EXPERIMENTAL DETERMINATION OF THE WEAR RESISTANCE OF DEVICES USED FOR CUTTING THE STALKS OF AGRICULTURAL PLANTS

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Abstract

The paper presents researches on the wear resistance of the blades integrated in the combine cutter for the harvesting of agricultural plants. The wear of the combine cutters causes production losses at harvesting both during operation and stopping machines to change the blades. Experimental determination of wear was made for blades on cutting attachment of three types of combines studied. The parameters determined in the wear study were the hardness, mass and roughness of both the new blades and the blades used for 100 hours of harvest operation. The analysis of the data on the degree of wear of the blades both quantitatively by determining the mass and qualitatively by studying the roughness of the used surfaces under identical conditions of operation, presents differential losses for the three combines that correlate with the blade hardness.

Key words: wear, cutting attachment, combine harvester, agricultural plants

Production losses at harvest occurring at a combine are divided into natural losses, heder losses and thawing and segregated losses. Of these, the most important is the loss from heder. Loss at the heder of the harvester during harvest is the consequence of a complex of crop cutting factors and the conditions under which this cutting takes place.

The cutting process is very complex because the stalks have variable textures of non-homogeneous materials with different properties in space and time. The cutting process requires a considerable amount of energy and results in a high wear of the cutting blades (Dasgupta *et. al.*, 1998)

There is a relatively large number of parameters influencing the wear of the cutting knives, and among these parameters it is worth mentioning: the type and the physico-mechanical characteristics of the stems to be cut, the position on the cutting stump (node or internode) (Yore *et. al.*, 2002) the density of the cut stalks and their position relative to the vertical (Dange *et. al.*, 2002; Ciulică *et. al.*, 2011). Other parameters that influence the wear are related to the physical-mechanical and geometric characteristics of the cutting knives (hardness and type of cutting) (Tabatabaee *et. al.*, 2006; Esehaghbeygi *et. al.*, 2009) and the working mode of these knives (with or without vibrations) (Mcneil *et al.*, 2009).

The operating principle of the cutting elements used by the harvesting equipment can be classified as cutting by impact and cutting with a cutting edge, and the cutting mechanism can be reciprocally and with a rotary impact (Kang *et. al.*, 2012).

Knife wear is a combination of impact wear and abrasive wear. These are the major cause of knife destruction and limitation of cutting blade life. In heavy working environments, sufficient protection against abrasion can not be ensured only by heat treatment, which leads to frequent replacement of the blades during work (Miu, 2015).

The modern techniques of studying surfaces and knife hardness lead to a better understanding of the wear and the factors that determine it.

The analysis of the data on knife wear was done both quantitatively and qualitatively by studying the roughness of the used surfaces blade and the hardness under identical operating conditions for three types of combines.

MATERIAL AND METHOD

Experimental determination of wear resistance of blades used for harvesting were performed for three types of combines (A, B, C). The cutters used to cut the stems of agricultural plants at the time of harvesting are of the type with the fingers and the upper knife, with the blade step

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equal to the pitch of the fingers p=76.2 mm (*figure 1*).

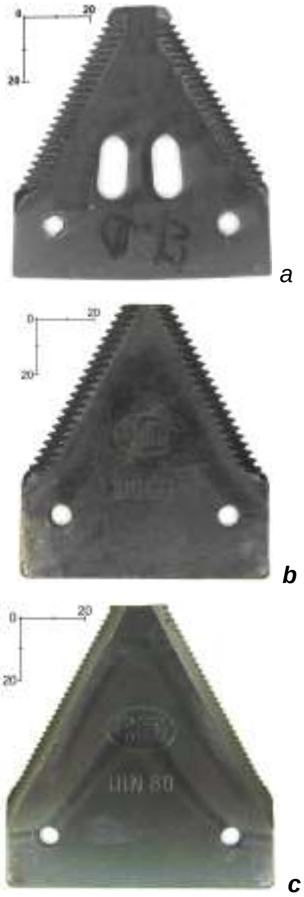

Figure 1 **Knife geometry**
a- combine A; b- combine B; c- combine C

The experiments were carried out during the harvesting of rape and wheat crops, installing new knife blades on the heder cutters in three distinct positions (left, middle, right). The knives were used for 100 hours under actual operating conditions. The preparation of knife blades for experimental determinations was performed by washing with water and solvent degreasing (gasoline) both at the beginning of the experiments and at the end of the experiments.

The method of research on the wear resistance of apparatus used to cut agricultural plant stems at harvest time is to determine the mass of the knife blades of the roughness of the surfaces and their hardness before and after 100 hours of operation.

The mass of the knives was determined with an analytical balance with the accuracy of ± 0.001. The new knives were degreased and weighed, and after 100 hours of operation, the knives were washed with water to remove the soil, dust, vegetable material slurries and solvent-free grease were then dried and then weighed.

Knife blade surface control is important to determine qualitatively changes in the surface of the blades due to abrasive wear. The ruggedness of the knife blades has been determined with a Taylor Hobson rugometer which is of the inductive type with a middle spindle supported on two knives (forming a lever) which has attached at one end an armature that moves inside the bobbins producing an electrical signal. The electrical signal is a function of the vertical movement and at the opposite end is positioned the touch probe having a rounded tip that comes into contact with the rusty surface of the knife blades (*figure 2*). The roughness profile is interpreted with the *µultra* software.

Figure 2 **Taylor Hobson rugosimeter used to determine the roughness of the knife blades**

Objective and qualitative interpretation of the roughness differences between the new and worn surfaces of the blade surface was made using the Ra parameter which is most commonly used. The Ra parameter results by direct calculation of the roughness profile. The roughness profile was determined on a straight segment for the knife blades of the three combinations studied (*figure 3*).

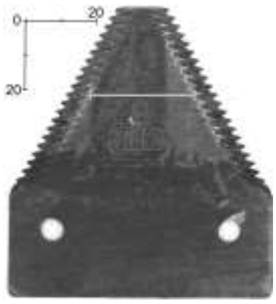

Figure 3 **The segment and the position on the knife blade**

The Rockwell hardness measuring equipment consists of a housing containing the loading mechanism for the initial load. The housing also has a support table for the test material to be tested vertically and horizontally. Also in the casing is the data acquisition system from the force transducers and the inductive sensor of the penetration head.

The acquisition system is linked to the computer, and through a program the data is processed (*figure 4 a*).

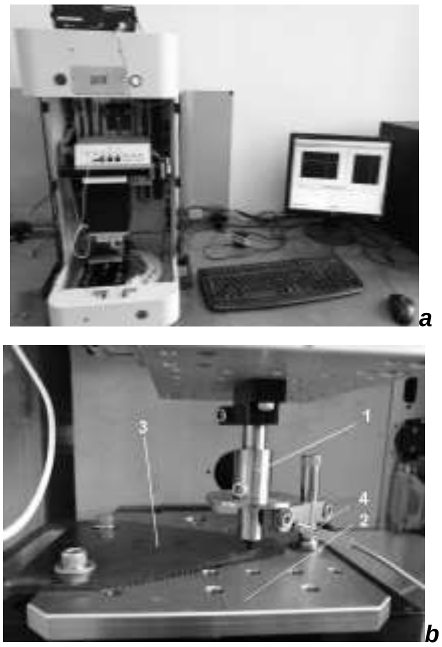

Figure 4 **Rockwell hardness measuring equipment a- general view; b- fastening systems**

1– penetrator; 2– support and fastening table; 3– knife blade; 4– calibration sensor to bring the displacement to zero.

In the experiments, the knife blades were prepared for the hardness tests following the following protocol and technical conditions as follows: the knife blades have flat surfaces and the test sample will be prepared so as not to have oxidized portions and the degree of machining to allow for the measurement of the track with the required precision; the positioning of the sample on the test table permits the application of the load perpendicular to the plane surface of the sample; the test knife blade is placed on the rigid table to be fixed to avoid any movement during the tests (*figure 4b*); a slow and even increase of the load is ensured; the load is kept constant for the prescribed time with an error of ± 1% (prescribed time: 15 ', 30').

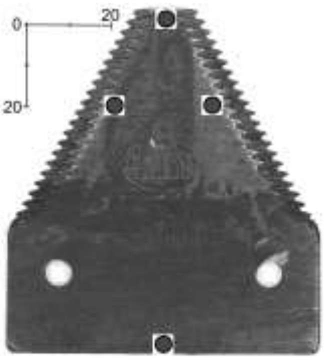

Figure 5 **Knife blade with four test points**

Experimental tests for each knife blade were four, positioned so that hardness variations could be highlighted (*figure 5*).

RESULTS AND DISCUSSIONS

The knife wear analysis for the three combines studied was done both quantitatively by weight loss determinations of the knife blades and qualitatively by determining the variation of the roughness parameter Ra and the blade hardness of the blades after 100 hours of operation. Parameter Ra is used most often in texture analysis of surfaces. Roughness assessments through the Ra parameter were performed on five consecutive sampling lengths and then the data is mediated. This ensures that the Ra value is specific to the measured surface and characterizes the surface. The unit of measurement for parameter Ra is in micrometers. The roughness profile obtained with the Taylor Hobson rugosimeter has a resolution of 16 million: 1 and is filtered using the *μultra* software.

Hardness is a property of materials that expresses their ability to resist the action of mechanically penetrating a heavier body into its mass. In determining the hardness of the materials, the size of the traces produced by a penetrating body called the penetrator, which is characterized by a certain shape and size and the force acting on it, is taken into account. The Rockwell method used in the experiment simplifies the methodology for determining the hardness of the knife materials and reduces the time required to perform the test, giving it the possibility of applying it to all categories of materials, regardless of the likely hardness they have. The experimental tests for each knife blade were four, positioned so that the hardness variations could be highlighted. It has been estimated from the outset that the hardness obtained at the point at the base of the knife blade will be reference hardness, considering that in the points on the side edges and at the top, the material has hardness greater than or equal to the base material. Charts for hardness determination at one point are plotted using computer software based on experimental data from test equipment. Graphics also determine the Rockwell hardness values in GPa.

The experimental results are presented (*table 1*). From the table it can be seen that under identical operating conditions of the knife blades for the three combines, the wear losses are different and these correlate with the hardness determined at different points on the knife blades.

Table 1

Variation of parameters at knife blades after 100 hours of operation

Combine	Knife position on heder	Weight loss knife (g)	Roughness variation ΔRa (μm)	Rockwell Hardness (GPa)		
				Point position		
				base	edge	peak
A	left	0.4015	0.047	1.85±0.01	2.12±0.07	3.81±0.06
	middle	1.9654	0.073	1.46±0.01	1.89±0.09	3.11±0.18
	right	0.7500	0.070	1.89±0.01	2.19±0.14	3.44±0.04
B	left	1.1535	0.141	1.49±0.01	2.07±0.12	2.45±0.10
	middle	1.4772	0.174	1.56±0.01	2.21±0.08	2.79±0.07
	right	0.4860	0.130	1.94±0.01	2.54±0.09	2.58±0.12
C	left	0.1493	0.377	1.62±0.01	2.57±0.19	3.62±0.19
	middle	0.6618	0.395	1.66±0.01	3.06±0.09	4.29±0.43
	right	0.5309	0.384	1.82±0.01	2.59±0.05	4.05±0.64

Quantitative due to wear after 100 hours of operation, the knife blades have experienced weight loss at all combines considered. The middle-mounted knife suffered the greatest weight loss compared to the left and right side knives. Thus, combining A due to wear, the middle knife has a weight loss after 100 hours of operation of 1.9654 g representing 2.498%. This is the biggest loss compared to the B and C combines for the middle knife. Qualitatively due to wear after 100 hours of operation, variations in roughness at the surface of the knife blades were recorded at all three combines. The middle-mounted knife blades suffered the largest variations in the roughness parameter. Thus, when combining C due to wear, variations in roughness after 100 hours of operation are 0.395 μm. This is the highest increase for the roughness parameter compared to the combines A and B where the values are 0.073 μm and 0.174 μm, respectively.

The hardness of the knife blades has also been determined. On all three studied combines, the knife blades mounted at the center of the knife record the greatest loss of hardness.

CONCLUSIONS

Experimental determinations were performed on finger cutters and upper knife, where the blade pitch is equal to the pitch of p = 76.2 mm, for three different combines. The harvesting campaign in which the experiments were carried out was in 2016.The experiments were carried out during harvesting on rape and wheat crops.The operating time of the knives under actual harvesting conditions was 100 hours. Quantitatively due to wear the knife blades recorded weight loss at all the combinations considered, and the greatest loss was recorded at the middle knife of combine A.

Qualitatively due to wear, variations in roughness at the surface of the knife blades were recorded at all three combinations, and the highest increase in the roughness parameter was at the middle knife of the C combine.

Under identical operating conditions of the knife blades for the three combines, different wear was obtained and these correlate with the hardness determined at different points on the knife blades.

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