IDENTIFYING THE CAUSE OF DESTRUCTION OF TEXTILE LINEAR STRUCTURES

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Abstract

The article presents investigations into the mechanism of continuity loss of textile linear products. A method and tools for implementing it have been developed with the aim of investigating loose textile products, and determining the causes of their destruction. Special emphasis is placed on the usability of the procedure we accepted for investigating the resistance of the product's structure to the action of an aerodynamic force which occurs during the transport of weft with a weak structure. Two mechanisms of yarn breakage, especially that of loose wefts, have been differentiated. The first consists in breaking fibres which form the yarn, and the second in mutual slippage of fibres. Both mechanisms can be determined by analysing the force-elongation curves over yarn stretching in both static and dynamic conditions. The influence of an air stream acting longitudinally to the yarn, its velocity and time of action were also determined, with the aim of recognising the conditions of pneumatic weft transport.

Key words:

loose textile structures, destruction, break, fibre slippage, defibring, weft, pneumatic picking

Introduction

The aim of this work is an attempt to answer the question of how linear textile products composed of staple fibres lose their continuity. This question is one of the basic problems of textile science and practice, long known to workers in the field, and remains a question of highest importance regarding the usability of a product. Many researchers have presented theoretical considerations of this problem. Two phenomena which could cause the loss of continuity have been indicated. The first consists in the breakage of the excessively loaded fibres which find their end in thread breakage, and the second in fibre slipping out from the bundle which leads to the cohesion loss of the staple fibre structure formed by the yarn.

The problem becomes remarkable in the case of the pneumatic transport of weak wefts which are characterised by a loose structure. Although the literature connected with related problems presents general considerations about yarn destruction, no aspect could be found which considered the influence of an aerodynamic force on the conditions of formation for either of the two above-mentioned destruction phenomena. Therefore in this work we have proposed an experimental verification of these phenomena on the basis of an analysis of load vs. deformation diagrams.

Breakage and slippage of fibres

We can easily determine, by simple observation of the stretching diagrams, the difference in shape between the case of fibre breakage and that of mutual fibre slippage. For example, the diagram in Figure 1 presents stretching which ends in the breakage of the fibres, whereas Figure 2 shows the continuity loss of a sample as the result of its defibration caused by slipping out of the un-cracked fibres. By analysing the characteristic 'force versus elongation' dependencies obtained by a tensile tester, the divergence of the declining parts of the stretching diagrams is visible. The two different states, fibre breakage and yarn defibration by slippage, can be unequivocally determined on this basis.

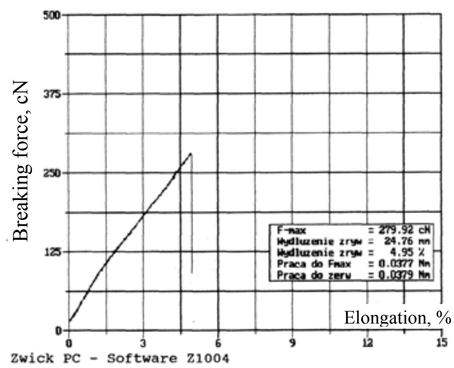


Figure 1. Stretching diagram of a thread which loses its continuity as a result of breakage

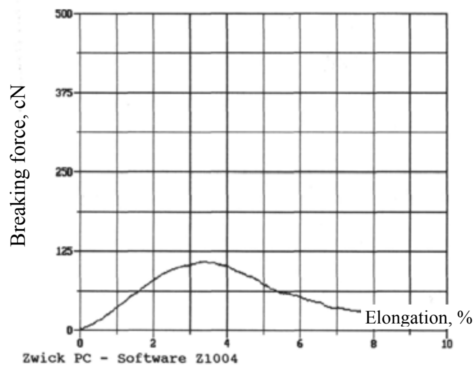


Figure 2. Stretching diagram of a loose textile product which loses its continuity as a result of defibration by slippage

However, both processes led to a loss of continuity, and they are of different quality; identifying each of them, and determining the created conditions of these processes, are the first steps on the way to discovering methods which could prevent the loss of continuity. Experiments indicate that the strength of loose textile structures in dynamic conditions is different than in static conditions. This proves the previously accepted statement that static tensile investigations are insufficient for estimating the usability of the tested structures which are destined for pneumatic transport, which takes place to the accompaniment of dynamic forcing. As the result of these considerations, we decided to carry out our experiments in dynamic conditions, and identify the states of continuity loss in them.

Dynamic destruction

We decided to transfer the observation of the phenomena of continuity loss carried out hitherto from the quasi-static range typical for a conventional tensile tester to the dynamic range. It seems that the possibility of giving empirical evidence of the occurrence in dynamic conditions of one of these two mechanisms (the breakage of the fibres or the fibre slippage out from the bundle) is an essential cognitive achievement. The ability to record and differentiate both the diverse continuity loss mechanisms on the basis of the records obtained gives the possibility of relating their occurrence to conditions existing during the test, conditions which can be introduced into the experiment in the form of independent variables. The changes of force with time, which we recorded during the phenomena of breakage and slippage (Figure 1 and 2), allowed us to attempt to interpret the diagrams obtained over dynamic stretching (Figure 3 and 4).

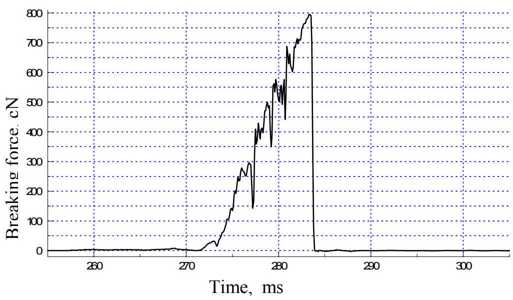


Figure 3. Yarn breaking diagram in dynamic conditions (breakage of fibres)

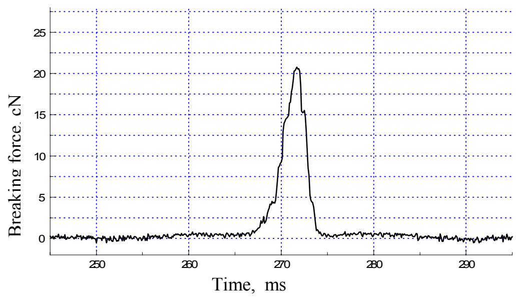


Figure 4. Yarn breaking diagram in dynamic conditions (slippage of fibres)

Measuring stand, measuring conditions and materials

A measuring stand was designed and constructed (Figure 5), allowing for separate and cumulative generation of a dynamic longitudinal force and an additional aerodynamic force applied externally. It was made possible to apply the dynamic load with continuously differentiated velocity in the presence or absence of an air stream acting, which could also flow with a pre-set velocity. The number of the air streams could also be selected. The above-mentioned pre-set abilities secure an appropriately wide range of loading conditions for the loose textile products tested, which allowed the simulation of real loading over picking-up with the use of one jet or a set of jets, as well as when picking-up in ways other than pneumatic, for example by cutting out the air stream.

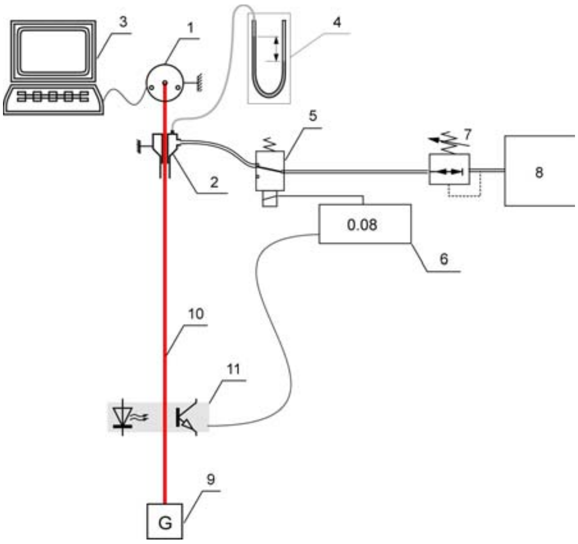


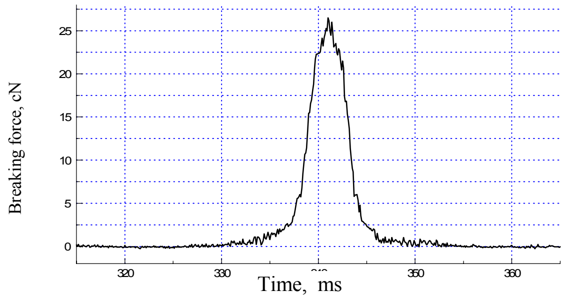
Figure 5. Measuring stand for dynamic stretching; 1 – tension gauge for the sample tested, 2 – jet, 3 – computer-aided measuring and control system, 4 – manometer, 5 –electrically controlled valve, 6 – time-lag switch, 7 – pressure reducer (controller), 8 – compressor, 9 – breaking load acting over free falling (h = 2 m, G = 200 g), 10 - sample tested, 11 – photo-optical sensor which releases the air stream in the jet (with programmed time-span).

Records were carried out under conditions of dynamic stretching, which simulated the fast increasing force corresponding with the force accompanying weft picking. The results, specifically the diagrams of breaking force, were the basis for our classification of the continuity losses into one of the two types mentioned above.

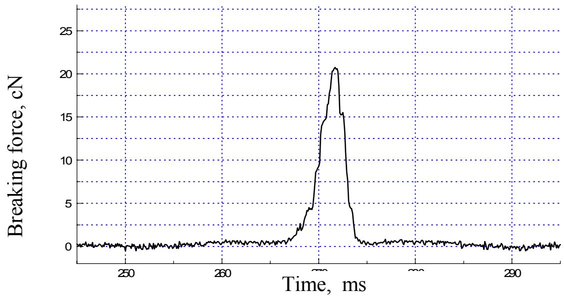
The loose textile product tested (10) was fastened by one end on the tension gauge (1), and the second end was loaded by a load (9) falling from a known height. The fall caused destruction of the sample. The possibility of a continuous selection of the falling height allowed for the creation of the velocity of the breaking force and the breaking acceleration at pre-set levels for the particular tests, with precise repeatability. What is more, the falling load was used as a factor releasing the air outflow along the sample by means of a photoelectric pulse. The airflow with pre-set parameters along the breaking sample created destruction conditions simulating the pneumatic weft transport. The tests were performed under two kinds of conditions: without the air stream, which degrades the sample, and with its presence. In order to present the second case, the testing stand was equipped with a pneumatic loom jet (2). The force acting on the sample and the time of continuity loss were measured both with and without the action of the air stream. Changes in the breaking force with time under dynamic conditions, without an air stream, for rowings with various twist values, are presented as examples in Figure 6. All the tests presented were carried out with cotton of 32-mm fibre length.

Research results and discussion

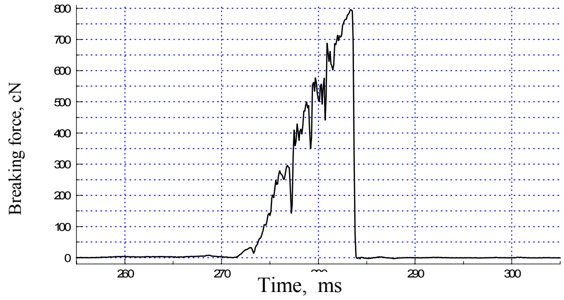
A set of diagram examples of the forces which cause the loss of continuity, differentiated by the change in one parameter (yarn twist, for example) which influences the tested process, is presented in Figure 6. By comparing the cases from a) to d), a change in the kind of continuity loss is visible. Case a) is an illustration of yarn breakage, whereas case d) is characteristic of defibration. The intermediate cases clearly show breaks of a part of the fibres, and at the same time the slippage of the remainder. The amount of the broken fibres in relation to those which slip off may change, as is visible from the set of characteristics obtained. Essential for estimating the kind of continuity loss is an analysis of the inclination value of the force-curve's slope after obtaining the maximum value. Monotonic changes in the slope were observed as a function of the sample's twist value. The diagram with a soft force-decrease slope, as shown in Figure 6d, is characteristic of defibration leading to continuity loss, whereas the diagram with a very steep slope (Figure 6.a) indicates the fibres' breakage which takes place at that time. The slopes of the increasing parts of the force F diagrams are often not smooth lines, as they mirror breakages or slides of fibre groups placed in momentary overloaded yarn cross-sections of the sample remaining under the impact of the increasing load.



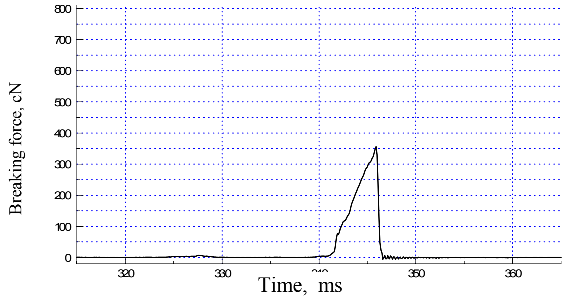
a) sample 125 tex, 185 twists/metre;



b) sample 125 tex, 175 twists/metre;



c) sample 125 tex, 125 twists/metre;



d) sample 125 tex, 115 twists/metre.

Figure 6. Changes of the stretching force F with time, under dynamic conditions, without air stream action, in dependence on twist value. The velocity of force applying was 5.5 m/sec

The quotient of ΔF/Δt (the ratio of the momentary maximum strength and the time over which the force decreases to zero) was accepted for quantifying the slope inclination. The process of determining the quotient ΔF/Δt is shown in Figure 7. The value of the quotient ΔF/Δt qualifies the phenomenon tested to one of both mechanisms, breakage or slippage.

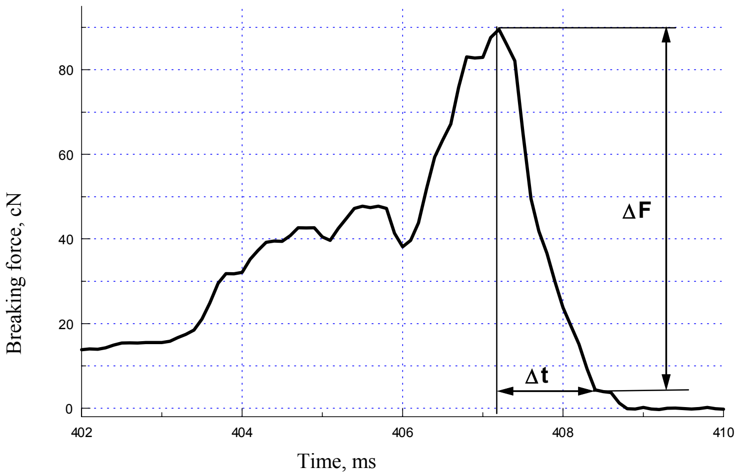


Figure 7. Determination of the quotient ΔF/Δt

According to current knowledge, a change in the above-mentioned quotient in dependence on the twist value can be expected. The dependence of the samples' strength on the nominal twist proves the increase (which after all is self-evident) in the cohesion forces between the fibres, caused by the higher twist, which in turn results in the structure's greater strength. The higher these cohesion forces are, the more the mechanism of destruction is displaced from the defibration range to the fibre breakage in the place in the yarn where the continuity loss occurs. Taking into account that at the constant loading velocity maintained over the tests, the sample defibration takes place ??[[on a longer way]] than breaking, which means that defibration required a longer time, we can search for the confirmation of this phenomenon in the characteristics obtained. And indeed, it is clearly visible in the set of characteristics presented in Figure 6 that the time period Δt decreases monotonically with an increase in twist; this means that the sample's ability to defibrate also decrease. The time interval near zero indicates the loss of continuity by breaking.

The analysis of $\Delta F/\Delta t$ carried out for the part of the falling-down diagram is an example of a quantitative analysis of the estimation of the results of air acting on the sample. As can be seen from the set of diagrams, the presence of air changes the destruction mechanism from breaking the fibres into their slippage.

The differences in the quotient $\Delta F/\Delta t$ values for a thread subjected to the action of an air stream and one without this action are presented in Figure 8.

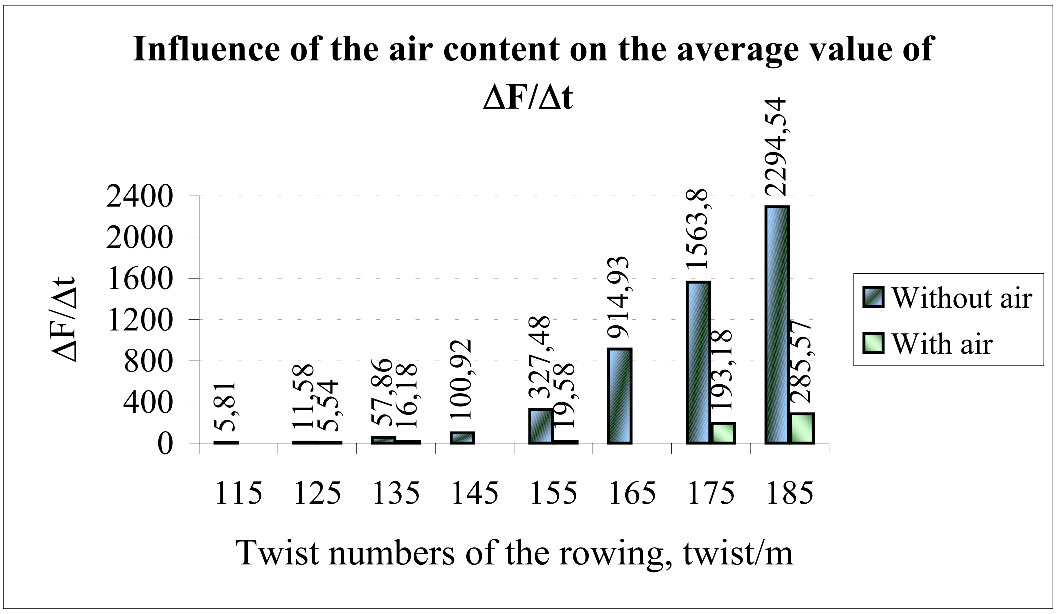


Figure 8. The dependence of the quotient $\Delta F/\Delta t$ on the twist of a sample with linear density of 125 tex, subjected to the action of an air stream with velocity of 63 m/s, and of one not subjected to such an action

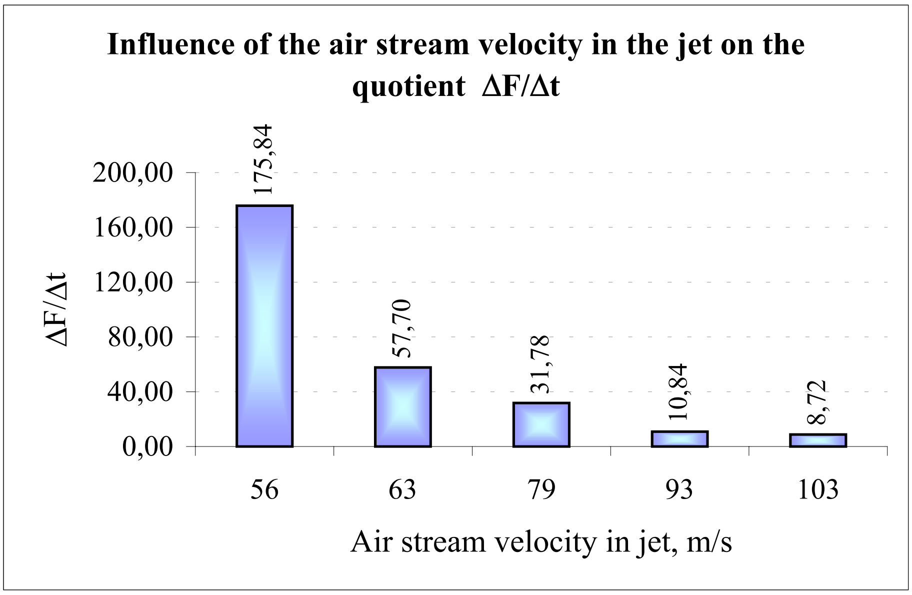


Figure 9. Dependence of $\Delta F/\Delta t$ for roving with 135 twists/m on the air stream velocity

We indicated that the action of air significantly increases the product degradation and destruction in dynamic conditions, and not only in static conditions. The influence of the flowing air on a multiple tensile strength decrease in the loose textile product was noted, as well as on the displacement of the phenomenon of structure destruction from the range of breakage to the range of defibration and slippage. The value of this displacement depends on the air stream velocity, which is clearly visible in Figure 9. With the increase in air velocity, the tensile strength of the drawn product decreases, and the mechanism of continuity loss takes the form of defibration instead of breaking. Thus, it unequivocally results that the aerodynamic force decreases the cohesion of the loose textile product to a similar degree.

We noted that with an increase in of the air stream velocity, the dropping of the quotient $\Delta F/\Delta t$ is caused by a decrease in the momentary maximum strength, as well as by the increase in Δt.

With the increase in the twist, the Δt value decreases for the cases while air is acting, as well as for those without air action. The greatest Δt values were obtained for these cases, when structures with the smallest twist values (of all those tested) were subjected to air action. With the decrease in nominal twist, the Δt value also decreases. Thus, both factors are conductive for decreasing the Δt value. Figure 8 presents these values as a function of twist for a roving not subjected to air action, compared to a roving subjected to the action of air. The above-mentioned considerations led to the conclusion about the extraordinarily significant influence of the air stream in the formation of the ability to defibrate the pneumatically transported object. With the increase in twist value, the difference between the value of $\Delta F/\Delta t$ for the sample subjected to air action and that not subjected to air action increases rapidly. For the sample twist values considered (from 125 twists/m to 185 twists/m), and for a sample subjected to the action of aerodynamic force, the values obtained and the shape of the curves suggest that the cause of continuity loss is a slipping of fibres alone. At the same time, the awareness arises that by appropriate selection of the parameters of the loose textile product, it would be possible to counteract the defibrating air action. One of the existing means, the increase in twist value, was applied in the case discussed. The possibility of using other factors also exists, such as longer fibres, fibres with a higher friction coefficient, or selection of air stream parameters.

In addition, we stated that the different twist value of the sample, the difference between the time Δt_a (the time of destruction with the presence of an aerodynamic force) and the time Δt_0 (the time of destruction without the aerodynamic force) is nevertheless maintained within a constant range of 1.5 ms. This relation is presented in Figure 10.

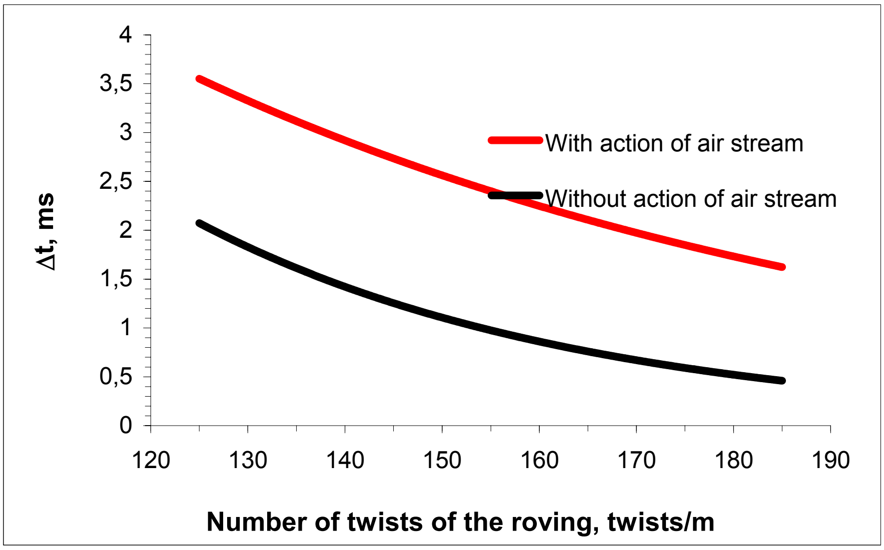


Figure 10. Time of destruction Δt as a function of the sample's twist value, in the presence of aerodynamic force acting, and without this action

The investigation method presented in this paper allows us to indicate the cause of continuity loss, and estimate whether breakage of fibres or slippage occur. Particular cases have been recorded, and evidence given for the existing breakage of fibres, for fibre slippage, and for intermediate processes of coexistence of both phenomena. All these cases are proved by the force diagrams.

A confirmation of the diverse progressions of the phenomena of loose textile product destruction under dynamic conditions can be found in the observation of the ends of broken samples, presented an as example by the photographs in Figure 11. The ends of the broken sample with a twist of 185 twists/m where the sample fibres have been broken have an essentially different shape than the ends of the sample with 95 twists/m destroyed in substance by defibration.

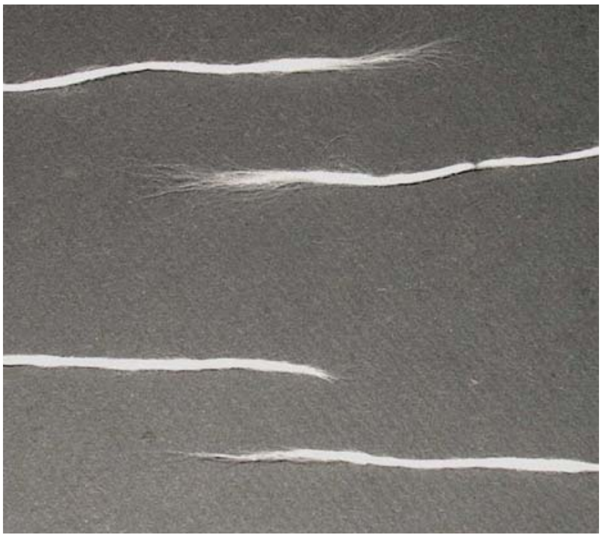


Figure 11. Photographs of the roving ends after destruction; from above: continuity loss by defibration of a roving with 95 twists/m, and continuity loss by fibre breakage of a roving with 185 twist/m.

The investigation tools prepared, and the tests themselves, create methods allowing the identification of which structures will be destroyed and under which conditions, as well as the description of the manner of destruction. This latter possibility allows us to initiate procedures which could help to prevent destruction. For example, we can select fibres as yarn structure components with appropriate friction coefficient, the length of the staple fibres, and other features which could protect the yarn structure against the destructive action of the airflow.

Summary

The method developed enables us to differentiate the mechanisms of continuity loss under dynamic conditions of the longitudinal loading of a loose linear fibre product which occurs by means of fibre breakage and by fibre slippage. The existence of an aerodynamic force is conductive to fibre slippage. The influence of the twist value and the aerodynamic force on the creation of the phenomena of breakage and slippage were stated on the basis of the relations determined. This allows us to decide on the usability of weft for pneumatic transport. The ability to identify the mechanism of continuity loss of a loose textile product has been achieved under conditions of the presence and the absence of a flowingair stream.

The following conclusions can be drawn:

- The action of an air stream which weakens the structure of the yarn and decrease its tensile strength is an essential influence.
- The air velocity, its time of action, and the twist of the product has an essential influence on this product's strength at dynamic loading.
- On the basis of the recognition carried out of the weft strength's abilities, we can state that a possibility exists to estimate the ability of wefts to pneumatic transport, and the determination of the parameter ranges of the medium which is transported, as well as those by which the transport occurs.

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