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KINEMATICS OF DRUM MOVEMENT OF THE CUTTING UNIT OF A STRAW CUTTER

Andrzej Bochat, Marcin Zastempowski

University of Technology and Life Sciences in Bydgoszcz
Faculty of Mechanical Engineering
ul. Kaliskiego 7, 85-796 Bydgoszcz, Poland
e-mail: zastemp@utp.edu.pl

Abstract

In the study there have been presented mathematical dependencies describing the kinematics of the drum movement of a straw cutter's cutting unit. Formulating of dependencies may be used at the stage of different types of analyses and simulation studies on new drum constructions of cutting units for cutting of a layer of vegetal material into chaff.

Key words: *straw cutter, drum cutting unit, kinematics of movement, vegetal material*

1.Introduction

The drum cutting unit constitutes the basic operating assembly of self-propelled, attached or stationary straw cutters. The task of the drum assembly is to cut the vegetal material (stalks or stems) into parts of a definite length – into chaff.

Application of this type of an assembly in straw cutters makes it possible to obtain the required degree of material's size-reduction [1, 3, 4, 7].

The rotational motion of a cutting drum results in relocating of cutting knives together with it. Knives moving in relation to the immovable counter cutting edge cause at the first stage squeeze – pressing of a layer of vegetal material and then its cutting.

Feeding of material between the knife's blade and the counter cutting blade takes place thanks to the rotary movement of pulling in-squeezing rollers, which pre-form and compact the material.

The essence of the process of feeding and cutting of vegetal material with the use of a cutting drum is presented in the Fig. 1.

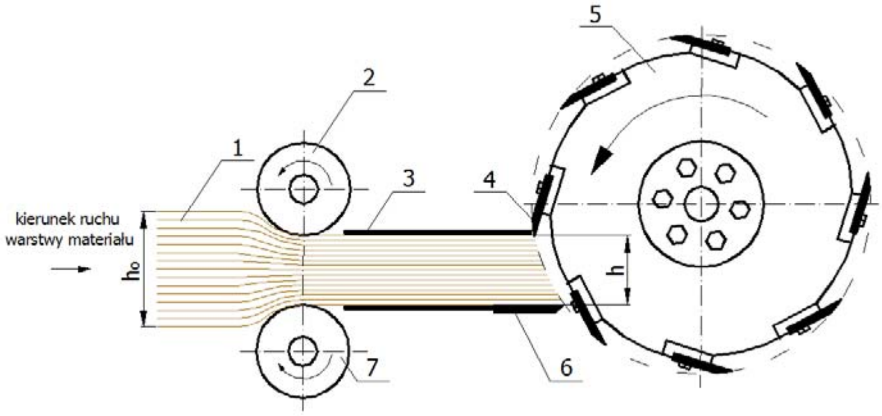

Fig. 1. Process of feeding and cutting of vegetal material with the use of a cutting drum:
1 – layer of material, 2 – upper pulling in- squeezing roller, 3 – pressure plate, 4 – cutting knife, 5 – cutting drum,
6 – counter cutting edge, 7 – lower pulling in-squeezing roller,
h_0 – height of the layer of material before compacting, h – height of the layer of material after compacting

One of the basic problems facing the design engineers of the straw cutter is the correct designing of their operating-drum cutting assembly. It shall be possible on condition of precise finding of dependencies between geometrical and kinematic parameters of construction of a given drum assembly and the location and thickness of the layer of the cut material.

It results from the literature studies, that the above issue [1, 2, 3, 4, 5, 6, 7] has not been precisely solved yet.

That is why in this study, the attempt of mathematical description of a cutting drum's movement has been assumed as the basic goal of the work particularly considering its knives at the stage of cutting of a material's layer.

2. Analysis of the issue

Analyzing a complex movement of a single cutting edge it may be noticed, that the cutting speed ϑ_c is a variable value and is strictly determined by the tangential velocity of knives ϑ_b and the speed of material feeding ϑ_m for cutting. The direction and value of the speed ϑ_c, vary together with the value of the drum's rotation angle φ. For any location of a knife's location, pursuant to Fig. 2, speed ϑ_c may be calculated from dependencies:

$$\vartheta_c = \sqrt{\vartheta_b^2 + \vartheta_m^2 + 2\,\vartheta_b\,\vartheta_m \cos\psi}\ . \tag{1}$$

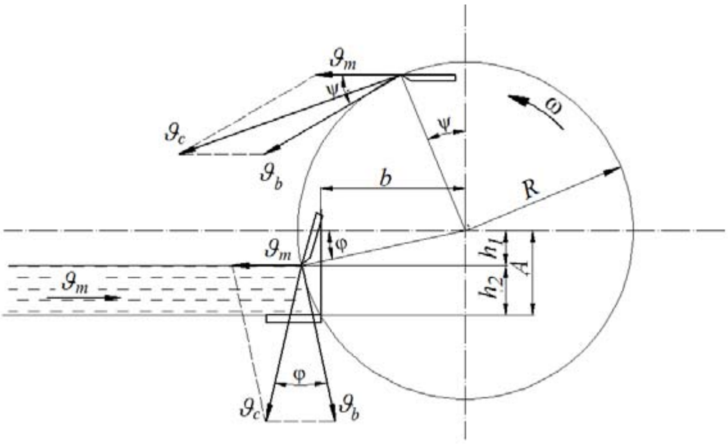

Fig.2. Location of the drum rotation's axis in relation to the counter cutting edge

In case of no specific location of the counter cutting edge in relation to the drum's axis, the knife shall cause pushing away of material what shall result in the increase of cutting resistances and the increase of unevenness of chaff's cutting.

Limiting location of the counter cutting edge at constant thickness of fed layer assuring correct cutting shall take place when the component horizontal linear velocity of a knife is equal to the material's feeding speed what takes place when :

$$\sin\varphi = \frac{\vartheta_m}{\vartheta_b}. \tag{2}$$

It results from the analysis of the Fig. 2, that:

$$h_1 = R\sin\varphi = R\frac{\vartheta_m}{\vartheta_b} = R\frac{1}{\lambda}, \tag{3}$$

where:

R – radius of cutting drum,

λ – kinematic ratio of a drum cutting assembly specified as a quotient of the tangential velocity ϑ_b of cutting knife to feeding speed ϑ_m of material to be cut.

So, the distance of the counter cutting edge from the drum's axis in the vertical plane may be calculated from the formula:

$$A = h_2 + \frac{R}{\lambda}. \tag{4}$$

While the distance of the drum rotation's axis from the counter cutting edge in the horizontal plane may be calculated from the dependence:

$$b = \sqrt{R^2 - A^2} = \sqrt{R^2 - \left(h_1 - \frac{R}{\lambda}\right)^2}. \tag{5}$$

From the analysis of equations (4) and (5) it results, that location of counter cutting edge in relation to the rotation's axis of a cutting drum depends on a drum's radius, thickness of cut laser of material and the kinematic index.

Due to the fact, that the cutting drum makes rotational motion and material moves with uniformly linear motion in its direction, the movement path of knives has the form of a trochoid which, pursuant to Fig. 3 is described by a parametric equation:

$$x_a = \vartheta_m t + R\cos\omega t, \tag{6}$$

$$y_a = R(1 - \sin\omega t). \tag{7}$$

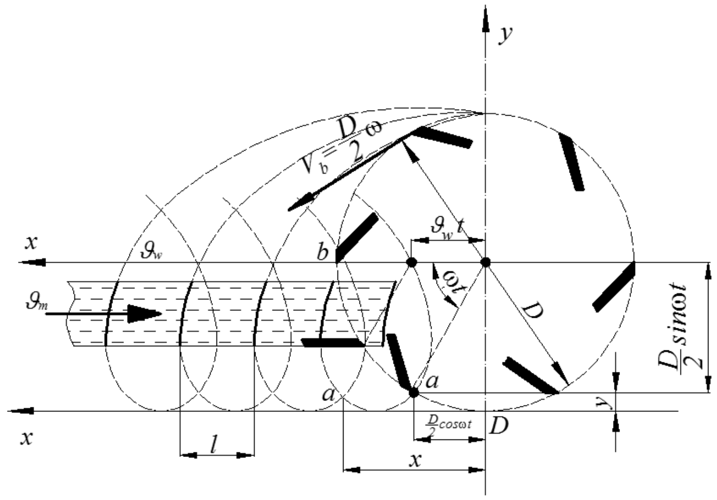

Fig.3. Path of drum's knives in relation to the cut layer of material

In order to determine resultant speed ϑ and acceleration a of a knife, one should appropriately differentiate equations (6) and (7) and to make appropriate mathematical operations.

Differentiating equations (6) and (7) once, the below was received:

$$\vartheta_{xa} = \frac{dx_a}{dt} = \vartheta_m - R\omega\sin\omega t, \tag{8}$$

$$\vartheta_{ya} = \frac{dy_a}{dt} = -R\omega\cos\omega t. \tag{9}$$

Taking into account that the resultant speed of the knife is described by the dependence:

$$\vartheta = \sqrt{\vartheta_{xa}^2 + \vartheta_{ya}^2}, \tag{10}$$

after conversions there has been received:

$$\vartheta = \sqrt{\vartheta_m^2 - 2\vartheta_m R\omega \sin\omega t + R^2\omega^2}. \tag{11}$$

However, differentiating twice the equations (6) and (7) there has been obtained:

$$a_{xa} = \frac{d\vartheta_{xa}}{dt} = -R\omega^2\cos\omega t, \tag{12}$$

$$a_{ya} = \frac{d\vartheta_{ya}}{dt} = R\omega^2 \sin \omega t. \tag{13}$$

Taking into account that the resultant acceleration of the knife is described by the dependence:

$$a = \sqrt{a_{xa}^2 + a_{ya}^2}, \tag{14}$$

after conversion there has been received:

$$a = \sqrt{\left(-R\omega^2 \cos \omega t\right)^2 + \left(R\omega^2 \sin \omega t\right)^2} = R\omega^2. \tag{15}$$

Distances between the adjacent trochoid loops deposited on the layer of cut material are equal to each other and constitute the so-called computational cutting length corresponding to the length of chaff.

The theoretical length of chaff l with sufficient approximation may be calculated from the dependence:

$$l = \frac{\vartheta_m}{n \cdot z} = \frac{\pi \vartheta_m}{30\omega \cdot z}, \tag{16}$$

where:

ϑ_m – speed of material feeding,
n – rotational speed of cutting drum,
ω – angular velocity of cutting drum,
z – number of knives.

3. Final conclusions

In the light of the conducted analysis of this issue, the following conclusions may be formed:

1. Mathematical dependencies presented in the study describing kinematics of drum movement of a cutting assembly of a straw cutter and in particular of its cutting knives, constitute the first attempt of comprehensive presentation of that issue.

2. Derived dependencies make it possible to establish relationships between the basic operational parameters of a cutting drum and its constructional and geometric features in the aspect of kinematics of the movement of knives cutting the layer of material.

3. Developing the dependencies may be used at the stage of simulation tests with new drum constructions of cutting assemblies of a straw cutter and in the process of automation of their operation's steering.

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