Summary of the doctoral dissertation

entitled: "Identification of the thread stretching process in extreme conditions of knitting technology."

Aleksandra Prążyńska, M.Sc

The aim of the doctoral thesis is to verify in a real environment the unique methodology for identifying the mechanical properties of the dynamic thread stretching process, both experimentally and theoretically, using rheological nonlinear models solved in the mathematical environment of finite element methods (FEM).

Thesis statement: The identification of a realistically defined process of dynamic thread stretching in textile technological processes brings positive findings as a result of experimental research using non-standard measuring devices as well as theoretical research applying the finite element methodology in the analysis of nonlinear rheological models.

The summary of the work includes a description of important issues, involving innovative and original solutions in the field of scientific research.

The conducted literature study includes an analysis of research of textile materials under static and dynamic stretching conditions using commonly used testing machines and constructed prototype devices. Issues related to the identification of mechanical properties of textile processes and materials using rheological models of viscoelastic bodies, including multi-parameter, three-body linear and non-linear models, and taking into account friction elements were also presented. The literature review also touched upon topics related to numerical modeling, which enables the use of a wide range of IT tools commonly used for engineering calculations related to, among others, solving problems related to the mechanics of a deformable body, dynamics or strength of materials.

In order to perform dynamic stretching tests, a unique research stand was designed and built in terms of mechanical, electronic, IT and a methodology for measuring and recording research results were developed. It made it possible to carry out measurements in the speed range from 0.5 to 100 m/s and the length of stretched thread sections from 200 to 1000 mm. To measure forces in the thread, a strain gauge sensor with a high natural frequency of 11 kHz was constructed, and the results were recorded on a computer equipped with a 10 MHz data acquisition card enabling the recording of an appropriate number of measurement points allowing for the correct mapping of the characteristics of the thread stretching process at high speeds. The tests were carried out for multi-filament synthetic polyamide (PA6) yarns with a linear weight of 56 and 156 dtex and polyester yarns with a linear weight of 55,111 and 167 dtex, which are the most common raw material used in knitting technologies. A series of empirical tests on dynamic thread stretching was performed. The total number of measurement variants was 150.

An analysis of experimental characteristics was carried out, which showed that an increase in the stretching speed causes a decrease in the values of forces in the threads and the relative elongation for the same length of the stretched yarn section.

Based on the literature analysis and own research, two three-parameter models, the Zener model and the Standard 2 model, were selected to conduct numerical simulation of the processes occurring in threads subjected to dynamic loads and they describe the process of thread stretching in terms of a viscoelastic body, simultaneously imitating the phenomena of relaxation and creep. For the adopted rheological models, their sensitivity to changes in the values of the input parameters, i.e. static and dynamic stiffness and viscosity coefficient, was determined.

In the next stage of work in the Autodesk® Inventor® software environment, a virtual analog model was built based on appropriately connected Kelvin-Voigt rheological model modules, for which the input parameters of the selected rheological models were defined. A series of simulation calculations of the dynamic thread stretching process was performed.

The nonlinear static and dynamic elasticity coefficients were determined on the basis of the obtained results of experimental tests carried out in static conditions on a testing machine at a speed of 2 mm/min and in dynamic conditions on a constructed measuring device. The nonlinear viscosity coefficient was calculated based on data read from the force-time characteristics obtained by measuring forces during stress relaxation in the threads. In order to conduct this research, an original research station was designed and built. The yarns were fastened between two clamps, a stationary one and a movable one and it's displacement was achieved by moving the piston of a pneumatic actuator. The force values were measured using a strain gauge sensor with a natural frequency of 20 kHz. The length of the stretched yarn section was 1000 mm and the measurement time was 300 s.

The difference in the behaviour of the static and dynamic thread stretching processes was demonstrated by comparing the obtained force characteristics as a function of deformation for selected measurement conditions.

A comparative analysis of the characteristics obtained on the basis of experimental and model tests was performed for all measurement variants, and a correlation coefficient was determined to verify the degree of their matching. A very strong agreement between the experimental curves and the numerical simulation curves was obtained, which leads to the conclusion that the tools used in the work for the physical description of the thread stretching process are useful.