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A PROTOTYPE OF A TECHNOLOGICAL LINE FOR PROCESSING DECORTICATED FLAX FIBRE

Key words: flax, decortication, separating fibre.

Abstract: This article presents an experimental prototype line developed at the Institute for Sustainable Technologies – PIB in Radom for the processing of fibres in a closed water system as an element in the process of an innovative technology for the manufacture of flax fibre originating from traditional varieties of fibre plants and new varieties of flax. The paper discusses the concept of this technological stage, describes the features of the proposed technical solution, and presents the purpose, construction and the operation of the line. Lastly, it provides conditions for fibre degumming aiming to provide more efficient fibres separating and dividing.

Prototypowa linia technologiczna do przetwarzania dekortykowanego włókna lnianego

Słowa kluczowe: len, dekortykacja, rozklejanie włókna.

Streszczenie: W artykule przedstawiono opracowany w Instytucie Technologii Eksploatacji – PIB w Radomiu prototyp doświadczalnej linii technologicznej do przetwarzania włókna w zamkniętym obiegu wodnym jako element w procesie innowacyjnej technologii wytwarzania włókna lnianego pochodzącego z tradycyjnych odmian roślin włóknistych oraz nowych odmian lnu. Omówiono koncepcję tego etapu technologii, scharakteryzowano cechy zaproponowanego rozwiązania technicznego, zaprezentowano przeznaczenie, budowę oraz zasadę działania linii. Podano warunki prowadzenia procesów rozklejania i odklejania.

Introduction

The prototype of a technological line for processing decorticated flax-fibre is the main element of the new technology for flax production with characteristics and quality alternative to produced-to-date material including the following stages of the technology:

– Flax decortication,
– Osmotic modification of decorticated fibre, and
– Breaking/cottonising of decorticated, osmotically modified fibre.

This technology, dedicated to fibre processing originating from the traditional flax varieties, significantly broadens its application possibilities. For several years in such European countries as France or Belgium, flax as a natural raw material has been part of the group of textiles strongly affecting the attractiveness of the market and able to safeguard social and economic challenges faced by European industry. In Poland, linen cultivation is not viable despite the favourable climatic conditions and the possibility of large-scale crops to ensure the homogeneity of thefibers. Grown on small farms that use different methods for cultivation and processing of raw material, flax is extremely diverse in terms of quality. This makes it difficult to use flax fibre for the production of high quality flax products. One of the processes having a negative impact on the quality of the extracted raw material is the retting process. New production technology of flax replaces it with the decortication process. This provides more uniform fibres, the parameters of which will not depend on the weather conditions and location of retting. The decortication technology of flax in relation to traditional production methods eliminates the laborious and costly long processes of straw retting and its drying before extraction [1, 2, 3]. The innovation of the proposed technology consists in the process of flax degumming after decortication. The method of continuous separation used for this process is based on the processes of fibre extraction from the stem [4, 5, 6]. Flax fibre produced by this technology has a new, high quality, which is especially suited for medical application and health promoting clothing [7].

The Institute for Sustainable Technologies-PIB in Radom undertook the construction of a prototype line consisting of modular equipment put together as a technological sequence. The purpose of this installation is to run a continuous osmotic process of decorticated flax modification consisting in physical degumming of the fibres in the aquatic environment through the interaction of temperatures, ultrasonics, hydrodynamic processes, and mechanical defibering. The installation is a unique [8], innovative, and prototypical manufacturing system without existing counterparts or earlier versions [9]. It can be used for both research, technological tests, and short series of industrial applications [10].

1. Concept and design assumptions

The concept of the prototype line for the processing of decorticated flax fibres is shown in the diagram in Fig. 1. It formulates the following main assumptions:

- Input material (Fig. 1A) as decorticated fibre flax with thickness from 0.3 to 0.6 tex in the form of beams with the outside diameter of 700 mm and the width of 150 m, where the weight of one beam is 15 kg;
- The degumming processes is done exclusively by physical methods and wet separation by exposure to ultrasound;
- Working in a closed technological water system;
- The processing of decorticated flax with a total width of about 1m;
- The modular design of the technological line;
- Moving rate of the input material 1–6 m/h.

The input as a packet of up to 8 batches (Fig. 1A) placed in the device for initial degumming (Fig. 1B) is treated with technological water with a regulated volumetric flow of about 1 m^3/h and at the temperature of 25–35°C for 24 hours. Next, when delivered to the continuous degumming line (Fig. 1c), it is unrolled on device 3, soaked, sprayed with temperature-controlled technological water and treated with ultrasound of various frequencies (tub 4 and 6). After de-bonding processes, the fibre is wrung in devices 5 and 7, loosened in module 8, and subjected to a drying process in dryer 9. For the cottonising process, the dried fibre is formed into a beam l on the receiving device 10. The line, integrated into a complete technological line, must have automatic control system and the required security.

An integral part of the line, whose diagram is shown in Figure 2, is the closed circulation system of technological water. The system performs a number of tasks, including producing and providing technological water for the relevant devices, providing continuous water purification from the suspended solid particles, removing soluble substances, microbiological purification, and temperature and flow control.

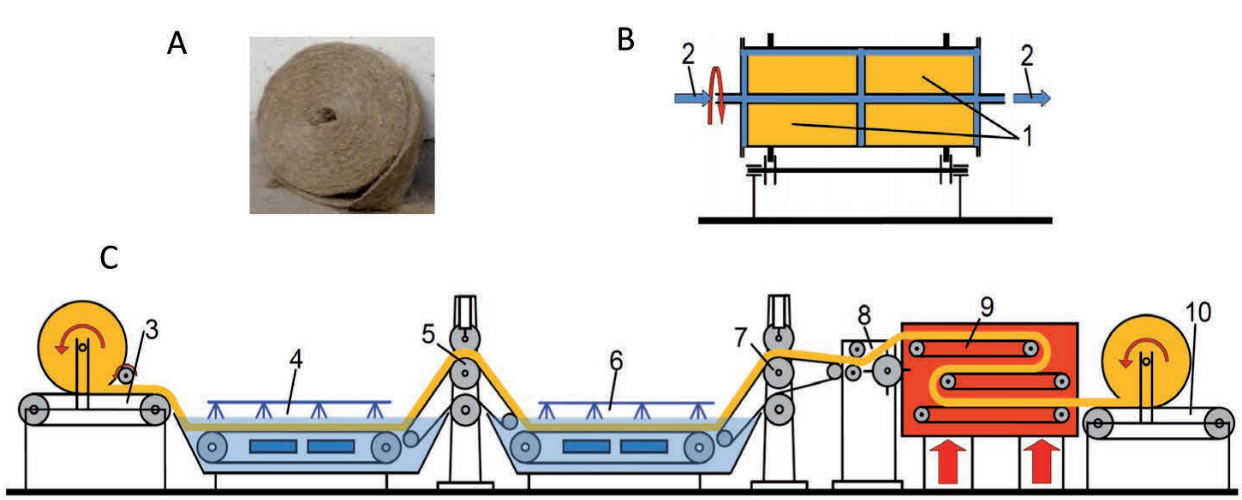

Fig. 1. The diagram of the model of the technological line for flax degumming of decorticated fibres. A – input material – beam of decorticated flax; B – the device for the initial degumming of fibres: 1 – decorticated fibre, 2 – water flow direction; C – continuous degumming line: 3 - unrolling device, 4 and 6 – the tubs for wet separation supported by ultrasound, 5 and 7 – wringing, 8 – loosening, 9 – drying, 10 – beam forming

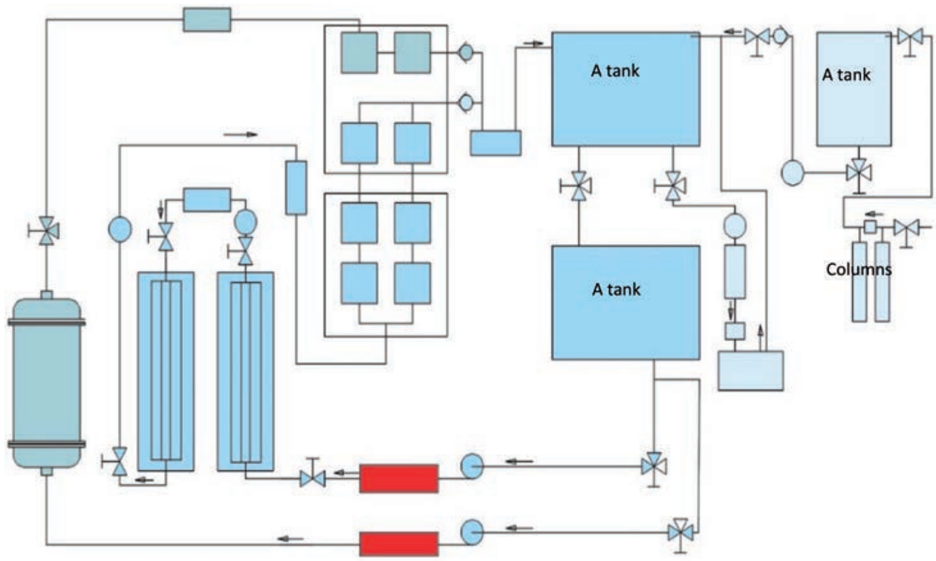

Fig. 2. **A diagram of the closed-circulation system of the technological water for degumming decorticated flax fibre. P1... P6 – pumps, F1...F4 – string filters (introductory cleaning), FS1 and FS2 – box filters, UV – UV lamp, FC – carbon filter, RO – reverse osmosis membrane filter**

2. The virtual model and the prototype line

A key step in the construction of the prototype line were tasks related to the design of virtual spatial models of installation component modules and a spatial model of the technological line. It provided the initial verification of the assumptions for the construction solutions for individual modules and for the configuration and spatial composition of the prototype line. Thus, a virtual prototype of a technological line model was created with a modular structure consisting of the elements for regulating, control, drives, electrical and pneumatic systems. Moreover, the stage included issues related to the safety of use and operation. The 3D view of spatial arrangement of the prototype installation for physical degumming of decorticated flax fibres is illustrated in Figure 3.

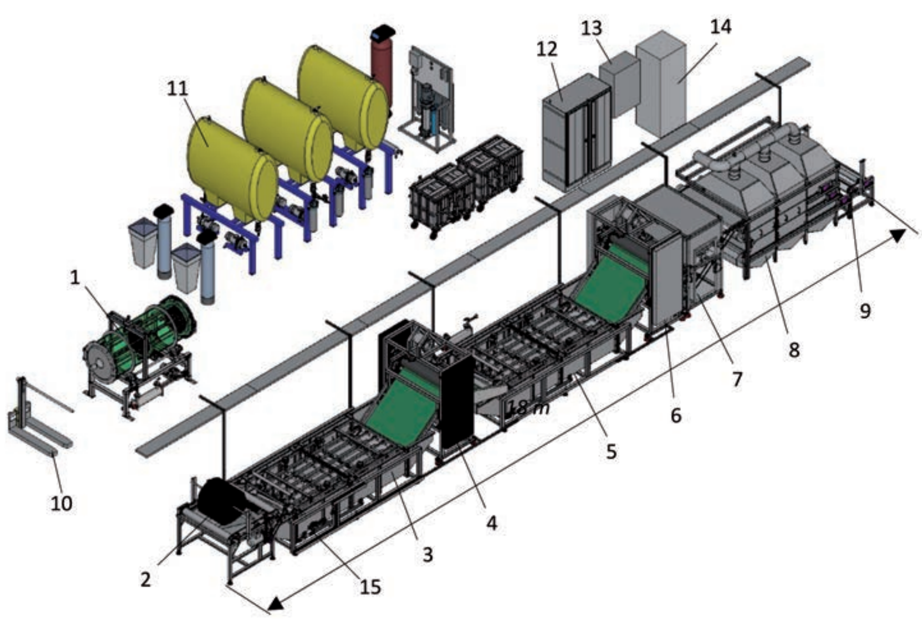

Fig. 3. **A 3D model of the technological line prototype for flax degumming of decorticated fibres. 1 – rotating reactor for the initial fibre degumming, 2 – unrolling module, 3 – degumming module I, 4, and 6 – squeezing/wringing module, 5 – degumming module II, 7 – loosening module, 8 – drying module, 9 – receiving module, 10 – unloading module, 11 – preparation of technological water, 12 – control cabinet, 13 – line drives controls, 14 – control cabinet for panels ultrasonic, 15 – pneumatic installation connection**

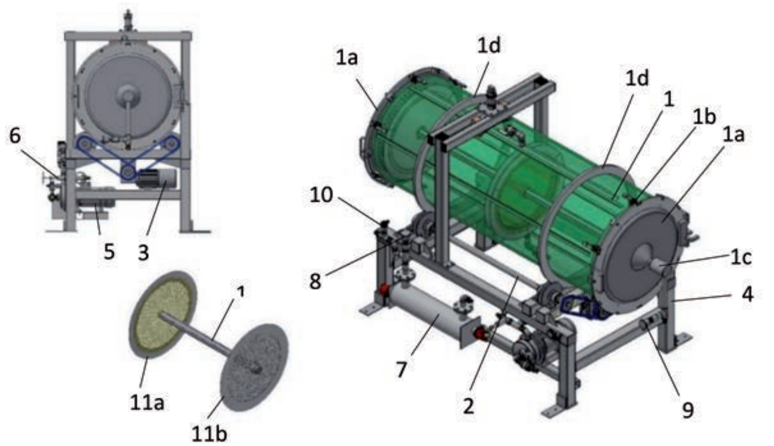

Fig. 4. Rotating reactor for initial fibre degumming: 1 – tank, 1a – disc, 1b – clamp, 1c – rotary flow through, 1d – rolling ring, 2 – drive shaft, 3 – electric drive with chain transmission, 4 – support frame, 5 – the pump, 6 – control valves, 7 – flow-through heating module, 8, and 9 – temperature sensor, 10 – pressure sensor, 11 – reel, 11a – permanent disc, 11b – the mobile disc

The main modules are the rotating reactor for fibre degumming (Fig. 4), degumming modules I and II (Fig. 5) and a module for the production and treatment of technological water (Fig. 6).

The reactor is a tank (1) closed on both sides with covers (1a), equipped with clamps (1b) for the covers with a water rotary pass (1c). The tank has a rolling ring mounted (1d) spikes working with the drive shaft (2) that is rotary powered (3) by a chain transmission. The tank contains the input of four to eight beams. Mounted on a support (4), it is supplied with technological water through the pump (5) and control valves (6) that regulate the flow level at about 1 m^3/h. Water heating within the range of 25 to 35°C is done by the flow-through heating module (7). Adjustment and stabilization of the temperature is done by a set of two temperature sensors (8 and 9), mounted respectively in front and behind the tank. The flow is controlled by the pressure sensor (10). The input feed in the form of fibre is placed on the reel (11) with perforated discs (11a and 11b). The tank together with the input works with rotary motion set within the range of 6 to 20 revolutions per minute. The duration of the degumming process in the reactor is 24 hours. After the initial degumming, the input from the rotary reactor is transported to the unrolling module (3) to the line of continuous degumming line (Fig. 3).

The fibre layer of about 1m width is fed to the transporter of the degumming module I (Fig. 5) located in the tub (2) placed on the support (1) and filled with technological water with the temperature

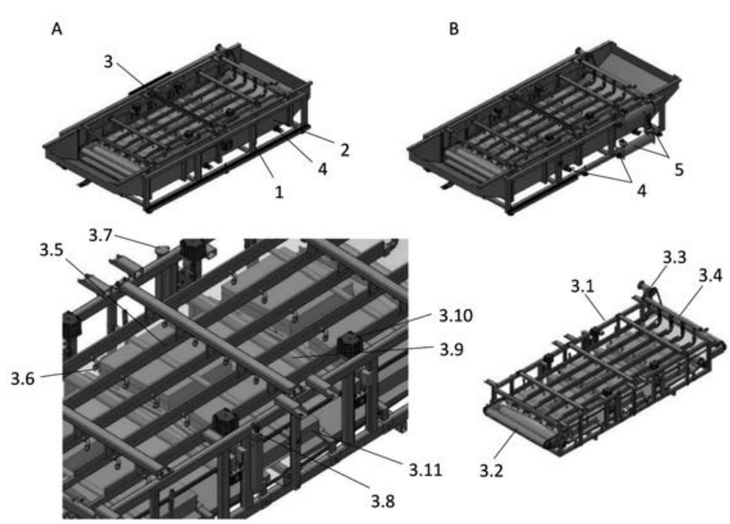

Fig. 5. Degumming modules I and II. A – degumming module I and, B – degumming module II: 1 – support, 2 – tub, 3 – mesh belt conveyor, 3.1 – frame, 3.2 – mesh, 3.3 – chain drive, 3.4 – collector, 3.5 – spraying beam, 3.6 – spray nozzles, 3.7 – temperature sensor, 3.8 – level sensor, 3.9 – shafting, 3.10 – motor, 3.11 – panel of ultrasound, 4 – heating elements, 5 – flow-through heating module

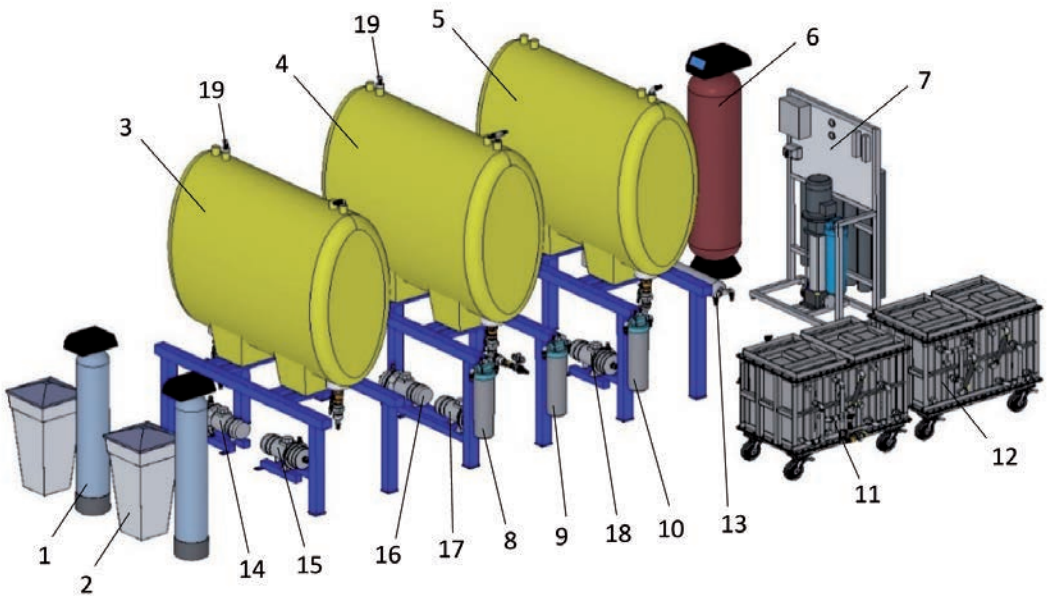

Fig. 6. Module for producing technological water treatment: 1 – two column water softener, 2 – brine tank , 3 – water storage tank, 4 and 5 – operational tanks, 6 – carbon filter, 7 – reverse osmosis, 8, 9, 10 – string filters, 11, 12 – box filters, 13 – UV water sterilizer, 14–18 – pumps, 19 – level sensors

of 35°C. Continuously maintained, an adequate level of water guarantees the complete immersion of fibre during transport for the entire length of the conveyor. The layer being fed is also subjected to spraying from the top and with ultrasound at a frequency 25 kHz. In the degumming module II, the fibre is again soaked and rinsed with water at 35°C and exposed to the ultrasound frequency 35 kHz. Mesh conveyors of the modules are driven by a chain transmission (3.3) using drives respectively from the unrolling module and the wringing module. On the frames (3.1) of the conveyors, there are collectors mounted (3.4) and spray beams (3.5) equipped with nozzles (3.6), temperature sensors (3.7), water level sensors (3.8) and mechanical lifting units for the mesh (3.9). Driven by pneumatic cylinders (3.10), they support the process of washing the transported fibre layer with alternate reciprocating motion. Between the mesh, stretched between the shafts, the ultrasonic panels are mounted (3.11). Modules are equipped with the heating elements (4) and flow-through water heaters (5). Illustrations of 3D models of degumming modules are presented in Figure 5.

Due to the high water demand, the module that produces and purifies water (shown in Figure 6) is very important, and it creates with other modules an installation of closed water circulation. It is responsible for filtering and separating leaching soluble substances and suspended solid contaminants created in the process of fibre degumming, which need to be removed from water circulation. The water used for the process is taken from the local water mains, and it is subject to demineralization inside a two-column softener (1) and then stored in the retention tank (3). With pumps (14), it fills the tanks (4 and 5), which, being connected vessels constitute the working volume of technological water, purified additionally through reverse osmosis (7). From there, the water is supplied to the degumming module I through the heating and spray modules. From the first tub, the water is pumped to degumming module II through the string filter (8) and spray modules. Next, it is pumped through the string filters (9) or (10) and box filters (11 and 12), and it flows through the sterilizer (13) and feeds the tank (5).

During the technological process, the batch of fibre is wrung between the degumming modules and before the loosening process. The fibre, having been loosened by combing and blow-off method is fed to the dryer conveyor where it is dried. Dry fibre is formed into a beam in the receiving device.

The line is integrated into a complete technological sequence and has an automatic control system and the required safety. The central control element is a modular object control with a dedicated control panel. Water flow and transfer movement of material is controlled by the pump module and drives with frequency inverters. The installation is equipped with a suitable test measuring and control instruments, sensors, and executive elements for the implementation of the technological process.

All modules and devices that make up the installation for degumming flax fibres have been made at the experimental Department of ITeE-PIB. The initial trials conducted for individual modules and the complete line confirmed the rationale for the assumptions made and verified the parameters adopted for this technological process. The photographs of the prototype line and its main modules are provided in Figure 7.

Fig. 7. A prototype of a technological line for processing decorticated flax fibre: a) view of the prototype of the technological line, b) – reactor, c) – unrolling module, d) – degumming module, e) – wringing modules, f) – water production and purification

Conclusions

The developed and manufactured prototype of a technological production line for fibre processing is an innovative constructional-technological solution that simplifies the previously applied methods of processing by decreasing the number of processing units, which results in reducing the labour and energy consumption of processing.

Compared to the traditional method of production processing of decorticated flax-fibre, the prototype line by using osmotic processes of separation primarily provides an intensification of the removal of non-cellulose compounds from the fibres and breaking.

The developed production technology of flax fibres with an alternative quality is easy to implement in small processing companies. It provides the use of processed fibres in spinning mills and the production of high quality flax products.

The fibre obtained as a result of this technology with the use of the prototype technological line, thanks to linear density similar to that of cotton fibre and the antibacterial properties of flax allows the manufacture of bioactive products based on Polish fibre-producing cultivation.

References

1. Mafikowski J.: The Effect of Sonie Agronomie Factors on the Amount and Quality of Homomorphic Fibre, Fibres&Textiles in Eastern Europe, 2003, vol. 11, nr 4(43), 20–25.
2. Zimniewska M., Frydrych 1., Mankowski J., Trywianska W.: Chapter 4: Process and quality control in cultivating natural textile fibres. Process Control in Textile Manufacturing, Publisher: Woodhead Publi.shing Limited, 2013, 81–107.
3. Kozłowski R., Mańkowski J., Kubacki A.: Efficient Technology for the Production of Decorticated Hemp and Flax Fibres and Linseed as a Raw Materia] for Different Industries, Journal of Naturals Fibers, 2004, vol. 1, nr 2/2004, 107–108.
4. Wojtysiak J., Podsiedlik W., Kozłowski R., Konczewicz W.: Sposób ciągłego odklejania włókien roślinnych oraz urządzenie do ciągłego odklejania włókien roślinnych. Numer zgłoszenia: P-383764. Zgłoszony 14.11.2007. Numer zgłoszenia międzynarodowego: PCT/PL2008/0000/81. Zgłoszony 13.11.2008_ Zgłaszający: Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy Radom oraz Instytut Włókien Naturalnych i Roślin Zielarskich.
5. Kozłowski R., Konczewicz W., Wojtysiak J., Podsiedlik W.: Urządzenie do obróbki surowców z roślin włóknistych oraz sposób ich obróbki. Numer zgłoszenia: PCT/PL2006/000085, data zgłoszenia 23.11.2006. Zgłaszający: Instytut Włókien Naturalnych i Roślin Zielarskich oraz Instytut Technologii Eksploatacji – Państwowy Instytut Badawczy Radom.
6. Konczewicz W., Kryszak N., Nowaczkiewicz E., Kozłowski R., Wojtysiak J., Podsiedlik W.: Osmosis Plienomena Based Degumming of Bast Fibrous Plants as A Promising Method in Primary Processing, Molecular Crystals and Liquid Crystals, 2013, vo1. 571, no 1, 116–131.
7. Zimniewska M., Mankowski J., Wladyka-Przybylak M.: Rozdział 1: Włókna naturalne, rodzaje, właściwości, kierunki zastosowań, Monografia: Biokompozyty z surowców odnawialnych., Wydawca: Politechnika Krakowska 2012, 15–34.
8. Mazurkiewicz A., Ruta R., Trzos M.: Badania prototypu. Metodyka wspomagania procesu weryfikacji właściwości eksploatacyjnych. Monograficzna Seria Wydawnicza Biblioteki Problemów Eksploatacji, Radom 2004.
9. Zbrowski A.: Metodyka badań prototypów i jednostkowych urządzeń technicznych. Monograficzna Seria Wydawnicza Biblioteki Problemów Eksploatacji Radom 2016.
10. Samborski T., Zbrowski A.: Mechatronic system for the production of highly secured documents. Solid State Phenomena Vol.198, Mechatronic Systems and Materials IV(2013); 27–32.