ABSTRACT

In the doctoral thesis, entitled "***Research on optimizing of working process for cutting stalks of agricultural plants at harvest time***", the author conducted theoretical and experimental research on optimizing the work process for cutting stalks from different cereals (wheat, sorghum and maize) and technical plants (sunflower, rapeseed and soybeans), in the technological phase of harvesting.

By carrying out experimental research, solutions and methods for cutting the stalks of agricultural plants at the time of harvest were determined, using for this purpose a laboratory stand, original, designed and made by the author of the doctoral thesis.

The aims of the doctoral thesis, in order to achieve the proposed goal, were the following:

- determination and analysis of the nowadays harvesting technologies for different crops, by static and dynamic cutting of the stalks;
- the current state of research and trends in the development of devices for cutting the stalks of agricultural plants at harvest time;
- conception, design and implementation of a laboratory stand allowing experimental research using working parts from composition of cutting devices with fingers and upper knife, at which the step of cutting blades is equal with the fingers step, p = 76.2 *mm*, from some of harvesting machines (Sema, Dropia 1110, Gloria 1120, Gloria 1422, Claas, John Deere, Fendt and New Holland etc.)
- influence of some constructive parameters of the cutting blades, from composition of cutting devices, on working process, respectively for different sharpening angles: $i_c = 20°$ (used by most of the harvesting machines manufacturers); $i_c = 15°$ and $i_c = 10°$;
- influence of the thermo-chemical treatments that on durability of the cutting blades, through application of a titanium nitride layer *TiN* (process called titanium application) in the working area of the edge;
- experimental research regarding determination of dynamic and kinematicss parameters of the working process for cutting through shearing forces of stalks, respectively the maximum and medium cutting forces, the active stroke of the cutting blades (*mm*), total and specific cutting energy, for static and dynamic cutting at a velocity of the cutter of 1 *m/s* and 2 *m/s*;
- experimental research regarding the influence of the position of plant stalks face to cutting plane on working process, for vertically position (90°) and longitudinally inclined with (45°);

- experimental research on the influence of the stalk cutting area, between nodes and per node, on the working process;
- experimental research regarding determination of cutting section area of agricultural plant stalks at harvest time;
- experimental research on the wear resistance of the devices used to cut the stalks of agricultural plants at harvest time;
- statistical analysis and interpretation of experimental data;
- optimization of working process of the cutting devices for agricultural plant stalks at harvest time.

Thesis has a total of 174 pages, and is structured into two parts "***Stage of knowledge***" and "***Own contributions***", which contains eight chapters. It contains 105 figures, 57 formulas, 45 tables, 129 bibliographical sources and 4 annexes.

The doctoral thesis is structured in two parts. In the first part are presented aspects regarding the current state of research in the field approached and the theoretical basis of the working process for crops harvesting by stalks cutting. In the second part of the thesis are presented the conditions for carrying out of the scientific approach, the results of experimental research carried out in laboratory and in real operating production conditions, as well as the analysis and interpretation of experimental data.

Chapter I of the thesis entitled "***General notions regarding harvesting technologies of agricultural plant stalks***" includes general aspects of harvesting technology of different cultures by cutting of stems. Also, it shows the importance and necessity of the research. The first subchapter addresses general characteristics, a brief history and development perspectives of harvesting machines for cereals and technical plants. The second section states the opportunity and need for research on optimizing workflow for cutting of agricultural plant stalks to harvest. At the end of the first chapter is presented in synthesis the mechanized harvesting technologies of the main cereals crops (wheat, barley, maize and sorghum) and technical plants (sunflower, rapeseed and soybean).

In the **chapter II** of the PhD thesis, entitled "***The current state of knowledge regarding devices for cutting agricultural plant stalks at harvest time***", are approached general aspects regarding the role of cutting devices in the technology of mechanized harvesting of cereals and technical plants crops, followed by a classification of cutting devices and their construction. From the point of view of construction the cutters are classified into two main groups, namely: devices which performs stalks' cutting by shear and by inertia. For harvesting of cereals and technical plants crops, harvesting machines are equipped with cutters by shearing. Following in this chapter, are presented the main types of cutting devices which equip the harvest machines, in particular those with cutting blades and reciprocation ones. For each group of cutting devices, the author highlights the advantages and disadvantages of their use at harvesting of different crops.

Chapter III of the doctoral thesis includes **"*Theoretical basis regarding working process of devices for cutting agricultural plants stalks at harvest time*".** Technological cutting operation of agricultural crops, for harvest, consists in destroying of fibres continuity respectively their sectioning. The stems of agricultural plants consist of cells arranged in tissues. These, in turn, comprise fibre-vascular fascicles, which have the role of resistance elements. For this reasons, the working process for cutting of agricultural plants stalks, performed destroy of continuity of fibro-vascular fascia. These fascicles, at some vegetal stems, are distributed evenly over the section, and the other ones in the peripheral region.

The stems of agricultural plants are anisotropic materials whose strength and plasticity depend on the structure of the tissues and their humidity. As a result, the working process for stalks cutting is complex, being conducted by locally crushing, flexing and stretching forces on the fibres, whose share is by way of support and working tool used. Cutting means slicing of agricultural plants stems for sectioning, or removal of parts of them, with the cutters. According to the mode of action, the cutting of the agricultural plants stems at harvest time is done in two ways: cutting by shearing (by supporting agricultural plants stems) and cutting by inertia (without supporting the stems of agricultural plants).

The first subchapter deals with cutting by shear of agricultural plant stalks at harvest time, when sectioning is performed by the active elements, knife and counter-knife, determining the resistance forces to cutting by sliding.

The second subchapter highlights inertial cutting, in which case the cutting is performed by a single active element, the knife, which applies a shear force on the stem of agricultural plants, with a relatively high velocity. Subchapter three addresses the dynamics of agricultural plant stem cutters. The cutting velocity of the blades is an important parameter, and on which depends the productivity of cutting devices from harvesting machines.

From the analysis of research conducted worldwide, results that cutting velocity significantly influences the working process and concluded that, for cutting of fibrous vegetal materials, by increasing of cutting velocity leads to a reduced energy consumption for stalks cutting.

The second part of the doctoral thesis includes ***"Own contributions"*** and is formed by the following chapters: *The purpose and objectives of the PhD thesis; Research material and method; Experimental results regarding cutting resistance of cereals and technical plant stalks; Experimental results regarding the wear resistance of the devices used for cutting of agricultural plants stalks; Experimental research regarding optimization of working process of the devices used for cutting of agricultural plants at harvest time.* Finally are presented *General conclusions and recommendations.*

Chapter IV of doctoral thesis is entitled ***"The purpose and objectives of the PhD thesis"***. The author aims to optimize the working process of cutting of agricultural plants stems at harvest time, by changing the constructive and kinematics parameters of the cutters, type of blade knife and reciprocation, which equips the self-propelled harvesting machines for grains and technical plants.

Based on the analysis of the actual knowledge stage was established main aim of the thesis, the optimization workflow for cutting of agricultural plants stalks at harvesting time. To achieve the aim we generally have in mind the following specific goals:

- establishment of current state of research conducted worldwide regarding harvesting technologies for cereals and technical plants;
- identification of current research stage regarding construction and kinematicss and dynamics parameters of cutting devices, at harvesting machines, manufactured worldwide;
- analysis, conception, design and implement of a scientific approach that should be set kinematicss and dynamics parameters of cutting devices for agricultural plants in order for their harvesting, as well as processing of obtained experimental data in order to optimize the working processes;
- establishing of technological solutions in order to increase the durability performance of the cutting devices form harvesting machines.

Chapter V of the doctoral thesis entitled ***"Research material and method"***. In order to achieve the aims of the doctoral thesis, the author conceived and designed the elements necessary for the scientific approach of conducting experimental research, both in laboratory conditions and in production condition. Thus, in the first part of this chapter is presented the general framework where they investigated, respectively the laboratories of Agriculture mechanization disciplines, from UASVM Iaşi, laboratories from Technical University "Gh. Asachi" of Iaşi and from various economic units in Bacău County. An original laboratory stand was designed to carry out the experimental research, and as experimental material, stalks from different cereal crops (wheat, barley, sorghum and corn) and technical plants sunflower, rapeseed and soybean) were harvested. The laboratory stand can be equipped with working organs from the components of cutting devices from different harvesters, such as: Sema – 110, Dropia – 1110, Dropia – 1430, Claas Lexion 420, Claas Vario 610, John Deere S 770, Fendt 5225 E and New Holland CX 8080 Elevation.

In order to change the geometry and increase the durability of the cutting blades, the support of economic agents from the machine building industry, such as FEPA S.A. and Rulmenţii S.A., was requested, both of them from Bârlad City, Vaslui County.

In this chapter is presented in detail the construction, operation and main parameters of the stand, designed to perform experimental research to simulate under laboratory procedural of the working process for cutting the stems from different cultures at harvest time. For carrying out the experimental tests have been used parts from cutting devices with reciprocating, with fingers and upper knife, wherein the cutting blade step is the same as that of the fingers (p = *76.2 mm*). The stand for performing the experimental tests is built of high-performance, mechanical and electronic components, of the latest generation, for performing the measurements as efficiently as possible. Thus, the laboratory stand for conducting experimental tests is equipped with a power transducer CTS63200KC25-200 Kg, TLD T50 displacement transducer and data acquisition systems, which facilitates the transfer of data to a personal computer (PC). Thus, the specialized software Lookout HMI-SCADA was installed on the *"C"* partition of the computer. Through it, the results regarding the cutting force (*N*) and the active stroke of the knife (*mm*) were processed, being saved as a table, in Microsoft Office Excel. Previously, tests were carried out to determine the tensile strengths between its components without performing the operation of cutting the stems. Note that, the cutting forces measured during the experimental tests, including the cutting forces *F* (*N*) itself, to which is added the frictional forces of the cutter resulting from "idling" operation of the device.

To achieve the aim of the PhD thesis, to optimize the workflow, were conducted trials with cutting blades at which the edges are active, smooth and jagged, were sharpened at different angles 20° (standard), 15° and 10°. To increase the wear resistance of the cutter, subsequently were hardened smooth and serrated cutting blades and counter-knives from Romanian harvesting machines Sema, Gloria and Dropia by depositing titanium nitride *TiN,* into a thin layer between 3 and 15 *μm,* on their surfaces, making a hardness of *2500 HV.* The cutting operation was performed for two positions of the knife face to stem: cutting by slicing (the knife moves perpendicularly, 90º to the longitudinal axis of the stem) and inclined cutting (the knife moves in an inclined direction to 45º to the longitudinal axis of strain). The speed of the knife is an important element in the cutting process. It is known that this is variable because the actuating mechanisms, which convert the rotational movement of the crankshaft into reciprocating rectilinear motion, cause a sinusoidal velocity of knife. The sectioning of agricultural plants was effectuated between nodes and per node, in static and dynamic working regime, by shearing, using two working velocities: 1 *m/s* and 2 *m/s.*

In order to be able to accurately measure the cutting force of agricultural plants stems using a knife, the transducers were previously calibrated using a dynamometer.

Also, prior to cutting of agricultural plants strains was done a measure of moisture of the studied material using the drying oven BIOBASE BOV-T 25F.

In subchapters 5.3 and 5.4 are presented the method of organizing and conducting of the research in order to determine the force resistance at cutting of cereal and technical plants stems of crops. The experiments are multifactor for each variety, in which five influencing factors were taken into account, respectively: the type of harvesting machines (made in Romania, Claas; John Deere, Fendt and New Holland); stem position (vertical and longitudinally inclined at 45°); the cutting area of the stems (between nodes and per node); the average velocity of cutting blades (1 m/s and 2 m/s) and the sharpening angle of the cutting blades (10°; 15° and 20°).

Further to this chapter is presented the research method for determining ***the surface of cutting section*** **(S),** resulted after sectioning of studied stalks. In order to be able to determine the cutting surface, the ***Image J*** program was used, through which the photographed images of the sectioned stems', were analyzed.

In the last subchapter 5.6, is highlighted the research method for quantifying the wear resistance of cutting devices which were used for cutting the strains of agricultural plants. It was made research using cutting blades from the cutting devices which belongs to the following harvesting machines: Claas, John Deere and Sema. In the 2017 grain harvesting campaign, new cutting blades were installed on the combine cutters presented above. Prior to installation, the cutting blades were weighed, measured and analyzed to determine their surface area, mass, roughness and hardness, after which were used for harvesting in the field, in real operating conditions, for 100 operating hours. The knife blades were mounted on the cutters of the cutting devices to their left, middle and right. After 100 hours of operation in the field, the blades were removed from the knives, were cleaned, degreased, and then weighed determinating againg the mass, surface, roughness and hardness.

At the end of this chapter, the partial conclusions on the research material and method used for conducting the experimental research are presented.

Chapter VI comprise "*Experimental results regarding cutting resistance of cereals and technical plant stalks at harvest time*". In subchapter 6.1 are presented the experimental results regarding resistance to static and dynamic cutting, by shearing, of the strains of agricultural plants from technical crops and cereals. In subchapter 6.2 are presented the experimental results regarding determination of cutting area of agricultural plants stalks from cereals and technical plants. Subchapter 6.3 deals with the specific energy for static and dynamic cutting of agricultural plants stalks at harvest time. In the last but one subchapter 6.4 are mentioned the experimental results regarding wearing resistance of the devices utilised for cutting of agricultural plants stalks at harvest time. Experimental results were noted for determination of the mass, surface, roughness and hardness of new knife blades, and for knives after 100 hours of field operation, in real operating conditions, mounted on the cutting equipment of Claas, John Deere and Sema harvesting machines. Partial conclusions are mentioned in subchapter 6.5.

Chapter VII highlights the interpretation of experimental data noted in subchapter 7.1. Subchapter 7.2 presents the optimization of working process for cutting the stems of cereal agricultural plants and technical plants. The results of the interpretation of the experimental data for wheat and sunflower crops are scored for the average values of cutting energy, the coefficient of variation and the significance test for five harvesting machines (Sema, Claas, Fendt, New Holland and John Deere). There are interpreted experimental data for cutting of agricultural plants stalks, between the nodes, with vertically stem $\alpha_1 = 90°$ and inclined at 45°, for static and dynamic cutting, by shearing, at working velocities of 1 *m/s* and 2 *m/s*.

In **Chapter VIII**, subchapter 8.1, are laid down general conclusions of the thesis, followed by subchapter 8.2 in which are noted the recommendations for a further development of research.