MEASURING YARN TENSION USING SENSORS IN TEXTILE AUTOMATED SYSTEMS

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Abstract: The automation of mechanical systems implies a deep knowledge of the behavior of the elements that participate in achieving the established objective, and, in particular, of the relationship in which they influence each other. In this paper, I presented how I designed and built an original sensor installation for measuring the tension in the textile yarn supplied to textile machines, which can be easily mounted on the yarn line in any direction.
Keywords: tension in the yarn, sensor, calibration, diagram, signal.

1. Introduction

Tension in a working thread is a force that occurs when it is pulled by other forces acting at its ends. It is found along the thread and opposes its deformation. It has applicability in various fields of industrial, household, hobby, etc. Of great importance in the production of quality industrial products in the textile field is the value of the tension in the textile supply thread. Depending on the position of the thread in the work process, physical peculiarities appear that influence the value of the measured parameter and, implicitly, the final results.

2. Experimental Research

2.1. Measuring Equipment

2.1.1. The Designed Sensory System

When establishing the investigation scheme, I took into account that the measurement installation would not cause structural changes in bonding forces with negative consequences on obtaining certain results.

I designed, developed and used in the experimental work the sensory system in Fig. 1.

On an accessible portion of the yarn path 1, two claws, marked 2, of circular section, embedded in a rigid body 5, are interposed, and halfway between them, a roller 3 is positioned, deviated perpendicular to the axis that joins the two claws marked 2, in such a way that the positioning of the flexible yarn along the path in the figure produces, under the action of the tensions T1 and T2 from the yarn branches wound over the roller 3, a force $\vec{F} = \overrightarrow{T_1} + \overrightarrow{T_2}$, which loads an elastic blade 4 when bending, on which a set of TERs (electroresistive transducer, also known as a stamp or strain gauge mark) is applied.

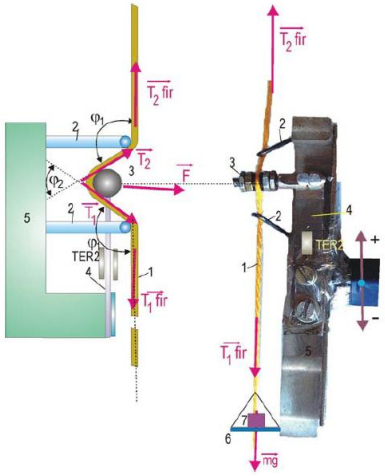


Fig. 1. The sensor measures the yarn tension that develop in the power line.

The placement of the yarn tension measurement sensor on the route of the textile supply yarn is done according to figures 2 and 3 (depends on the position of the yarn during work).

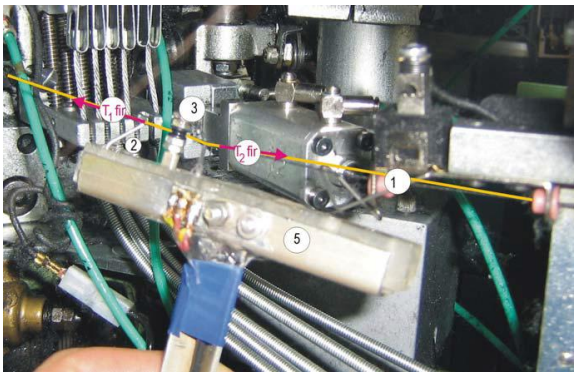


Fig. 2. Location of the yarn tension measurement sensor on the path of a textile thread feeding from the circular knitting machine.

At the output of the strain gauge measuring amplifier At, (Fig. 3), to which the TER2 assembly is connected, a signal U_T proportional to the tension in the supply textile thread.

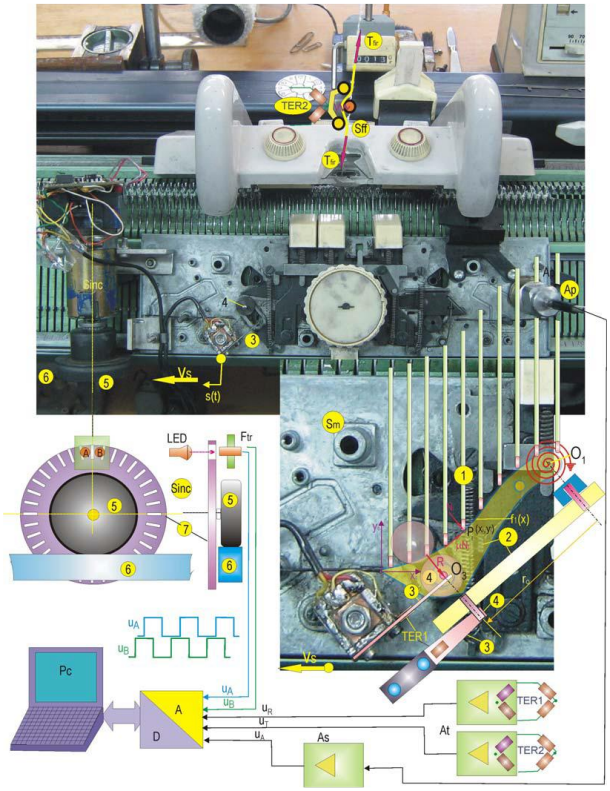


Fig. 3. Scheme of the experimental investigation facility.

2.1.2. Sensor Calibration

This sensor required a special calibration procedure, because the effect of friction forces between the wire, the claws 2 and the roller 3 must be taken into account, with a resultant appearing between the tensions on the branches. Considering the fixed textile supply thread and moving the sensor along the thread, there are the relationships:

- for moving the sensors upwards, in the positive direction (+)

$$T_1 = T_{1\,fir} \cdot e^{-\mu\varphi_1};\ T_2 = T_1 \cdot e^{-\mu_r\varphi_2};$$
$$T_{2fir} = T_2 \cdot e^{-\mu\varphi_1} \quad (1)$$

- for moving the sensor down, in the negative direction (-)

$$T_1 = T_{1\,fir} \cdot e^{\mu\varphi_1};\ T_2 = T_1 \cdot e^{\mu_r\varphi_2};$$
$$T_{2fir} = T_2 \cdot e^{\mu\varphi_1} \quad (2)$$

μ and μ_r being the coefficients of friction between the thread and the profile of hooks 2 and with roller 3, respectively.

The magnitude of the force F acting on the blade 4 (in Fig. 1) proportional to the output voltage U_T of the stain gauge amplifier to which the sensor´s TER assembly is connected will be:

$$F = (T_1 + T_2)cos\frac{\varphi_2}{2} = \frac{U_T}{k_T} \quad (3)$$

Taking as a basis the tension T_{1fir} the force F will have the form:

- to move the sensor up,

$$F^+ = T_{1fir} \cdot e^{-\mu\varphi_1}(1 + e^{-\mu_r\varphi_2}) = \frac{U_T^+}{k_T^+} \quad (4)$$

and

- to move the sensor down,

$$F^- = T_{1fir} \cdot e^{\mu\varphi_1}(1 + e^{\mu_r\varphi_2}) = \frac{U_T^-}{k_T^-} \quad (5)$$

Making the report

$$\frac{F^-}{F^+} = e^{2\mu\varphi_1 + \mu_r\varphi_2} \quad (6)$$

it results that the sensor is more charged when it moves downwards.

To calibrate the sensor, the textile thread was fixed in a vertical position (as in Fig. 1), at the upper end being attached to a fixed support, and at the lower end a plate 6 progressively loaded with tare weights mg 7 was attached, the tension at the lower end of the yarn being T_{1fir}= mg. At a weight m=150 gr on the plate, the voltage diagram U_T confirms the above formulations when changing the direction of movement of the sensor along the thread, as can be seen in Fig. 4.

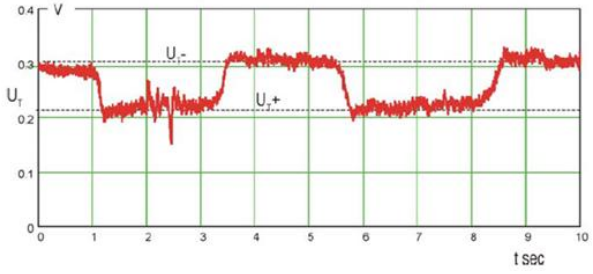


Fig. 4. Diagram of the sensor´s U_T signal when the sensor moves along the thread.

For a range of mg load values, the calibration characteristics of the sensor, which are linear, are plotted in Fig. 5. The two calibration constants k_T^+ and k_T^- are used to determine the tension of the yarn behind the sensor and in front of it, respectively, in the direction of movement of the thread.

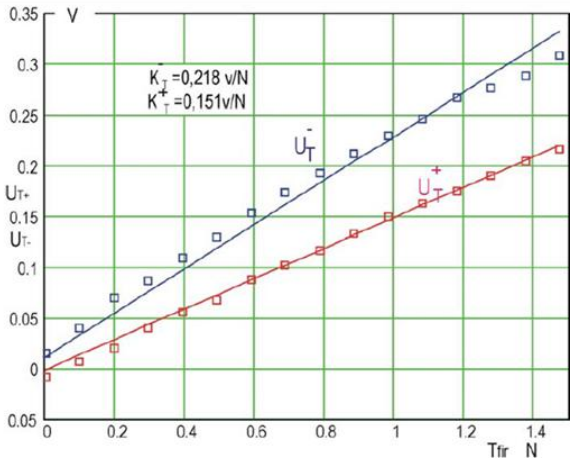


Fig. 5. Sensor calibration diagrams for measuring the tension in the supply textile thread.

2.1.3. The Purchase System

The automatic measurement was performed using a laptop equipped with a data acquisition board [12] containing: a multichannel analog-to-digital (A/D) converter for inpitting signals directly from the conditioning amplifiers, a multichannel digital-to-analog (D/A) converter and digital input-output (I/O) channels. The program installed on the laptop is compatible with the purchase card and has the role of coordinating it and retrieving the purchased data on the laptop. With these features, the automatic measurement of one or more parameters is done by computer. By connecting the data acquisition board to the Note Book type computer, with input on the PCMCIA type interface, a complex measurement and recording system for experimental measurement investigations usable in field conditions can be created. It is portable, due to the miniaturization of the system whose weight does not exceed 2-3 kg including the amplifiers for conditioning the signals from the transducers. In this case, the strain gauge amplifier At, which measures tensions states through electroresistive transducers (TER), located on the mechanical structures of machines and equipment Such a portable system can record up to 16 independent parameters, which represents a satisfactory number of useful signals for large-scale experimental research[9].

The transducer represents the primary element for converting the value of a mechanical parameter into a processable electrical signal in order to evaluate the measured parameter.

This primary, output of the transducer sometimes creates difficulties in transmitting it to the processing equipment. For the setup used in this experiment, the difficulty is related to the low level of the Δu signal, which is greatly attenuated for long lengths of the connecting conductors to the measuring amplifier.

3. Results Obtained for the Measured Thread Tension

3.1. Yarn Tension Diagrams

3.1.1. Yarn Tension Diagrams Obtained for Different Operating Modes of the Linear Knitting Machine

During the measurements, yarn tension values were taken directly from the machine structure. Figures 6 and 7 show the variations in yarn tension, ΔTfir, for two and, respectively ten needles on the rectilinear machine. The diagrams represented in the two figures contain the representation of the signals given by the measurement of several parameters within the experiment, each analysis being performed with sensors specific to the parameter evaluated. In order differentiate between the obtained representation, the graph of each signal is represented with a different color. In this case, the variation tension in the yarn is illustrated in purple.

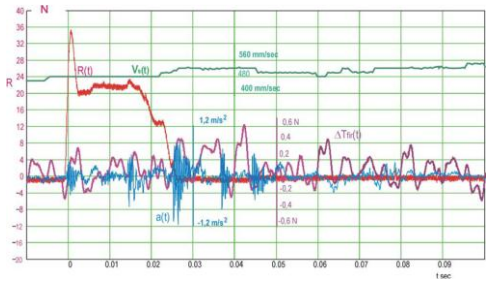


Fig. 6. Tfir(t) diagram for a operating mode with two needle active (purple).

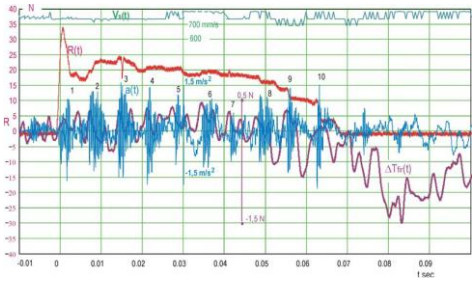


Fig. 7. Tfir(t) diagram for a operating mode with ten needle active (purple).

The duration of the working stage depends on the number of active needles involved in the knitting process (the working stage is represented in red on the diagrams).

Thus, in the two-needle knitwhere the average speed of the sled is 480 mm and the lending duration is ≈0,022 sec, the space covered by the sled is approximately 480mm/sx0,022 s=10,56 mm, a space in which two steps ps=5 mm. enter, while for the 10 needle

regime the result is 730mm/sx0,07=51 mm, a space in which 10 steps enter.

The behavior of the thread tension in the two situations is observed. In the case of working with two active needles, the variation of the thread tension remains constant, with predominantly positive values (slightly below the reference line) until the end of the stich, even if the work area is left. In the case of working with ten needles, the variation in thread tension shows greater variations towards the end of the working range, with negative values starting to appear, and upon leaving the working range, the variation moves below the reference area, recording negative values until the end of the stitch.

In the case of the analysis for a complete phase with a maximum number of active needles, the yarn tension **Tfir** is measured before it enters the knitting field and its relaxed values are observed when the needles have passed the deposition phase and enter under the incidence of the lower profile of the symmetrical cam of the attack one The yarn tension signal is reversed in direction so as not to overlap with the other signals. Very large relaxed values (as shown in Fig. 8), compared to the others, occur when the direction of travel of the sled changes. Here, sudden variations in speed occur, and the thread is pulled with force.

The values obtained in the situations presented highlight the way the wire is stressed during active work and after its completion, allowing a pertinent prognosis in the operating mode of the equipment.

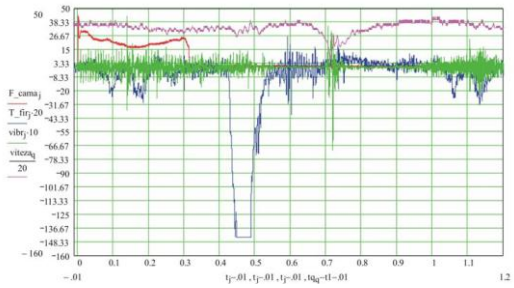


Fig. 8. Tfir(t) diagram at a working mode with the maximum number of active needles (in purple)

3.1.2. Yarn Tension Diagrams Obtained for Different Operating Modes on a Circular Knitting Machine [7]

For measurements taken on the circular machine, the product is made entirely on the same machine, passing through different work phases, specific to each area of the product. In these conditions, I took into account its work phases. And on this machine, I measured several parameters using sensors specific to each one, the graphs resulting from the signals for each of them having a different color. In this paper, the parameter of interest is the yarn tension and is represented in the diagrams in green.

In the case of the cylinders performing the pendulum movement, the tension values oscillate symmetrically with respect to a reference line, reflecting the change in the direction of rotation of the cylinders, due to the needles that perform the pendulum movement together with the cylinders, as can be seen in Fig. 9.

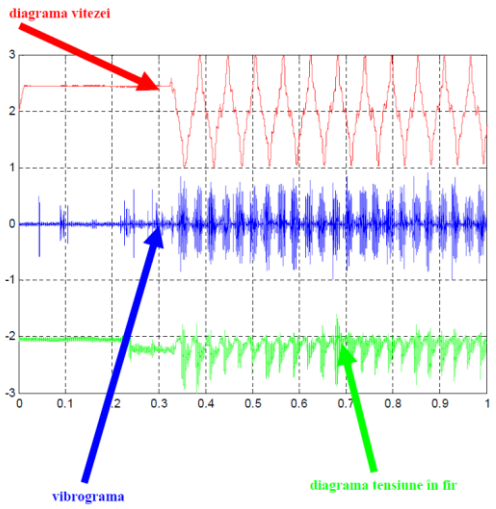


Fig. 9. Tfir(t) diagram for pendulum motion (in green).

For the other phases within the manufacturing cycle, the movement of the cylinders is circular, continuous, until the end of the phase. The yarn tension diagram clearly reflects this (Fig. 10), as do the other graphs of the messured parameters.

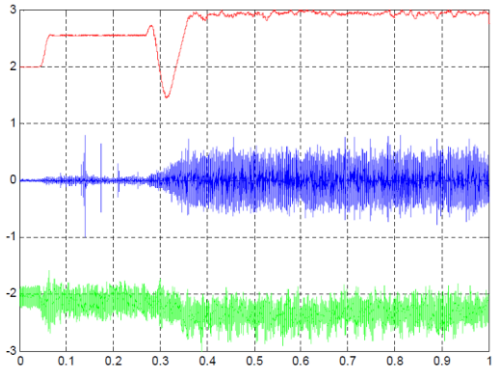


Fig. 10. Tfir(t) diagram for circular motion (in green).

4. Conclusions

The research conducted opens new lines of approach to problems that arise in the operation of textile machinery and beyond, considering the analyzed parameter. Installations designed to certain dimensions can be adapted to the dimensions of a machine thet it to be analyzed and presents similar parameters to be

evaluated. Last but not least, this study could form the basis for the creation of control systems that automatically regulate optimal operation in the wire tension area.

As a necessity to improve the productivity of machines and the quality of the resulting products, sensory systems attached to, or incorporated into machines contribute significantly to monitoring the behavior of kinematic elements, raw materials and finished products during the operation of the machine.

These lead to a suite of attributes of automatic machines, such as:

- decrease the number of personnel at the same production capacity, or increase production capacity at the same number of personnel
- the work norm increases, which leads on the one hand to an increase in the remuneration of a worker and on the other hand to a decrease in the total payroll
- the area occupied by the machines decreases (the fact that a single worker serves several machines can lead to a more judicious placement of them
- reduces the number of scraps and increases the reliability of the machine due to the more prompt "reactions" of the electronic circuits compared to the human operator

In the presented work, I paid great attention to the experimental approach in measuring the tension value in the thread through a sensory system to test the accuracy, behavior and possible effects. The scheme for measuring and recording on a computer the tension values in the working thread for different working stages of the machines, provides an extensive database with applications both in the production process and in the construction of new models of machines, with high-performance characteristics.

5. References

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Personal Notes

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Biography: Throughout her teaching and scientific career, Adriana Elena Micșa was concerned with the behavior of mechanical systems, creating mathematical model for them, 3D simulations of their behavior in different stages of evolution and working states. She gives a major interest to automatic mechanical systems that are directed by sensory structures connected to specific programs.
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