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THE COMPUTER AIDED FIELD MODELLING OF MULTIPLE DISC CUTTING GRINDERS

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Summary: *A modelling of quasi-cutting field occurred in multiple disc mill based on computer aided research is presented. The influence of constructional features on milling field of biological material is the expected result. The base to improvements of useful characterizations is the recognition of possibility existing solutions and qualification of range efficient in processing of features constructional working device from admissible area. There are necessary steps to recognition of dependence and describing mathematical model which field milling of biological material connected with features of constructional device.*

Keywords: *modelling methodology, quasi-cutting field, multiple disc cutting mills,*

1. Introduction

Nowadays the importance of mill process according to decrease energy consumption is becoming more widespread. Milling forces and stresses are most often estimated from machinability databases. A large amount of data must be gathered and stored to take account of the different conditions of machining (type of process, geometry and material of the tool, workpiece material, cutting speed, etc.). Much effort has been devoted to develop such cutting models. One of the useful is model based on quasi-cut phenomenon plates with holes [1], [2].

2. Methodology

The preposition of a designing methodology, based on geometrical propriety, applicable to quasi-cutting biological materials is discussed in this article.

This kind of disintegration is preferred for e.g. grain. As an example, the quasi-cutting bulk of the biological material field is presented (Fig.1). These field are used to estimate the actual tool-disc geometry and texture of the generated surface on the basis of measured quasi-cutting forces and stresses.

2.1. The quasi-cutings fields model

To describe the quasi-cutting fields model there are following stages undertaken:

- recognition quasi-cutting of propriety of material,
- build and research of multiple - disc models,

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- construction of working multiple - disc set,
- initial cutting using one disc cutter,
- cutting on small parts about waited dimensions on milling consist of 3 working disks,
- statistical and essential analysis of obtained results.

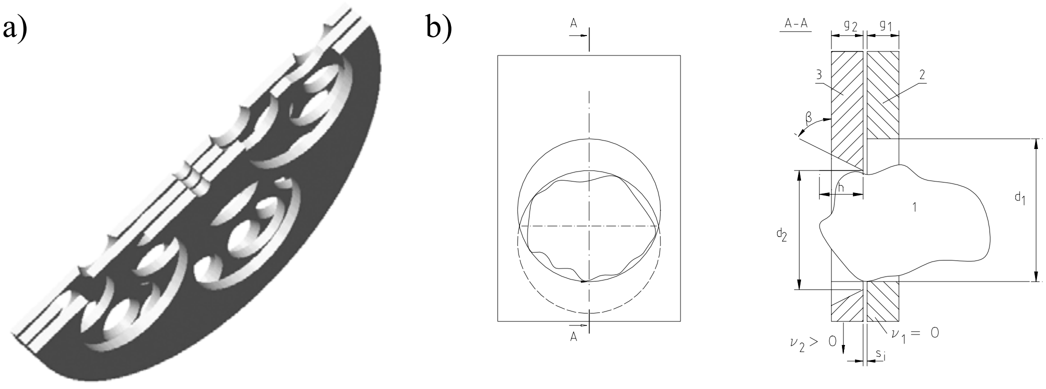

Fig. 1. The section view of disks (a) and the section quasi-cutting field (b). 1 - quasi-cut material, 2 - motionless slat, 3 - moving slat, β - angle of blade, s_i - gap between disks, h - section of material intended to cutting off, g_1, g_2 - thicknesses of disks 1 and 2, d_1 - diameter of holes in motionless disk, d_2 - diameter of holes in moving disk

The stress values, as propriety of material, depended on direction of forces are represented by common equations:

$$r = \frac{P_w}{F_R} \tag{1}$$

$$\sigma = \frac{P_k}{F_R} \tag{2}$$

where:

P_w - longitudinal forces,
P_k - transversal forces,
F_R - field of quasi-cuting section.

While modelling the milling surface at the first stage, the integration if instantenous milling field was used (fig. 1, fig.2):

$$F_R = \int_{x_1}^{x_2} \left\{ b_2 + \left[R^2 - (x - a_2)^2 \right]^{\frac{1}{2}} \right\} dx - \int_{x_1}^{x_2} \left\{ b_1 - \left[R^2 - (x - a_1)^2 \right]^{\frac{1}{2}} \right\} dx \tag{3}$$

where:

$a_1,\ a_2,\ b_1,\ b_2$ - coordinates of the hole centres,
R - the hole radius.

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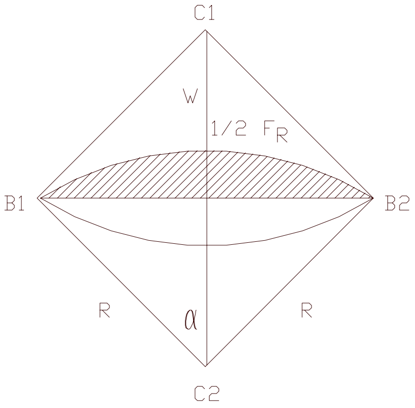


Fig. 2. The circle segment

The calculation of the milling section F$_R$ between two holes which have centre coordinates $C_1(a_1,b_1),\ C_2(a_2,b_2)$ means stating the distance between the centres of the holes; assuming that the field F_R is the sum of two equal circle segments stated by the chord $\mathrm{B}_1\mathrm{B}_2$. The circle segment area (Fig.2) is calculated from the formula:

$$\frac{1}{2}F_R = \frac{1}{2}(\alpha - \sin\alpha)\cdot R^2 \tag{4}$$

where:

α is the centre angle,

$\angle \mathrm{B}_1\,\mathrm{C}_1\,\mathrm{B}_2 = \angle \mathrm{B}_2\,\mathrm{C}_2\,\mathrm{B}_1$.

In order to calculate sin α it has been assumed, that the triangle's area $\mathrm{B}_1\mathrm{C}_2\mathrm{B}_2$ equals to $\frac{\mathrm{B}_1\mathrm{B}_2}{2}\cdot\frac{\mathrm{C}_1\mathrm{C}_2}{2} = R^2\sin\alpha$, but:

$$\left(\frac{\mathrm{B}_1\mathrm{B}_2}{2}\right)^2 + \left(\frac{\mathrm{C}_1\mathrm{C}_2}{2}\right)^2 = R^2 \tag{5}$$

hence

$$\frac{\mathrm{B}_1\mathrm{B}_2}{2} = \sqrt{R^2 - \left(\frac{\mathrm{C}_1\mathrm{C}_2}{2}\right)^2}$$

and for $\mathrm{C}_1\mathrm{C}_2 = w$ = obtained:

$$R^2\sin\alpha = \sqrt{R^2 - \left(\frac{w}{2}\right)^2}\,\frac{w}{4}$$

$$\sin\alpha = \frac{w}{4R^2}\sqrt{R^2 - \left(\frac{w}{2}\right)^2} \tag{6}$$

and

$$\sin\alpha = \frac{w}{4R}\sqrt{1-\left(\frac{w}{2R}\right)^2} = A$$

In order to calculate angle α rhombus $B_1C_1B_2C_2$ was applied, and then:

$$CC = 2R\cos\frac{\alpha}{2}$$

hence:

$$\alpha = 2\arccos\frac{w}{2R} \qquad (7)$$

as according to computer software values of the function (arctg) may easily and quickly be calculated, so:

$$\alpha = arctg\left[\sqrt{1-\left(\frac{w}{2R}\right)^2}\Bigg/\frac{w}{2R}\right] = B \qquad (8)$$

In such a way, the dependence is given the form:

$$F_R = (B-A)R^2 \qquad (9)$$

On the geometrical dependences we can obtain the following formula:

$$F_R = \left\{\left(2arctg\frac{\left[1-\left(\frac{w}{2R}\right)^2\right]^{\frac{1}{2}}}{\frac{w}{2R}}\right) - \frac{w}{4R}\left[1-\left(\frac{w}{2R}\right)^2\right]^{\frac{1}{2}}\right\}R^2 \qquad (10)$$

The simulational calculations of milling field and milling forces were operated as an algorithm written in Turbo-Pascal (Fig. 4).

The effective disintegrating surface for two shields (Fig. 3) is shown on a drawing as an example.

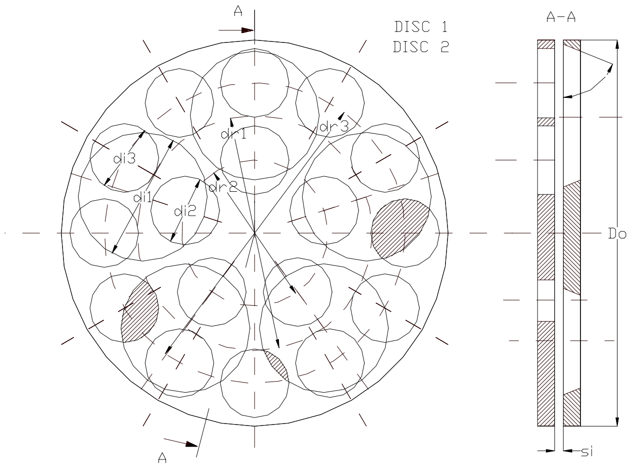
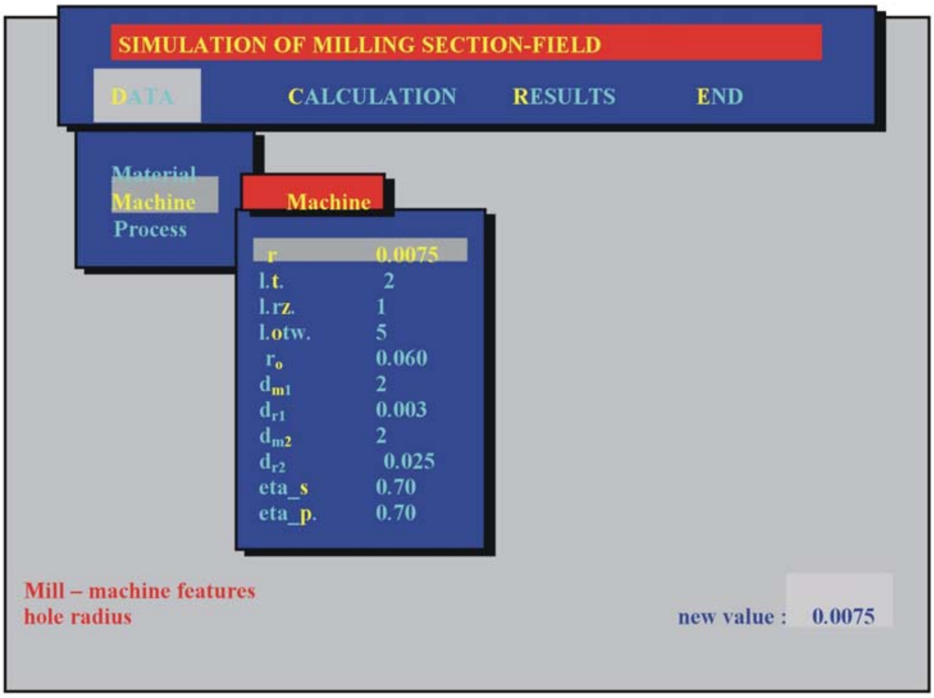


Fig.3 Relations and area of surface between the edges of numerous openings, on two storeys



r	0.0075
l.t.	2
l.rz.	1
l.otw.	5
r_o	0.060
d_{m1}	2
d_{r1}	0.003
d_{m2}	2
d_{r2}	0.025
eta_s	0.70
eta_p.	0.70

Mill – machine features
hole radius

new value : 0.0075

Fig.4 The TURBO-PASCAL simulational data of milling field and forces

Based on geometrical dependences on Fig.1, model of arrangement of powers working on edge of cutting disk and piece of materials with regard of friction. Influence of piece of material on force value can formulate following powers: powers of material cohesion P_s, to equal product of endurance of material on cutting off in parallel surface to axis of material R_{tr} by field of surface of section field F_F, normal powers N from which cut off section tightened is to materials and powers of friction $\mu_1 N$, at where symbol μ_1 means coefficient of friction between the materials.

2.2. Based on computer simulation of milling section

The calculation of milling section based on geometrical interdependences were described in [2], [4]. The computer calculations of quasi-cutting fields and loads (Fig.4) were operated as follows:

- reading the data about the material, machine, process and the purpose of miling,
- conditional analysis of milling surface and calculations for variables: of time, of the angle of discriminated hole, the number of hole lines in the disc, etc.,
- the simulation of milling loads, the energetic milling indicator and energy consumption for efficiency variables, characteristic features of the milled material, constructional features of the mill and time intervals,
- the presentation and evaluation of the obtained results of construction support.

2.3. Evaluation of the obtained results

The constructive features of the working set of the multiple disc seed mill should be selected in such a way that the function achieves the maximal value (because of the e_R, indicator value) or minimal (beacause of the value of the unit energy consumption indicator E_R) [4].

The point where the function value fulfils the required criterion is called problem solution: $x^* = (x^*_1, \ldots\ldots, x^*_n)$. The solution is, of course, from the permissible area:

$$x^* \in \Phi$$

The principle of the support in the direction of getting the extreme solution can be defined:

$$\{X^* \in \phi\} : \left\{ \bigwedge_{x \in \phi} Z(x) \geq Z(X^*) \right\}, \tag{11}$$

in the case of minimization of energy consumption ($Z=E_R$)

$$\{X^* \in \phi\} : \left\{ \bigwedge_{x \in \phi} Z(x) \leq Z(X^*) \right\} \tag{12}$$

in the case of maximization of energetistic milling indicator ($Z=e_R$).

If the target point is known in the target space (e.g. $E_R < 10\,\mathrm{kJ/kg}$), it is possible to conduct the procedure aiming at approaching the given solution. The procedure means searching for such δ_F, δ_{ER} which are expressed by the following formula:

$$\delta_F = \frac{F_{\max} - F_{\min}}{F_{sr}} \Rightarrow 0, \quad \delta_{ER} = \frac{E_{R\max} - E_{R\min}}{E_{sr}} \Rightarrow 0 \tag{13}$$

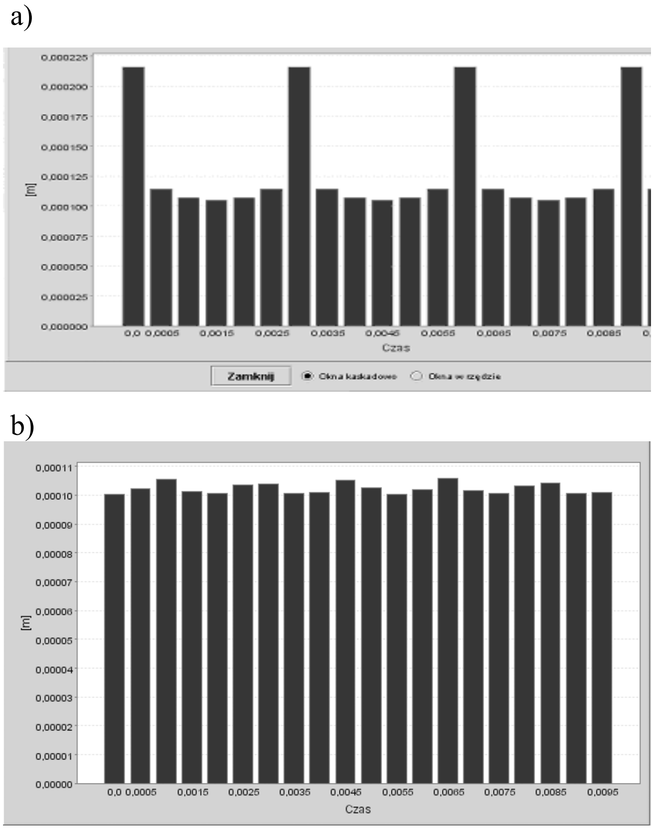


Fig.5. Graph of temporary disintegration intersections – increase of openings between shields = 2 (a), and = 5 (b).

A preliminary analysis of the results shows diversity of new solution of interesting estimators characteristics. It results from the analysis, that both the energetic effectiveness as well as optimum disintegration intersections are very sensitive to the changes of constructive features. Exemplary graphs for constructions differing with the increase of the number of openings between shields for unit value, are presented on Fig.5.

We may see, that on the figure there appear characteristic, temporary files, very unfavourable from the point of view of energetic process. However, the decrease of the number of shields constituting the increase between shields for value 1 results in the fact, that the solution becomes more interesting due to the minimum intersection increase criteria and energetic efficiency. At optimisation from the set of predefined features with simultaneous searching, the space of solutions from the point of bigger number of constructional parameters, the option „defined optimisations" is selected". Several strategies helpful during construction's supporting are included there.

3. Conclusions

From mechanical point of view quasi-cutting field biological materials (especially stem fiber materials) realized across edges of cutting openings belongs to difficult problems regard to occurrence of complicated state of tensions in material cut. Analysis quasi-cutting of material by multiple disc mill indicates higher susceptibility of fibre stem, grainy materials on cutting than hard materials.

Based on the methodology and modelling aided by computer the constructive features of working set of multiple disc mill should be selected in such a way that the function achieves the maximum shear stress and minimum energy principles. The modelling methodology and equations of field cutting are based upon the results obtained by several researchers over a period of the last years [4 - 6]. Using the suggested methodology the area of suboptimal constructional features of multiple disc shredder was designed in order to decrease energy consumption ($E_T \leq 50\ kJkg^{-1}$), increase mass capacity ($W_{4,8} \geq 145\ kgh^{-1}$) as expected dimensions ($0,5\ mm \leq f \leq 1,8\ mm$).

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