarn made of filament fibres.

Table 1 presents test results of the structural parameters of the component yarns mentioned above.

All the variants of the component yarns were formed on a PY11 machine for

Table 1. Structural parameters of component yarns.

Parameter	Unit	CO/O	CO/B	WO	PAN 3.3	PAN 1.7	PES	
Linear density of yarn	tex	20.1	20.0	22.1	24.2	25.6	8.4	
Linear density of fibre		0.17	0.17	0.59	0.33	0.17	0.12	
Twists	t.p.m	777	975	612	539	520	-	
Metric twist coefficient α_m	-	110	138	91	84	83	-	
Hairiness for length of	1 mm	No/m	154	101	133	143	146	-
	3 mm		43	18	56	63	43	-
	5 mm		12	15	6	7	25	-

Table 2. Plan of the experiment and results obtained.

Variant No.	Yarn composition	Type of nozzle	Air pressure, MPa	Adhesive force, cN		
				min.	max.	av.
1	CO/O+CO/O	S	0.40	11.30	28.90	19.40
2	CO/B+CO/B			7.60	27.40	16.30
3	WO+WO			14.30	43.70	26.30
4	PAN 3.3+PAN 3.3			26.40	96.80	56.90
5	PAN 1.7+PAN1.7			1.30	29.10	10.60
6	CO/O+CO/O	K	0.20	1.00	3.90	2.40
7	CO/B+CO/B			1.70	4.30	3.10
8	WO+WO			2.10	7.00	4.30
9	PAN 3.3+PAN 3.3			1.50	24.80	9.30
10	PAN 1.7+PAN1.7			1.30	21.30	7.70
11	CO/O+PES	K	0.20	54.50	97.60	82.50
12	CO/B+PES			44.00	84.00	65.70
13	WO+PES			25.90	56.70	45.10
14	PAN 3.3+PES			17.30	74.20	52.40
15	PAN 1.7+PES			46.70	93.40	41.90
16	CO/O+PES	S	0.40	22.60	77.70	49.50
17	CO/B+PES			2.10	53.50	19.90
18	WO+PES			6.80	51.70	29.00
19	PAN 3.3+PES			4.70	66.50	30.50
20	PAN 1.7+PES			1.70	41.90	18.50

pneumatic linking of yarns. The speed of collecting linked yarn was 300 m/min.

The composition of yarns for each variant and values of technological parameters at which the linking process was conducted are presented in **Table 2**, along with the results of adhesive force measurement.

In the technological studies, the following two nozzles (Heberlein, Switzerland) were used for the pneumatic linking of yarns:

S – ‘circumferential’ nozzle with an air duct located tangentially to the duct for yarns being linked

K – ‘go-through’ nozzle with an air duct located perpendicular to the axis of the duct for yarns being linked.

These nozzles of various construction have different effects of the air stream on yarns being linked. The main difference in their construction is in the location of the duct feeding the air to the duct in which component yarns are subjected to linking. Nozzle S has an air duct located tangentially to the yarn duct, thus the air stream flows ‘circumferentially’, while nozzle K has an air duct located perpendicular to the yarn duct, thus the air stream flows through the yarn.

Results of research on the adhesive force and their analysis

Figures 7 and **8** present exemplary courses of curves obtained in tests determining the adhesive forces for selected variants of component yarns formed in various arrangements and with two different linking nozzles.

Component yarns made of staple fibres linked in nozzle S (variants 1 – 5) have higher values of adhesive force than the same yarns linked in nozzle K (variants 6 – 10). In the case of component yarns consisting of polyester yarn made of filament fibres, the results are the opposite – yarns linked in nozzle K (variants 11 – 15) have higher values of adhesive force than those linked in nozzle S (variants 16 – 20). Such an effect is caused by the construction of the nozzle shaping the air stream linking the yarns and by the structure of component yarns used in the linking process. Nozzle S, in which the air stream acts ‘circumferentially’, shapes the effect of linking yarns by wrapping both of the component yarns subjected to linking with fibres from the surface layers of component yarns made of staple

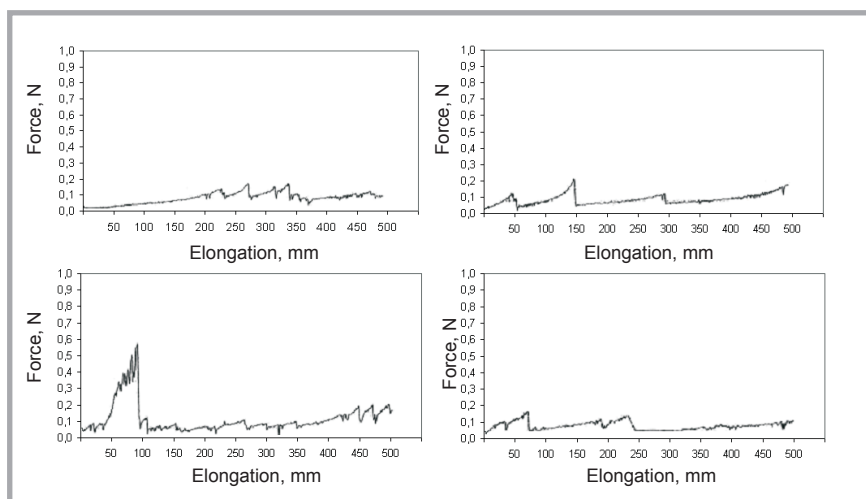


Figure 6. Exemplary graphs of the adhesive force obtained by the modified measuring method with the use of an element feeding yarn to the separating zone.

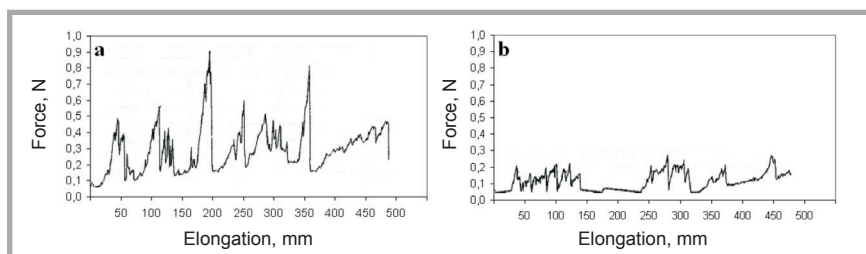


Figure 7. Exemplary curves of the adhesive force for component yarn composed of polyacrylonitrile yarns made of 3.3 dtex fibres linked in: a) nozzle S; b) nozzle K.

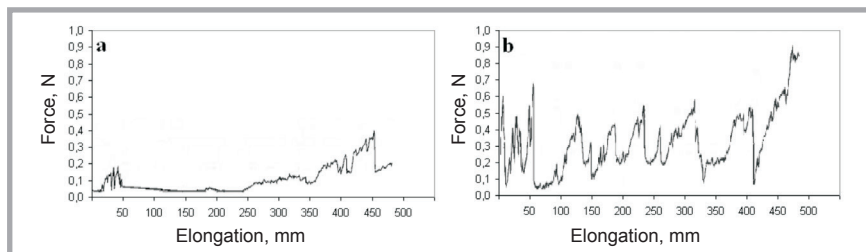


Figure 8. Exemplary curves of the adhesive force for component yarn composed of cotton rotor yarn and polyester yarn linked in: a) nozzle S; b) nozzle K.

fibres. The number of fibres participating in the linking process is two times higher than in the case of forming the linked yarn, where one of the component yarns is made of filament fibres. This explains the higher values of adhesive force for yarns made of staple fibres formed in nozzle S.

In nozzle K the air stream acts perpendicular to the component yarns being linked. As a result, fibres from the surface layers of the composite yarn made of staple fibres migrate and go through the space of the second component and wrap both of the component yarns being linked. Simultaneously the stream of compressed air acting on the yarn made of filament fibres opens the space between the elemen-

tary fibres and enables the migration and jamming of fibres from the surface layers of the component yarn made of staple fibres. This explains the higher values of the adhesive force in yarns composed of filament fibres formed in nozzle K.

During the realisation of research tests, it was noticed that the adhesive force depends on the hairiness of component yarns subjected to linking. Component yarns made of cotton (CO/O and CO/B) as well as polyacrylonitrile (PAN 3.3 and PAN 1.7) used in the tests varied in the values of hairiness. Classic cotton yarn (CO/O) had higher values of hairiness in comparison to rotor cotton yarn, while polyacrylonitrile yarn made of 3.3 dtex fibres (PAN 3.3) had higher values of hairiness

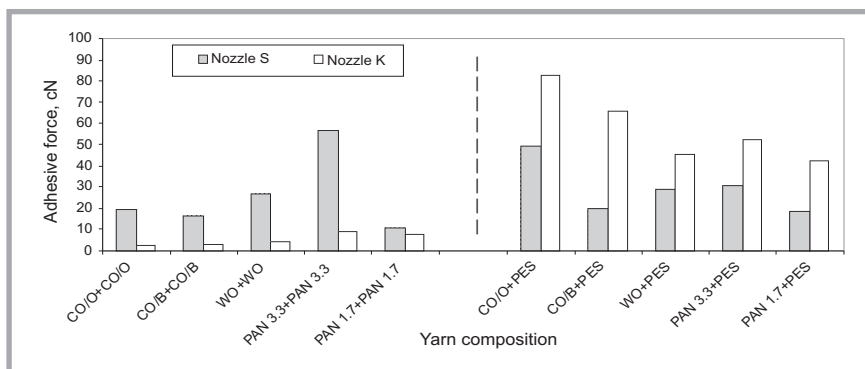


Figure 9. Results of adhesive force measurement for all variants of yarns tested.

than polyacrylonitrile yarn made of 1.7 dtex fibres (PAN 1.7). Linked yarns composed of component yarn of higher hairiness had higher values of adhesive force, which can be explained by the number of fibres participating in the process of linking yarns by fibres of both components going through one another and wrapping both of the component yarns with fibres from the surface layers of the component yarns made of staple fibres.

Moreover polyacrylonitrile yarns used in this research varied in the linear mass of elementary fibres, which is also important from the point of view of the adhesive force. Yarns linked with the use of component yarn made of fibres of high linear mass (3.3 dtex) had higher values of adhesive force than those linked with the use of component yarn of fibres of low linear density (1.7 dtex).

The type of nozzle used in the research as well as the parameters and structure of component yarns determine the properties of linked yarns, meaning the effect of linkage measured by the force required to separate the component yarns. The influence of the force linking the component yarns on the parameters of yarn, such as rigidity, strength and its behaviour in manufacturing flat textile products should be studied. It is also important to determine the minimum value of the adhesive force required to process these yarns without disturbances in order to obtain flat textile products.

The aspect mentioned above will be the subject of future publications.

Summary and conclusions

1. We found it necessary to determine the linkage criterion of components in pneumatically linked yarns composed of two yarns made of staple fibres. We recognised such factors as the adhe-

sive force, possible to be determined in the process of separating the yarns.

- The method for testing the force of pneumatically linking yarns was determined as a measure of the force separating the component yarns.
- A system for measuring the adhesive force was designed and partially constructed at the IW consisting of a tensile machine for measuring the strength of yarns and a device in the form of an attachment feeding the yarn to the separating zone with a controllable feeding element moving perpendicularly.
- The adhesive force is measured with the use of a tensile machine, whose values are recorded on a graph as a function of the elongation.
- The measuring method developed at the Textile Research Institute can also be used to determine adhesive forces for component yarns in which one of the components is a filament yarn.
- The research conducted showed a tendency in the values of the adhesive force as a result of applying different sets and kinds of component yarns as well as different types of nozzles for pneumatic linking.
- It is necessary to continue the research in order to determine the influence of the adhesive force of component yarns on their quality and technological usability of linked yarn.

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