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MODELING OF THE KINEMATIC MOVEMENT OF THE DRUM CUTTING UNIT IN CHAFF-CUTTER

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Abstract: *In the study there is presented the original mathematical model of the kinematics drum's movement of the working machine type chaff cutter's. The advantage of this model is, that is includes the mathematic dependencies between the construction features and parameters of the drum cutting assembly which essentially influence the cutting process of the layer of the plant material and the length of the cut section's material. This model may be applied at the stage of new constructions of the drum cutting assemblies.*

Keywords: kinematics of movement, drum cutting unit, modelling, chaff cutters, cutting process

1. Introduction

The basic working assembly appearing in machines of chaff cutter's type is the drum cutting assembly. Its task is to cut the plant material into sections of determined length. This process is necessary for the purposes of obtaining material for power purposes or for fodder (Zastempowski et al., 2013).

The quality of the cutting assembly depends not only of the state of the cutting edge (degree of its sharpening), but also on setting the drum's rotation axis with regard to the cross-cutting edge and the height of the fed plant material's layer.

From the analysis of the generally available literature it results, that the subject matter of kinematics and dynamics of the cutting units movement of the machines' operating assemblies was discussed in its publications only by Bochat and Zastempowski (2017) and by Zastempowski (2017). The subject matter related to the general mathematical modeling of the states of operating machines, optimization of their construction or the assessment of the functioning's effectiveness was also entered into in studies by, Zastempowski & Bochat (2014, 2015).

In order to optimize the construction and to improve effectiveness of the drum cutting assembly's functioning it shall be necessary to determine the detailed relations between the features and construction parameters of the drum cutting assembly, for which there takes place the correct cutting process and developing of a model describing a theoretical length of the cut material's sections.

2. Methods

Analysing the complex knife blade's movement it may be observed, that the cutting speed v_c, is the variable value and is closely connected with the peripheral knives' speed v_b and the feeding speed of the material to be cut v_m. The direction and value of speed v_c change together with the value of the drum's φ value of rotation angle. For an optional knife blade's location, according to fig. 1, the speed v_c may be calculated from the relationship:

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$$v_c = \sqrt{v_b^2 + v_m^2 + 2v_b v_m cos\psi}. \quad (1)$$

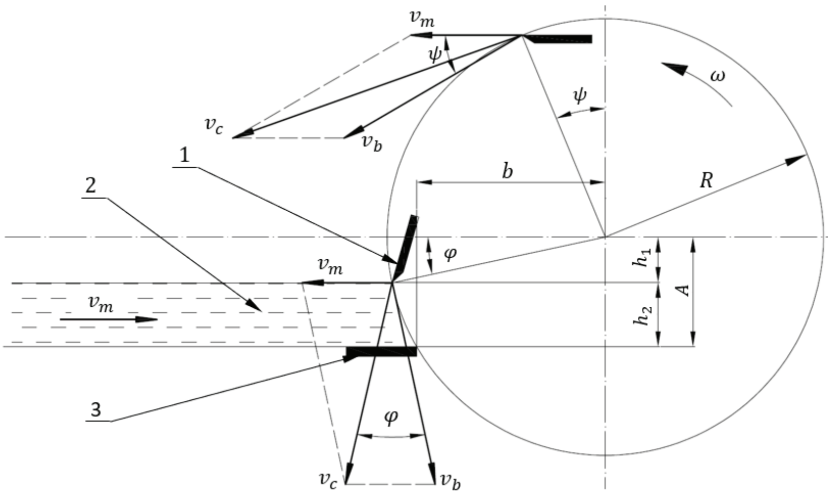

Fig. 1: Location of the drum rotation's axis towards the cross-cutting edge (Bochat, 2010): 1 – cutting edge (knife), 2 – layer of material to be cut, 3 – cross-cutting edge

For the purposes of the correct cutting process' performance, it is necessary that the speed component $\vec{v}_c$ on the material feeding axis be directed in accordance with the material $\vec{v}_m$ travelling speed, or else pushing off of the fed material shall occur and the cutting process shall not go correctly. Assuring the consistency of the horizontal speed component $\vec{v}_c$ is performed by shifting of the crosscut edge by the dimension A (Fig. 1). The critical location of the crosscut edge, at the constant thickness of the fed material's layer h_2, ensuring the correct course of the cutting process takes place when the vector $\vec{v}_c$ is perpendicular to the vector $\vec{v}_m$. The following relations result from Fig. 1:

$$sin\rho = \frac{h_{1\,min}}{\mathrm{R}} \quad i \quad sin\rho = \frac{v_m}{v_b}$$

that is:

$$h_{1\,min} = \frac{v_m}{v_b} R \quad (2)$$

The minimum value of $h_{1\,min}$ established in such a manner, ensures the correct performance of the cutting process. However, the maximum acceptable height of the cut material's layer $h_{2\,max}$ amounts to:

$$h_{2\,max} = A - \frac{v_m}{v_b} R \quad (3)$$

The equation determining the maximum cutting height in the dimensionless form, assumes the following form:

$$\frac{h_{2\,max}}{R} = \frac{A}{R} - \frac{v_m}{v_b} \quad (4)$$

The relationship (4) is also presented in Fig.2. In known drum cutting assemblies' constructions, the range of variability of the dimensionless parameters occurring in the equation (4) is the following:

$$0{,}3 < \frac{A}{R} < 0{,}7 \quad i \quad 0{,}03 < \frac{v_m}{v_b} < 0{,}11$$

Due to the fact, that the cutting drum makes a rotary motion, and the material dislocates with the uniformly straightforward movement in its direction, the movement path is in the form of trochoid which, according to fig. 3 is described by the parametric equation:

$$x_a = v_m\, t + R\, cos\omega t, \quad (5)$$

$$y_a = R(1 - sin\omega t). \quad (6)$$

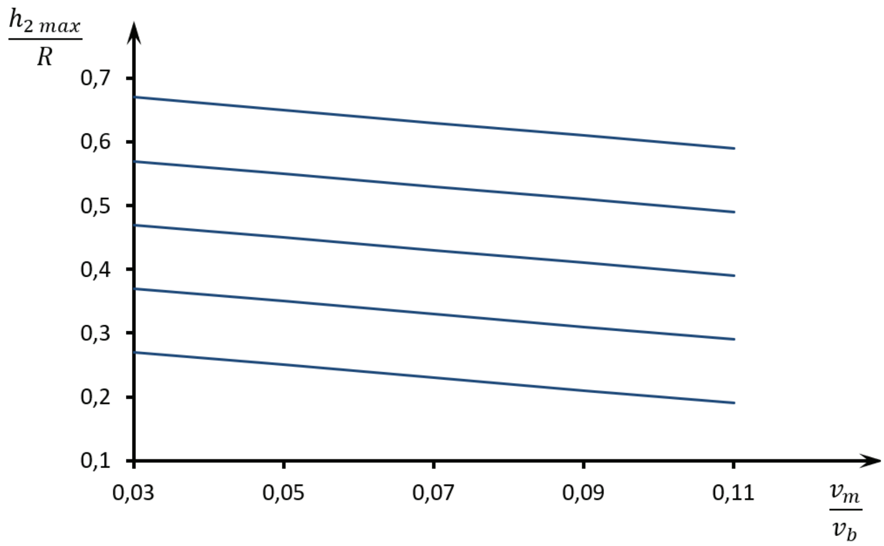

Fig. 2: The maximum height of the material's cutting layer (own study)

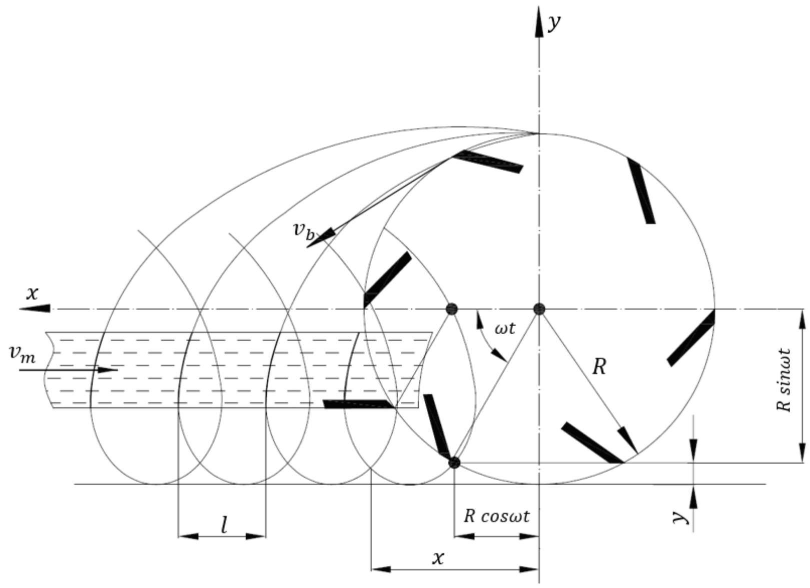

Fig. 3: The trajectory of the drum's blades with reference to the cut material's layer (Bochat, 2010)

In order to determine the resultant speed v and acceleration a of a knife, it is necessary to differentiate the equations (5) and (6) and to conduct appropriate mathematical activities. Differentiating the equations (5) and (6) once, we get:

$$v_{xa} = \frac{dx_a}{dt} = v_m - R\,\omega\,sin\omega t, \tag{7}$$

$$v_{ya} = \frac{dy_a}{dt} = -R\,\omega\,cos\omega t. \tag{8}$$

The knife's resultant speed is described by the relationship:

$$v = \sqrt{v_m^2 - 2\,v_m R\omega\,sin\omega t + R^2\omega^2}. \tag{9}$$

However, differentiating twice the equations (6) and (7) there was received:

$$a_{xa} = \frac{dv_{xa}}{dt} = -R\,\omega^2\,cos\omega t, \tag{10}$$

$$a_{ya} = \frac{dv_{ya}}{dt} = R\,\omega^2\, sin\omega t. \tag{11}$$

So, the knife's resultant acceleration is described by the relationship:

$$a = \sqrt{(-R\,\omega^2\, cos\omega t)^2 + (R\,\omega^2\, sin\omega t)^2} = R\omega^2. \tag{12}$$

The distances between the neighboring trochoids' loops accumulated in the layer of cut material are equal and constitute the computational cutting length corresponding to the length of the cut material's section. The theoretical length of the cut material l may be calculated from the dependence (13) having the form of:

$$l = \frac{v_m}{n\,z}, \tag{13}$$

where:

z – number of the cutting drum's knives.

As there occur simple relationships:

$$n = \frac{30\,\omega}{\pi} \text{ i } v_b = R\,\omega.$$

The relationship (13) finally assumes the form:

$$l = \frac{\pi}{30}\frac{v_m}{v_b}\frac{R}{z}. \tag{14}$$

3. Conclusions

The kinematics movement model of the drum cutting assembly of the chaff cutter proposed in the study, makes it possible to conduct simulation calculations of the plant material's process for the variable features and construction parameters: v_b, v_m, R, A, h_1, h_2, ω and t.

The results of the simulation calculations on the developed mathematical model may, in case of positive experimental verification, form the elements necessary to design and analyze many variants of cutting drums' construction and to choose an optimum solution on that basis.

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