Prosimy cytować jako: Inż. Ap. Chem. 2011, 50, 2, 11-12

Józef FLIZIKOWSKI

e-mail: fliz@utp.edu.pl

Department of Production Technology and Engineering, Faculty of Mechanical Engineering, University of Technology and Life Sciences, Bydgoszcz

Objectives of the intelligent grinding system

Introduction

Not only the machine, the whole complex functional/drive system has its purpose but also each of its subassemblies, each element serving certain function in the arrangement that is able to develop that is also to apply load, cause plastic strain with rational effectiveness and progressive increases of specific surface area at lower and lower effective work of the grinding process.

The aim of the work is to relate operational parameters of the grinding process (product quality, effectiveness of the process and harmlessness of effects), elements and relations of the technical system to strength states of the grains/granules ground.

Assumptions

The most important conclusions based on assumptions and findings, when defining models of effects: product quality, effectiveness of the process and harmlessness of effects – objectives of the evolutionary intelligent grinding process, include strength-related causes [1–10, 12, 13]:

1. The pressure of quasi-cutting p_{t-s} applied to the surface point-wise and linearly;
2. An increase of surface area – volumetric and surface strain;
3. In a chosen scope of load – pressure, the measure of volumetric strain is not a change of volume ΔV but a change of volume for a unit of primary volume:

$$\Theta_{t-s} = \frac{\Delta V}{V}, \quad (1)$$

volume contraction occurs during quasi-cutting of micro grain. According to *Hook's* law: Θ_{t-s} and p_{t-s} are proportional values, so

$$K_{t-s} = \frac{p_{t-s}}{\Theta_{t-s}}, \quad \text{and therefore} \quad p_{t-s} = -K_{t-s}\Theta_{t-s}, \quad (2)$$

is a modulus of volume elasticity for quasi-cutting. Minus (–) because p_{t-s} is positive, and Θ_{t-s} – negative (an increase of ΔV is negative).

Conclusion based on assumption 3: the greater the compression modulus of volume elasticity for quasi-cutting of micro grain, the greater pressure p_{t-s} is necessary to cause strain Θ_{t-s}, the more resistant it is to any changes of volume, the less compressible it is. Since the pressure is applied point-wise and partly linearly, a description of the modulus of volume elasticity may not be used for the analysis of quasi-cutting.

4. With the pressure of quasi-cutting p_{t-s} applied onto the top surface of micro grain with the clamped (adhesively, permanently) basis, the grain is deformed into „parallelepiped" with angle α

$$tg\alpha = \frac{\Delta l}{l}, \quad (3)$$

width of the grain (l) does not change. The shape changes without a change of volume, so

$$\frac{\tau}{\alpha} = G_{t-s} \text{ and therefore } \tau = G_{t-s}\alpha \quad (4)$$

G_{t-s} – rigidity modulus for quasi-cutting.

Conclusion based on assumption 4: the greater the rigidity modulus for quasi-cutting of bio-polymer, fibre grain (granules), the more difficult it is to change its shape in the process of grinding.

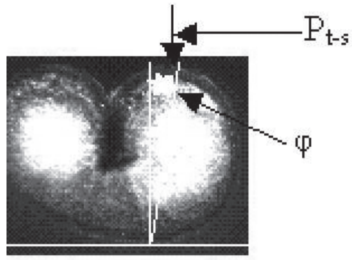

Fig. 1. An example of the grain subject to force P_{t-s} and twisted by angle φ [8]

5. Pure comminuting non-dilatational strain, during quasi-cutting of grain, occurs as a consequence of the twisting/torsion of the grain with moment of force P_{t-s} on an arm equal to width l.

The model of grain feed: for the solution of the model, in particular the modulus of quasi-cutting, the grain was used with bottom surface (point-wise, linearly) strongly, adhesively clamped (Fig. 1) [8].

Twisting moment was applied point-wise (linearly) to the top surface. The moment causes a rotation of the grain by angle φ (depending on the type, properties and condition of the grain). The further procedure is conducted according to the existing rules of physics, mechanical engineering and current developments in the research on quasi-cutting [3, 4, 6, 8]. A dependence is obtained for static pressure of quasi-cutting, assuming a circular section of the grain:

$$p_{t-s} = \frac{dP_{t-s}}{2\pi x dx} \quad (5)$$

Influences by this pressure, each element of the external layer of the grain is deformed as follows:

$$\tau = G_{t-s}\alpha \quad (6)$$

However, angle α (Fig. 1):

$$\alpha = \frac{\Delta l}{L}, \quad L = l - \text{grain width}$$

Whereas $\Delta l = x\varphi$, so

$$\alpha = \frac{x}{L}\varphi \quad (7)$$

Target load application and comminution strains

Modification of (6) and (5) with (7) results in the following:

$$\frac{dP_{t-s}}{2\pi x dx} = G_{t-s}\frac{x}{L}\varphi \quad (8)$$

so

$$dP_{t-s} = 2\pi G_{t-s}\frac{\varphi}{L}x^2 dx \quad (9)$$

When the above is multiplied by x, the moment applied to the grain layer is obtained:

$$dM_{t-s} = 2\pi G_{t-s}\frac{\varphi}{L}x^3 dx \quad (10)$$

Following integration, the moment of useful forces, for permanent comminution strain is [4, 6, 8]:

$$M_{t\text{-}s} = \int_0^r 2\pi G_{t\text{-}s}\frac{\varphi}{L}x^3 \mathrm{d}x = 2\pi G_{t\text{-}s}\frac{\varphi}{L}\int_0^r x^3 \mathrm{d}x = \frac{\pi}{2}\cdot\frac{\varphi}{L}G_{t\text{-}s}r^4 \quad (11)$$

so

$$G_{t\text{-}s} = \frac{2L}{\pi r^4 \varphi}M_{t\text{-}s} \quad (12)$$

Considering a variable relation $r = aL$ (a = (0.6 – 0.8) – dependent on an angle of the grain position in relation to the clamping (Fig. 1)), the above gives the final dependence for the modulus of quasi-cutting of the grain:

$$G_{t\text{-}s} = \frac{2}{\pi(0.13 - 0.41)L^3\varphi}M_{t\text{-}s} \quad (13)$$

Taking into account the surface pressure of the tool edge applied to micro grain P_n from the longitudinal force P_w:

$$P_n = \frac{P_w \cos\rho}{\sin(\alpha + \rho)} \quad (14)$$

where:

α – an angle at which the grain is leaned,

ρ – friction angle.

Knowing [5, 7] that:

$d_{śr}$ – mean (substitute) diameter of the grain,

μ – coefficient of friction between the tool and the grain

$$P_n\mu\frac{d_{śr}}{2} \geq M_{t\text{-}s} \quad (15)$$

we can define an experimentally useful form of the modulus of and quasi-cutting, dependant on the analysed variables:

$$G_{t\text{-}s} = \frac{\mu d_{śr}}{\pi(0.13 - 0.41)L^3\varphi}P_n \quad (16a)$$

which for $P_n = P_{t\text{-}s}$ gives:

$$G_{t\text{-}s} = \frac{\mu d_{śr}}{\pi(0.13 - 0.41)L^3\varphi}P_{t\text{-}s} \quad (16b)$$

This relation between the twisting moment (from the quasi-cutting force) and the modulus of quasi-cutting of the grain enables precise (experimental) determination of the modulus. This requires measuring (establishing dimensions) of:

L – grain width,

r – torsion radius,

φ – torsion angle,

$M_{t\text{-}s}$ – twisting moment (from force $P_{t\text{-}s}$).

Summary

General equations used for continuous medium strength are not sufficient to resolve the issue of the function of the comminution objective: concerning the distribution stresses and strains in the ground grain (granules). A static and geometric analysis should therefore be supplemented with special equations connecting various aspects of the analysed phenomena, i.e. forces and strains, in particular separating strains. Those dependences are obviously determined using physical properties of the grain.

The practical possibility of such an extrapolation is verified in an experiment conducted with most of the ground materials, under the following conditions [3, 4, 10]:

- simultaneous application of all stresses, as well as individual application of each stress (if possible) does not result in a plastic state of the material,
- material may practically be regarded as isotropic (In general, the case of anisotropic materials falls within the scope of the theory of elasticity),
- strains are minor compared to the dimensions of the tested object,
- the deformation process is isothermal (The theory of elasticity deals not only with isothermal processes but also adiabatic processes and other possible deformation processes related to a temperature change. However, these aspects have not been discussed herein).

The above conditions enable practical application of the independence of forces principle and elementary *Hooke's law* (for simple stretching and cutting, in the context of target quasi-cutting) in order to analyse the stress state for the grinding process of any complexity, for the objective function: calculation of strains in any direction and any point within the analysed grain/granules. Strains related to operational parameters: surface efficiency, volumetric efficiency, effective work and the degree of comminution – practical, efficiency-related objective function.

REFERENCES

[1] *J. Yan, J. S. Strenkowski*: Journal of Materials Processing Technology 174, 102 (2006).

[2] *L. Powierza*: Zarys inżynierii systemów bioagrotechnicznych. Część I. ITEE, Radom 1997.

[3] *J. Flizikowski*: Rozprawa o konstrukcji. ITEE, Radom 2002.

[4] *J. Flizikowski*: Projekt implementacji inteligentnego systemu wspomagania konstrukcji młynów specjalnych, MNiI, ATR-AGH, Warszawa, Bydgoszcz, Kraków 2005.

[5] *I. Rokach*: Numeryczno-analityczne modelowanie prób udarowych. Monografie nr 50, Wyd. Politechniki Świętokrzyskiej, Kielce 2005.

[6] *J. Flizikowski*: Plastic devices for Energy Engineering. Nanoenergy, Tapis Rouge, Paryż 2008.

[7] *J. Sidor*: Badania, modele i metody projektowania młynów wibracyjnych. Wyd. AGH Rozprawy/Monografie nr 150, Kraków 2006.

[8] *G. Szala*: Analiza energochłonności technologicznego ścinania ziaren zbóż. Grant MNiI/UTP Warszawa, Bydgoszcz 2007.

[9] *W. Grellmann, S. Seidler*: Deformation and fracture behavior of polymers. Berlin: Springer-Verlag 2001.

[10] *J. Zawada (Red.)*: Wprowadzenie do mechaniki maszynowych procesów kruszenia. Wyd. ITE, Radom, Warszawa 2005.

[11] *D. E. Goldberg*: Algorytmy genetyczne i ich zastosowanie. WNT, Warszawa 2003.

[12] *J. Świątkowski, J. Flizikowski*: Inż. Ap. Chem. **49**, nr 5, 111 (2010).

[13] *J. Flizikowski*: RECYKLING 1(109), 8 (2010).

The research financed by the funds of the National Centre for Research and Development in 2010-2013 as a development project.