

# INFLUENCE OF YARN KIND ON THE DYNAMIC OF THE TWISTING-AND-WINDING SYSTEM OF THE RINGSPINNING MACHINE

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## **Abstract**

*In the article presented, the influence of yarn material parameters on the dynamic and stability of the working conditions in the twisting-and-winding system of the ringspinning frame during package (cop) formation was analysed. A computer programme simulating the dynamic phenomena during the spinning process formed the basis for this analysis. Changes of tension and balloon shape dependent on the yarn kind, characterised by yarn material density, the modulus of initial yarn rigidity and yarn friction coefficient were tested and analysed.*

## **Key words**

*Ring spinning frame, twisting-and-winding system, dynamic phenomena, simulation, yarn kind, yarn material density, modulus of initial rigidity, friction coefficient.*

## **1. Introduction**

Despite the development of new spinning techniques, the traditional manufacture of yarn with the use of ringspinning frames is still applied. One reason for this situation is that ringspinning machines allow yarn to be manufactured within a broader range of linear densities in comparison to other yarn spinning techniques. Regarding the advantages of classical spun yarn, the improvement of working conditions and raising the level of efficiency is the constant aim of machine producers and spinners. These are in turn linked with the optimisation of working conditions in the twisting-and-winding systems of ringspinning frames.

The increase of spindle rotation velocity is one possible way to raise the spinning frame efficiency. However, the consequence of this is an increase in yarn tension, which can lead to yarn breakage over a level recognised as standard. This is very unprofitable and should be avoided. The number of yarn breakages can be limited by decreasing yarn tensions occurring during their processing with the spinning frame. Exact knowledge of the influence of different construction parameters and technological conditions, as well as that of yarn parameters on the yarn tension and the balloon shape is indispensable for achieving an appropriate yarn tension level.

In real conditions of a working spinning frame, it is very difficult to gain information regarding the influence of selected parameters and factors on the dynamic of the twisting-and-winding system. In this situation, taking into account the present level of science and techniques, the most effective method for obtaining data for the system's dynamic are investigations using mathematical models. A simulation programme devised at the Department of Technology and Structure of Yarns allows observation of the influence of particular factors on the system's dynamic – factors which can act in a common and an isolated way [1].

These considerations, the aim of which was to demonstrate the influence of yarn properties on the intensity of the dynamic phenomena occurring in the twisting-and-winding system during ring spinning, began with the estimation of the dependency between yarn material parameters and the system's dynamic [2]. Next, an analysis was carried out which examined the isolated influence of yarn surface

properties on the course of the dynamic phenomena related to the object [3]. The last stage of investigation was devoted to the common influence of the above-mentioned factors on the system's dynamic. This results in the aim of this research work as formulated below, and in the test results presented in this paper.

## 2. The aim of investigation

The aim of this research work was to obtain information regarding the influence of yarn kind on the dynamic of the twisting-and-winding system during package formation, as characterised by such properties as:

- material density  $\rho_y$ ,
- modulus of initial rigidity  $E_y$ ,
- friction coefficient of yarn against steel  $\mu_y$ .

## 3. Test programme and conditions of the simulation tests

The investigation presented in this article comprises an analysis of the common influence of yarn material and yarn surface properties on the dynamic of the spinning process for two technological conditions characterised by yarn manufacture in:

- 1) the correct operation of a twisting-and-winding system, in which only basic extortions occur, i.e. those arising from the geometry of the spinning line;
- 2) a twisting and winding system working imperfectly, in which the yarn disturbances have a deterministic and stochastic character (Tables 1 and 2).

**Table 1.** Parameters introduced into the programme which characterise the imperfections of the twisting-and-winding system

PARAMETERS WHICH CHARACTERISE THE IMPERFECTIONS OF THE TWISTING-AND-WINDING SYSTEM			
Pos.	Description	Unit	Quantity
1	Eccentricity of the guiding eye in relation to the ring	mm	1,7
2	Eccentricity of the spindle in relation to the ring	mm	1,0

**Table 2.** Irregularity factors of the parameters used for simulation

IRREGULARITY FACTORS OF THE PARAMETERS			
Pos.	Description	Unit	Quantity
1	Irregularity factor of the linear density of yarn	-	0,180
2	Irregularity factor of the rotational velocity of the spindle	-	0,020
3	Irregularity factor of the yarn delivery velocity	-	0,005
4	Irregularity factor of the yarn friction coefficient against the elements of the twisting system /	-	0,015

As can be seen from Tables 1 and 2, the eccentricities of the guiding eye and the spindle in relation to the ring are accepted as deterministic disturbances, whereas the irregularity factors of yarn linear density, rotational velocity of the spindle, yarn delivery velocity, and yarn friction coefficient against the elements of the twisting system stand for stochastic disturbances.

The simulation was performed on a yarn of linear density  $T_t = 12 \text{ tex}$ , and at two characteristic stages of package formation: winding on an empty bobbin, which is characterised by maximum balloon height ( $H_{\max}$ ), and formation of the last package layer associated with the minimum balloon height ( $H_{\min}$ ).

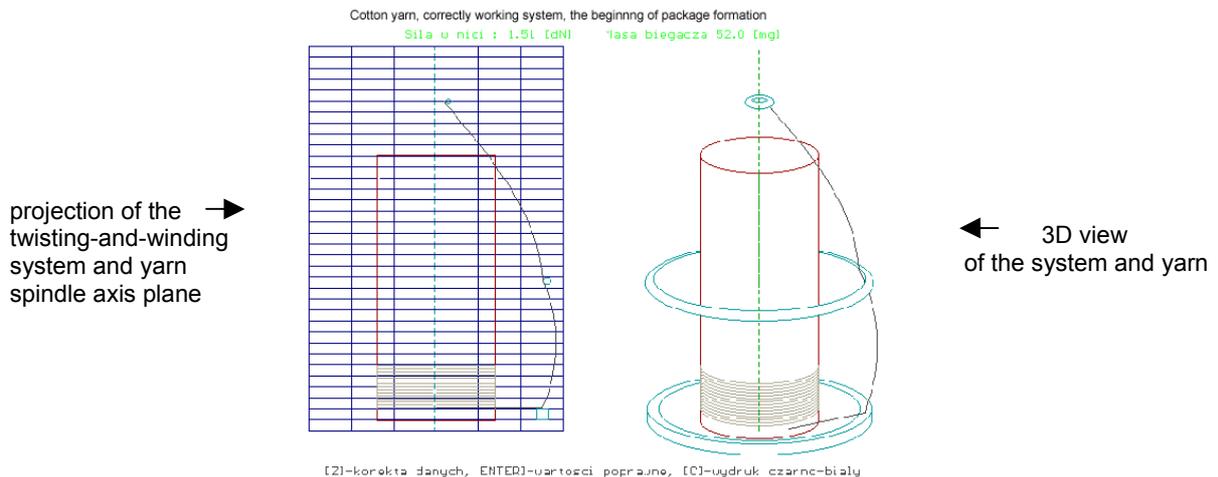
Yarn parameters which correspond with the properties of different yarn sorts, as used in the tests, are presented in Table 3.

**Table 3.** List of parameters changed in the experiments [4, 5]

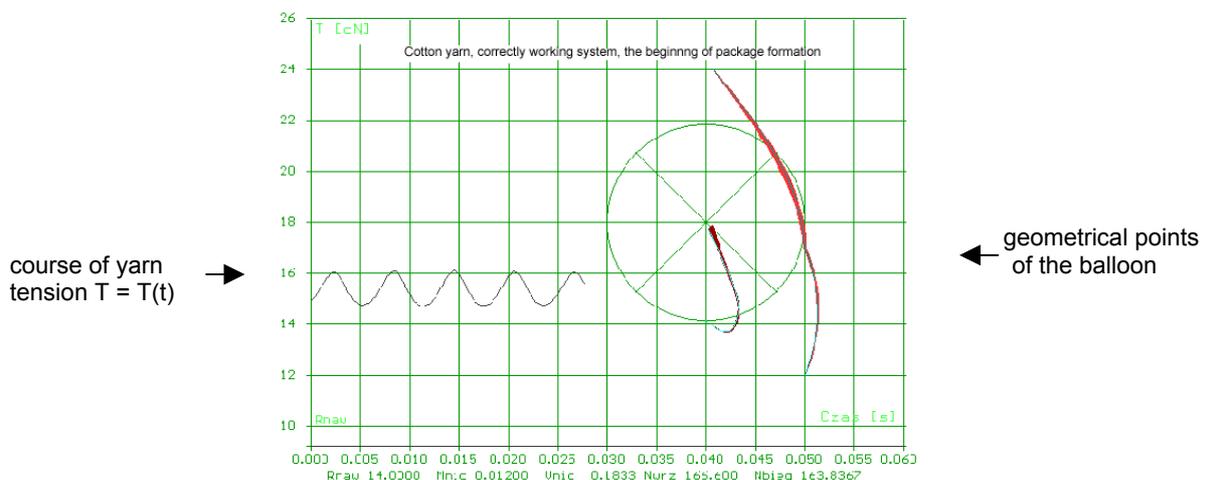
PARAMETERS CHANGED IN THE EXPERIMENT			PARAMETER QUANTITIES FOR THE PARTICULAR RAW MATERIAL				
Description	Denotation	Unit	cotton CO	wool WO	flax FL	polyester PES	viscose VI
Yarn material density	$\rho_y$	g/cm <sup>3</sup>	0,84	0,83	0,82	0,75	0,83
Modulus of yarn initial rigidity	$E_y$	N/tex	0,45	0,22	0,90	0,32	0,33
Kinetic factor of yarn friction against steel	$\mu_y$	-	0,29	0,44	0,27	0,17	0,37

#### 4. Programme of simulating the system's dynamic

The programme was devised on the basis of a mathematical model of the dynamic of a twisting-and-winding system, a model which also included external disturbances. The programme lets the user conduct numerical experiments on systems characterised by any kind of parameter [1, 2, 3].



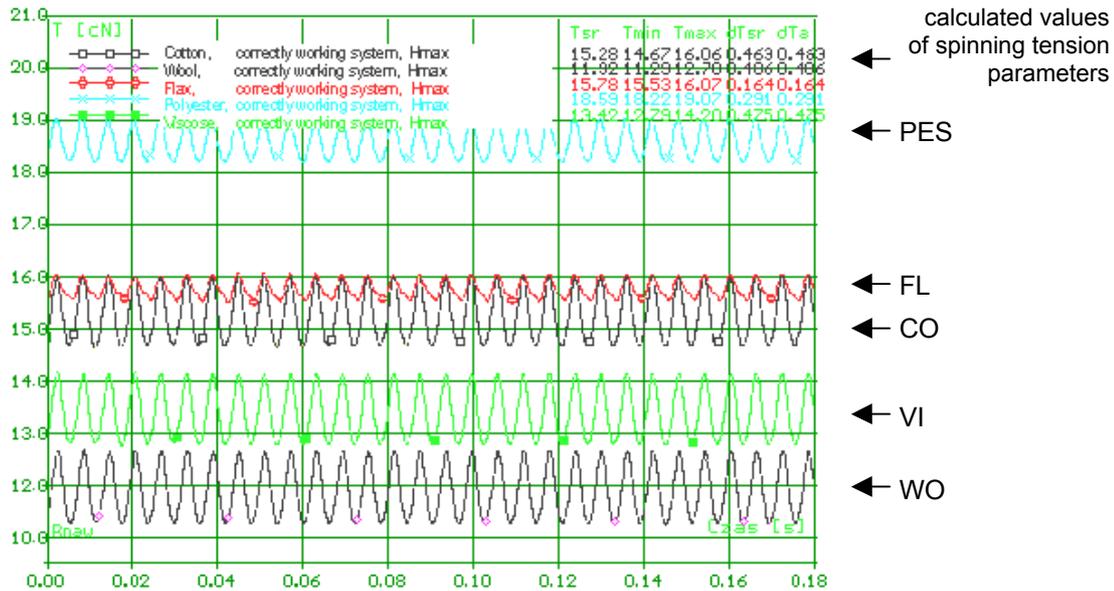
**Figure 1.** Stationary balloon shape for cotton yarn (CO); correctly working system; the beginning of package formation



**Figure 2.** Simulation of the dynamic of a correctly working twisting-and-winding system while winding the first package layer ( $H_{max}$ ) of cotton yarn (CO)

The programme allows:

- the determination and graphical presentation of the stationary balloon shape for the given system's working parameters, and for the assumed traveller mass or yarn tension (Figure 1);
- the simulation of the dynamic process for the assumed technological and constructional parameters of the system as well as the assumed disturbances characteristic, a simulation which also includes the determination and visualisation of the spinning tension course versus time, as well as of the momentary balloon shape (Figure 2);
- the graphic presentation of tension courses versus time, allowing for the comparison of the effect of different system's working conditions (Figure 3);



**Figure 3.** Comparison of yarn spinning tension versus time  $T(t)$  for yarns from the particular raw materials: cotton (CO), wool (WO), flax (FL), polyester (PES), and viscose (VI). Correctly working twisting-and-winding system with basic disturbances; balloon height –  $H_{max}$

- the calculation of values of these parameters which characterise yarn tension in the spinning zone, as listed below:
  - minimum tension -  $T_{min}$ ,
  - maximum tension -  $T_{max}$ ,
  - average tension -  $T_{av}$ ,
  - average amplitude of tension oscillations -  $dT_{av}$ .

## 5. Example results of simulation tests

### 5.1. Dynamic of the correct operation of a twisting-and-winding system during the preliminary stage of package formation

Examples of the stationary view of the balloon shape and of the dynamic of a system working correctly while winding the first layer of cotton yarn (CO) are presented in Figures 1 and 2. A comparison of yarn tension simulation courses for all yarns under consideration prepared from different raw materials are shown in Figure 3, whereas the calculated tension values are listed in Table 4.

From the analysis of Figure 3 and Table 4, we can conclude that the existing working conditions caused the highest spinning tension when manufacturing polyester yarn (PES). Next were flax yarn (FL), then cotton yarn (CO) and viscose yarn (VI); the lowest tension occurred during wool yarn (WO) production. On the other hand, the highest tension amplitudes can be seen for wool yarn, the for viscose, cotton and polyester yarn, and the lowest for flax yarn.

**Table 4.** List of results of tension simulation for the tested yarns for a correctly working twisting-and-winding system (balloon height –  $H_{max}$ ).

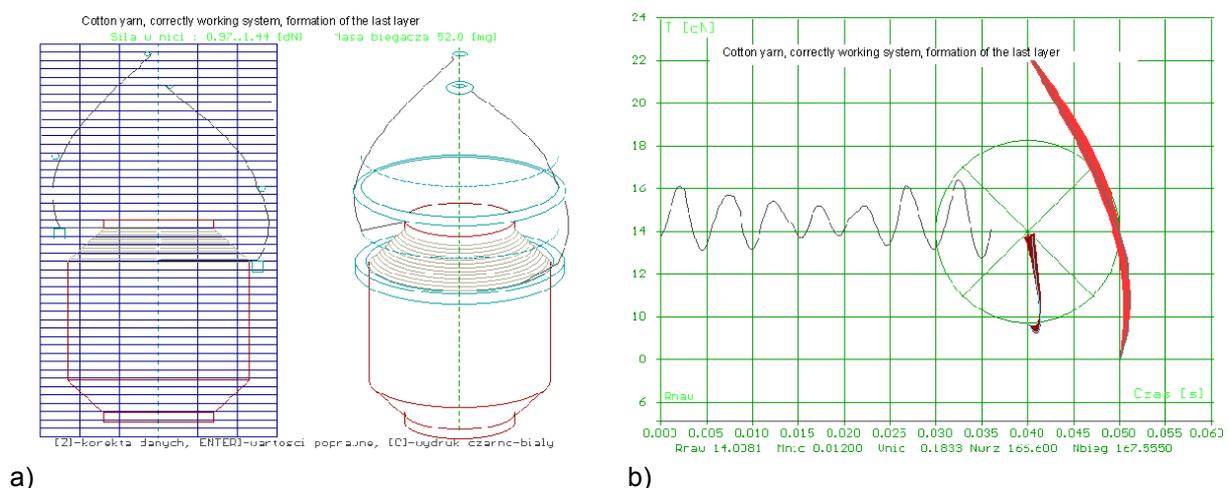
Parameter	Minimum tension	Maximum tension	Average tension	Average tension amplitude
Denotation	$T_{min}$	$T_{max}$	$T_{av}$	$dT_{av}$
Unit	[ cN ]	[ cN ]	[ cN ]	[ cN ]
CO	14,67	16,06	15,28	0,463
WO	11,29	12,70	11,92	0,486
FL	15,53	16,07	15,78	0,164
PES	18,22	19,07	18,59	0,291
VI	12,79	14,20	13,42	0,475

The results obtained were verified statistically. A preliminary hypothesis, that the kind of yarn has no influence on the dynamic of the twisting-and-winding system, was assumed. The F Snedecore and t-Student significance tests were applied successively [6]. The analysis allowed for the statement that a multiple correlation exists between the altered yarn material parameters and the spinning tension values obtained.

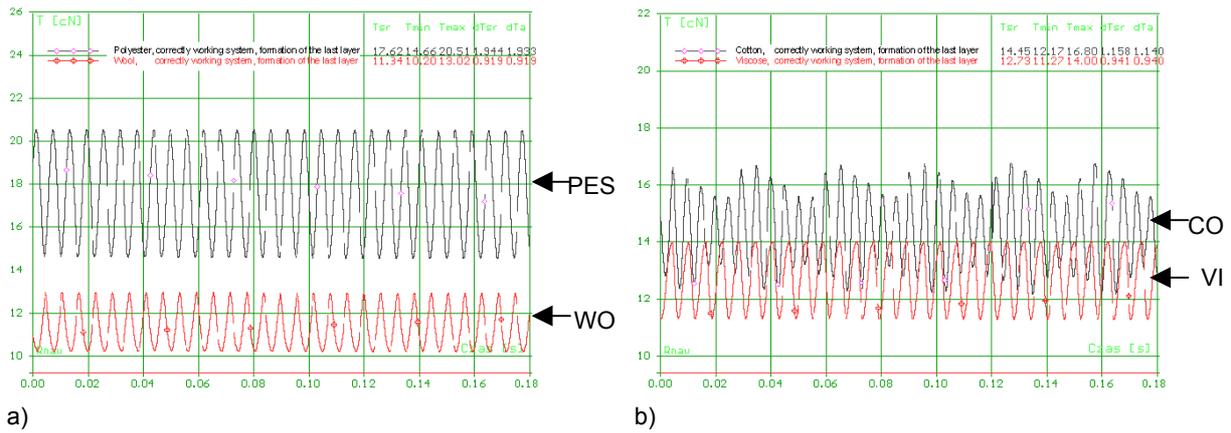
## 5.2. Dynamic of the correct operation of a twisting-and-winding system during the final stage of package formation

The stationary balloon shape and the simulation of the dynamic of a system working correctly while winding the last package layer (the balloon height -  $H_{min}$ ) are shown in Figure 4.

The comparison of yarn tension simulation courses are presented in Figure 5, and the numerical values of the yarn tensions obtained are listed in Table 5. On the basis of this data, we may state that the highest average tension value is observable for polyester yarn. Lower values are characteristic of cotton and viscose yarns, and the lowest for wool yarn. The same sequence can be stated for the average values of yarn tension amplitudes. While spinning flax during the last phase of package formation (at  $H_{min}$ ), the existing working conditions of the twisting-and-winding system caused a collapse of the balloon. This situation is presented in Figure 6.



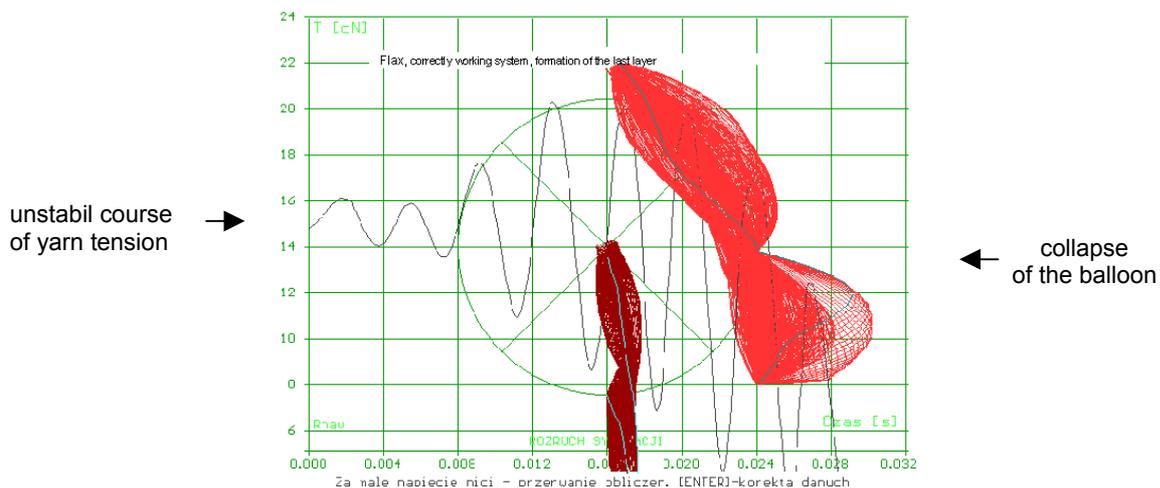
**Figure 4.** a) Stationary balloon shape, b) simulation of the dynamic of a correctly working twisting-and-winding system ; formation of the last layer of cotton yarn (CO)



**Figure 5.** Comparison of yarn spinning tension versus time  $T(t)$  for yarns from the particular raw materials: a) polyester (PES) and wool (WO); b) cotton (CO) and viscose (VI). Correctly working twisting-and-winding system; balloon height –  $H_{min}$

**Table 5.** List of results of tension simulation for the tested yarns for a correctly working twisting-and-winding system (balloon height –  $H_{min}$ )

Parameter	Minimum tension	Maximum tension	Average tension	Average tension amplitude
Denotation	$T_{min}$	$T_{max}$	$T_{av}$	$dT_{av}$
Unit	[ cN ]	[ cN ]	[ cN ]	[ cN ]
CO	12,17	16,80	14,45	1,158
WO	10,20	13,02	11,34	0,919
FL	<i>COLLAPSE</i>			
PES	14,66	20,51	17,62	1,944
VI	11,27	14,00	12,73	0,941



**Figure 6.** Simulation of the dynamic for flax yarn. Correctly working twisting-and-winding system; the end of winding ( $H_{min}$ )

A comparison of results for the balloon heights  $H_{max}$  and  $H_{min}$  leads to the conclusion that during package formation the average tension values for the yarns analysed decrease, whereas the amplitudes rise. Additionally, as can be seen from the comparison of the courses shown in Figure 5 and the values presented in Table 5, particular characteristics of flax and cotton yarn appear at the minimum balloon height. In the case of cotton yarn an unstable course of the tension appears, which is characteristic of the situation immediately before a balloon collapse. On the other hand, in the case of flax yarn an unstable course of both yarn tension and the balloon shape can be observed.

### 5.3. Dynamic of the twisting-and-winding system with imperfections of deterministic and stochastic character during the initial phase of package formation

A twisting-and-winding system with imperfections of deterministic and stochastic character is the equivalent of a real system long exploited. In Figure 7, an exemplary stationary balloon shape and a simulation of the dynamic process are shown for a system with imperfections at a maximum balloon height. A comparison of simulation courses for this system is presented in Figure 8, whereas Table 6 includes the values of tension as calculated for the tested yarns of different raw materials.

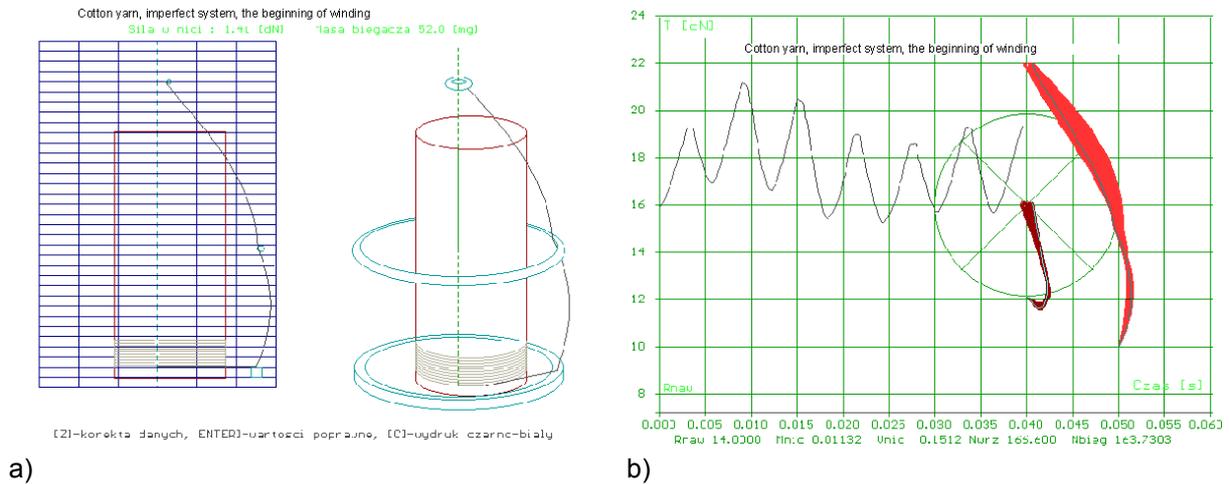


Figure 7. a) Stationary balloon shape, b) simulation of the dynamic of the twisting-and-winding system for spinning cotton yarn (CO); imperfect system, the beginning of winding ( $H_{max}$ )

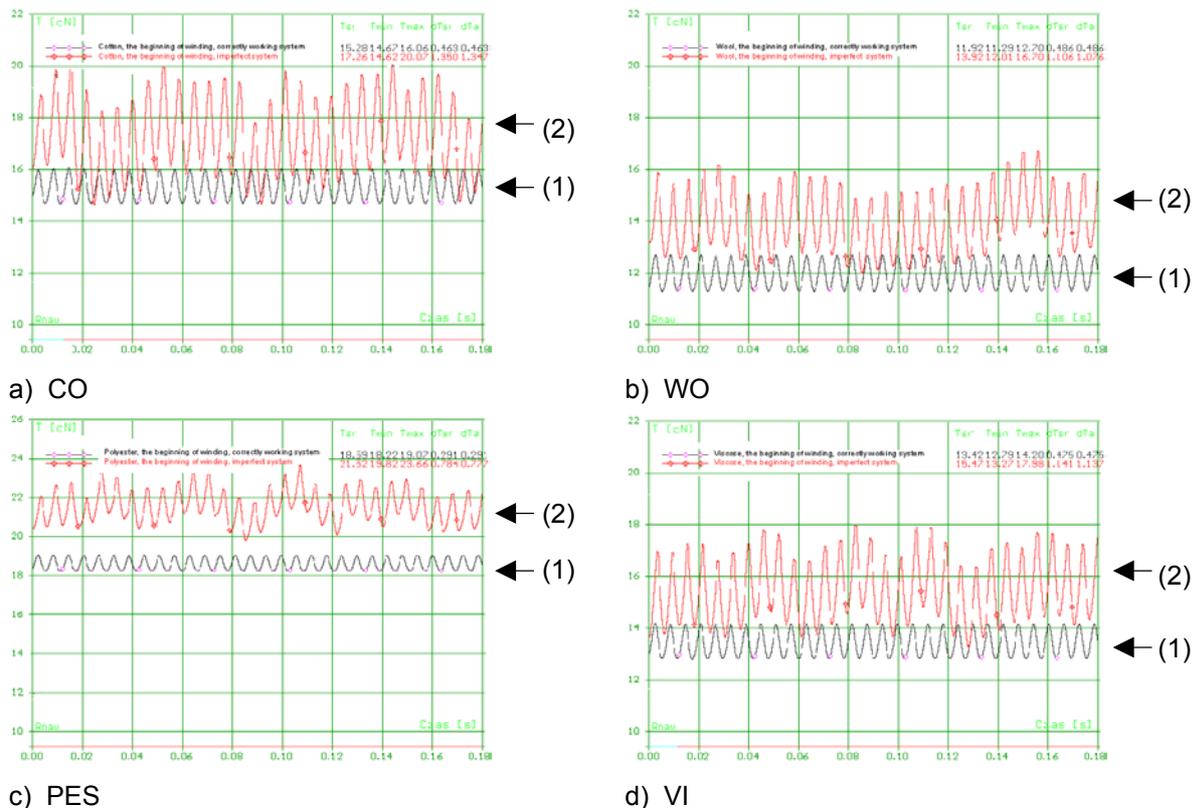


Figure 8. Comparison of simulation courses of yarn spinning tension  $T(t)$  with the use of twisting-and-winding systems: correct working (1), and with imperfections of deterministic and stochastic character (2), during the initial phase of yarn winding (on the bobbin), at  $H_{max}$ : a) cotton yarn (CO), b) wool (WO), c) polyester (PES), d) viscose (VI)

**Table 6.** List of results of tension simulation for the tested yarns for an imperfect twisting-and-winding system (balloon height -  $H_{max}$ ).

Parameter	Minimum tension	Maximum tension	Average tension	Average tension amplitude
Denotation	$T_{min}$	$T_{max}$	$T_{av}$	$dT_{av}$
Unit	[ cN ]	[ cN ]	[ cN ]	[ cN ]
CO	14,62	20,07	17,26	1,350
WO	12,01	16,70	13,92	1,106
FL	<i>C O L L A P S E</i>			
PES	19,82	23,66	21,52	0,784
VI	13,27	17,98	15,47	1,141

When comparing the two twisting-and-winding systems, that which works correctly and that which has imperfections, one can observe the distinct differences between the values and the courses of yarn spinning tension for all tested yarns. When working with an imperfect system, the average tension values and tension amplitudes increase, and a balloon collapse occurs during the final stage of package formation.

## 6. Summary

On the basis of the tests performed, it has been stated that the material of yarn and the yarn surface properties influence the yarn tension when spinning with a twisting-and-winding system working imperfectly, as well as with a correctly working system. However, the degree of influence is different depending on the yarn material. The approximation of the correct working system to a real one, by introducing disturbances, strengthens the phenomena observed.

By comparing the participation of the particular features of the raw materials under consideration, we can state that flax material influences most distinctly the course of yarn tension versus time and the balloon shape. Characteristic features already manifest themselves for the correctly working system during the preliminary stage of package formation. The reason for this behaviour by the flax yarn is its high rigidity.

The next raw material which reveals its characteristic features during use of a correctly working system is cotton. When manufacturing cotton yarn, the pulsatory character of yarn tensions (which signals a balloon collapse) can be observed during the final phase of package formation. For all other raw materials, the yarn tension courses are stable.

The programme devised permitted observation of the intensity of influence which different yarn raw materials have on the dynamic of the twisting-and-winding system of a ring-spinning frame under equal technological conditions. For an engineer, this facilitates the selection of machine working parameters without the need to carry out experiments with a real object, i.e. a working spinning frame.

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