RELATIONSHIP BETWEEN THE VELOCITY COEFFICIENT AND MOMENT OF FORCE TO CUTTING WITH A DISC KNIFE

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Abstract. *A number of food products are effectively cut with disc knives with smooth cutting edge. Due to the elasticity of the food products, the deformation that arises during their dissection causes friction forces between the side walls of the knife and the product. Given these frictional forces formulas are derived for the resultant friction power and friction torque [1].*

This article is a continuation of previous studies [1; 2; 3; 4]. A study is proposed on the influence of the parameter λ, representing the ratio of the cutting velocity of the disc to the feeding velocity, on the resultant friction moment.

Keywords: *moment of force, friction, velocity coefficient, disc knife, food*

Introduction. With the expansion of the modern food industry it is required to optimize and increase the quantity and quality of the final product. In this regard, various technological processes in food production are examined theoretically and experimentally in order to improve them.

Subject of the present theoretical study is the mechanical cutting process, which is one of the most common processes in different sectors of the food industry. Cutting devices using disc knives are discussed. Their main advantages are in the relatively simple construction and convenience in operation. The disc blades provide quality food processing combined with high cutting speeds. That is why they are the subject of a number of studies.

Cutting food products is accompanied by elastic compression of the material. The deformation creates significant frictional forces between the side walls of the knife and the material getting cut.

In previous studies [1] a formula is derived for the resultant moment as friction is reported between the side walls of the knife and the product getting cut:

$$M_{fr} = 2\mu \frac{Ea}{3l}\left[r^3 J_6 - (r - \Delta - B)^3 J_7 + 3B(r - \Delta)(r - \Delta - B)tg\varphi_1\right], \qquad (1)$$

where

μ – coefficient of friction

E – modulus of elasticity of the product getting cut, Pa

a – half of the disc knife`s width, m

l – width of the product getting cut from the one side of the knife, m

r – radius of the disc knife, m

B – thickness of the product getting cut, m

Δ – height of the disc blade`s part, which is incised in the board, m

Parameters J_6 and J_7 are called third and fourth resistance characteristics and are given by the following elliptic integrals

$$J_6 = \int_{\varphi_l}^{\varphi_u} \frac{\lambda - \cos\varphi}{\sqrt{1+\lambda^2 - 2\lambda\cos\varphi}} d\varphi \,; \; J_7 = \int_{\varphi_l}^{\varphi_u} \frac{\lambda - \cos\varphi}{\cos^3\varphi\sqrt{1+\lambda^2 - 2\lambda\cos\varphi}} d\varphi \,.$$

Here $\lambda = \frac{v_c}{v_f}$ is a velocity coefficient, which is the ratio between the cutting velocity $\overrightarrow{v_c}$ and feeding velocity $\overrightarrow{v_f}$ of the disc knife.

The limits of the integrals J_6 and J_7 are determined by:

$$\varphi_l = \arccos\frac{r-\Delta}{r} \;;\; \varphi_u = \arccos\frac{r-\Delta-B}{r} \,.$$

Parameters μ, E, a and l depend on the nature of the product getting cut and are derived experimentally. The values of r, B, Δ and λ are still subject to both theoretical and experimental studies.

This work offers a study on the influence of the velocity coefficient λ on the resulting friction moment.

Output data

Object of the current research is a double bevelled disc knife with smooth edge. Numerical analysis for a raw material meat has done with the following parameters:

- coefficient of friction $\mu = 0.05$;
- modulus of elasticity of the product getting cut $E = 12.10^3\,Pa$;
- half of the disc knife`s width $a = 0.15.10^{-3}\,m$;
- width of the product getting cut from the one side of the knife $l = 0.45.10^{-3}\,m$;
- radius of the disc knife $r = 0.105\,m$;
- thickness of the product getting cut $B = 0.07\,m$;
- height of the disc blade`s part, which is incised in the board $\Delta = 0.007\,m$.

Results

Resistance characteristics and the moment of force are solved and shown when the velocity coefficient is $\lambda = 10, 20, 30, 40$ and 50. The received results are shown in a table 1 and figures 1, 2 and 3.

Table 1. Values of the resultant resistances when $\lambda \in [10,50]$

λ	10	20	30	40	50
J_6	0,9308	0,933	0,9333	0,9335	0,9336
J_7	7,35	7,3735	7,3777	7,3792	7,3799
M_{fr}, *Nm*	0,0926	0,09287	0,09291	0,09293	0,09294

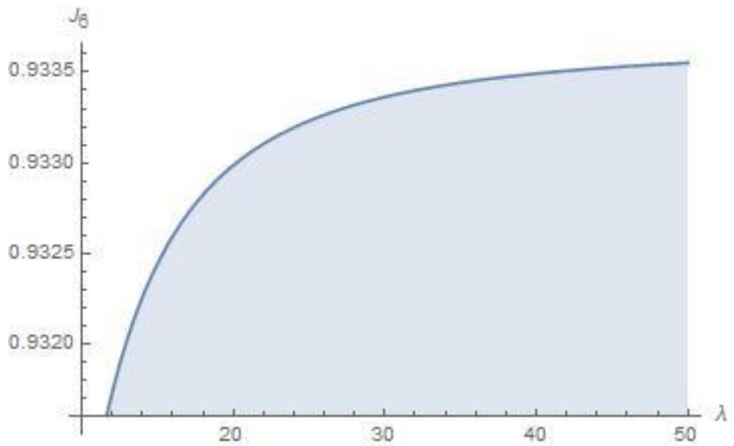

Fig. 1. Relationship between the third resistance characteristic and the velocity coefficient λ

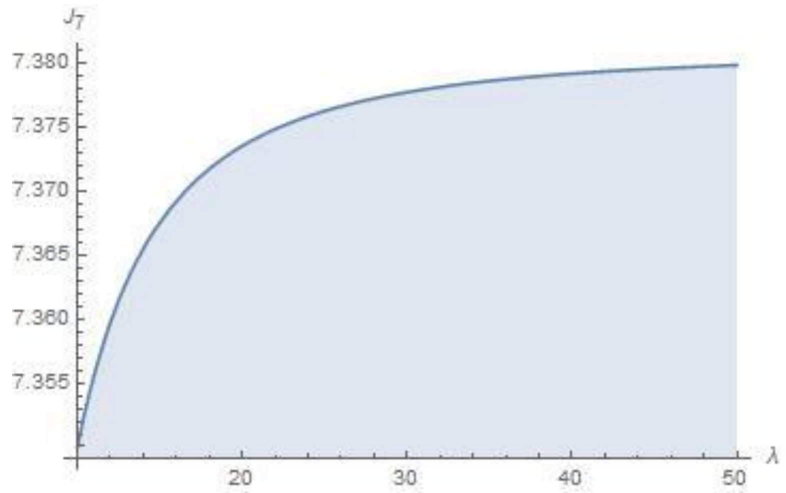

Fig. 2 Relationship between the fourth resistance characteristic and the velocity coefficient λ

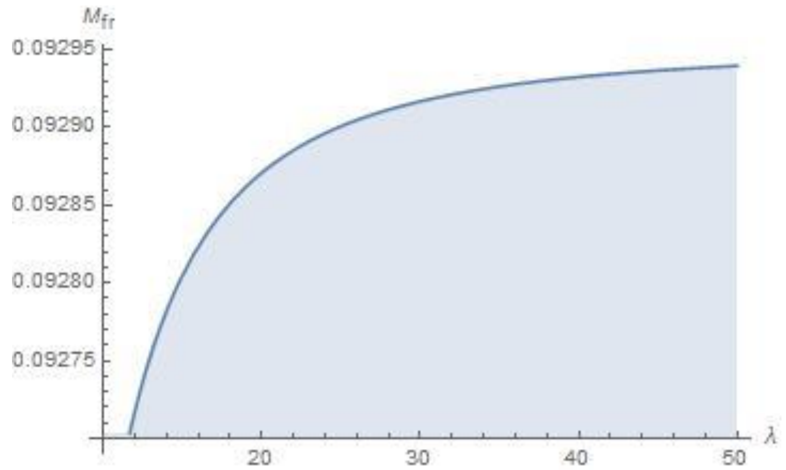

Fig. 3 Relationship between the resultant moment of force and the velocity coefficient λ

Conclusion. When λ increases, the resultant moment of force during disc knife cutting of food products caused by the friction between the material and the knife side walls increases as well. The slope of the tangent at any point of the graph of $M_{fr} = M_{fr}(\lambda)$ decreases as λ increases.

The relationship between the moment of force and the velocity coefficient is not a linear. It is close to an elliptic curve.

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