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Influence of the grinded material in the crumbling process

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Abstract

Hammer mills reduce the particle size of materials by impacting a slow moving target, such as a cereal grain, with a rapidly moving hammer. The transfer of energy that results from this collision fractures the grain into many pieces. Particles produced using a hammer mill will generally be spherical in shape with a surface that appears polished. This work emphasizes the influence of the restitution coefficient dependent on the grinded material in the crumbling process. Because of the energy losses during the percussion between the hammer and the material to grind the restitution coefficient goes through changes that have as an effect the accentuate abatement of the productivity of beater mills.

Keywords: signal analysis, percussion, restitution coefficient, energy coefficient, deformation degree

1. Introduction

The crumbling process is made in beater mills able to generate high intensity forces, forces which produce plastic deformations and fissures in the material. To make the crumbling the energy given up to the material must be able to destroy its internal cohesion forces. The crumbling process is made in two phases:

- the compression phase, when the collision between the hammer and the material particle takes place when the hammer and the particle have the same speed. During this phase the kinetic energy of the particle transforms into deformation the mechanical work;
- the relaxation phase, when the deformation energy transforms itself in kinetic energy.

Because a part of the kinetic energy is lost through the oscillations of the hammers produced during the collision, the percussion is not ideal, but a loss emphasized by the restitution coefficient [3-9]. The separation of the two phases is emphasized by the fact that the speed of the percussion centre of the hammer is equal to the speed of the centre of the particle of material submitted to the crumbling (figure 1).

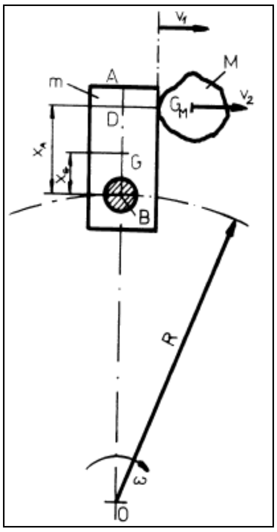

Figure. 1 The percussion between the hammer and the material particle

The evaluations of the results of the collision with the particles of material are emphasized by the transmission ratio of the percussion in the joint.

The experimental verification on beater mills having as crumbling material barley and maize confirm the correspondence between the level of the measured vibrations, the transmission ratio of the percussion

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(k), the mass coefficient (ν), the energy coefficient (χ), and the deformation degree (η_E) [1,2].

Transmission ratio of the percussion (k)

$$K = \frac{P''_{12}}{P'_{12}} \qquad (1)$$

P'_{12} – the percussion between the hammer and the material during the compression phase

P''_{12} - the percussion between the hammer and the material during the relaxation phase.

The mass coefficient (ν):

$$\nu = \frac{m_2}{m_{1red} + m_2} = \frac{1}{1 + \frac{m_{1red}}{m_2}} \qquad (2)$$

m_2 – the mass of the particle submitted to the crumbling

m_{1red} – the mass in relation to the centre of percussion.

The energy coefficient (χ):

$$\chi = \upsilon\left[\left(1 - k^2\right) + \left(1 + k\right)^2 \frac{1}{1 + \frac{m_2}{m_{1red}}}\right] \qquad (3)$$

The deformation degree (η_E):

$$\eta_E = \frac{\Delta E}{E_{1c}} = \frac{1 - k^2}{\frac{m_{1red}}{m_2} + 1} = \upsilon\left(1 - k^2\right) \qquad (4)$$

Δ_E - the deformation energy

E_{1c} – the kinetic energy of the hammer before percussion

Because the material submitted to the crumbling has an attitude towards the plastic domain (function to the nature of the material and of the humidity of the product) we consider that the value of the restitution coefficient is below 0.5.

2 Determination techniques

For the determinations was used a beater mill MCF7 equipped with a rotor with 32 hammers situated on four axes. On every bearing of the mill was assembled a piezoelectric pickoff of vibrations to take over the perturbations of the rotor as a result of the disequilibrium owed to the striking collisions between the hammer and the material to grind. The perturbations received by the pickoff generate a tension signal proportionate to an acquisition interface and stored in a file on a computer. The analytical processing and the analysis of the acquisitioned signals have been made later, through the programs in MATCAD.

3. Experimental determinations

The experimental determinations were made on the mill MCF7 at different charging rates of the active electric engine for the crumbling material maize, respectively barley. In figure 2 we have the frequency spectrum for the crumbling material maize to a charging of the active electric engine of the mill of 80A, and in figure 3 the appropriate signal in the time domain. In figure 4 is represented the frequency spectrum for the crumbling material maize to a charging of the active electric engine of the mill of 100A and in figure 5 the appropriate signal in the time domain. In figure 6 is represented the frequency spectrum for the crumbling material maize to a charging of the active electric engine of the mill of 120A, and in figure 7 the according signal in the time domain. In figure 8 is represented the frequency spectrum for crumbling material barley to the charging of the active electric engine of 100A and in figure 9 the appropriate signal in the time domain. In figure 12 is represented the frequency spectrum for the crumbling material barley to a charging of the active electric engine of the mill of 140A and in figure 13 the appropriate signal in the time domain. The percussion between the hammer and the material to grind is emphasized in the frequency spectrum in a series of spectral lines. The difference between two spectral lines is equal to the rotation frequency of the rotor. High amplitude to a rotation frequency usually indicates an unbalance. We notice that the amplitude to the rotation frequency is modified at almost every rotation; this indicates that we do not have an unbalance, because the amplitude should remain constant. But when the percussion between the hammer and different quantities of material to grind takes place, the amplitude of vibrations at the rotation frequency varies at every rotation. In the frequency spectrum we observe a spectral line at a frequency equal to 198.4Hz (four axes *49.4) which identifies itself with the frequency of the hammers placed on four axes. Comparing the signals registered in the frequency domain for the same material at different charging of the active engine of the mill we observe abatement to a higher charging. This can be explained by the fact that as the charging with materials increases, the quantity of energy absorbed by the mass of material submitted to the crumbling is higher, the material to crushing acting as a vibration absorbent.

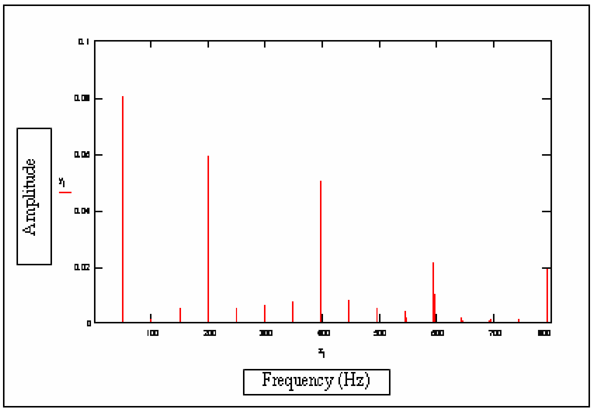

Figure 2. Frequency spectrum. Maize. Charging 80 A

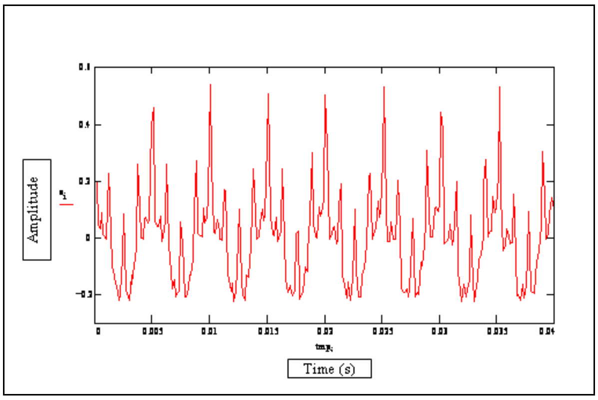

Figure 3. Signal in time domain. Maize. Charging 80 A

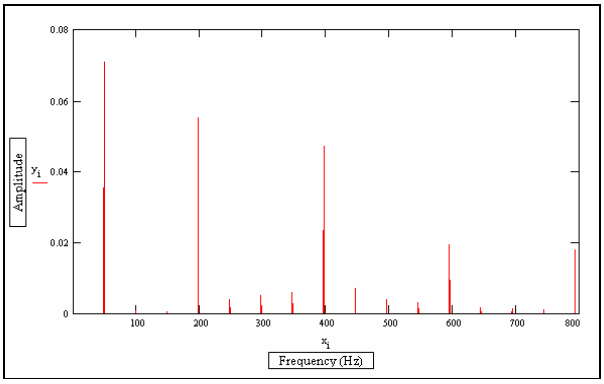

Figure 4. Frequency spectrum. Maize.Charging 100 A

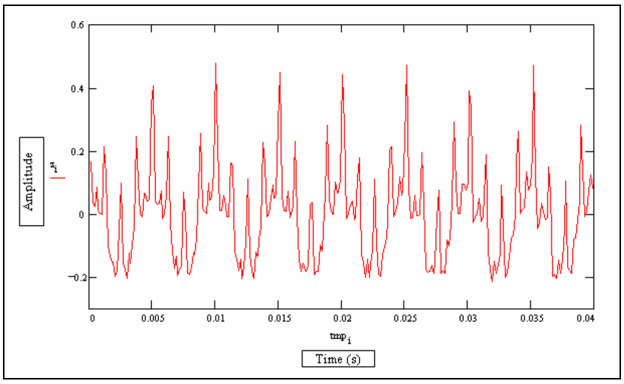

Figure 5. Signal in time domain. Maize.Charging100 A

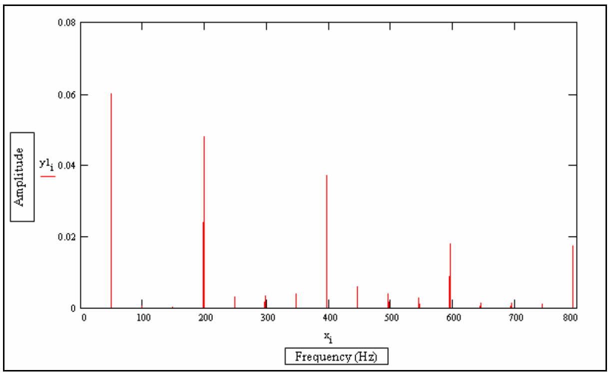

Figure 6. Frequency spectrum. Maize. Charging 120 A

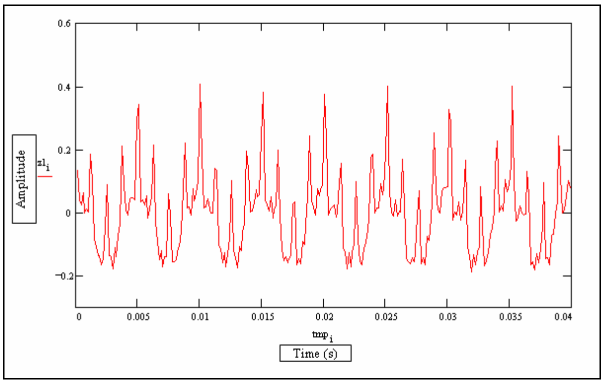

Figure 7. Signal in time domain. Maize. Charging 120 A

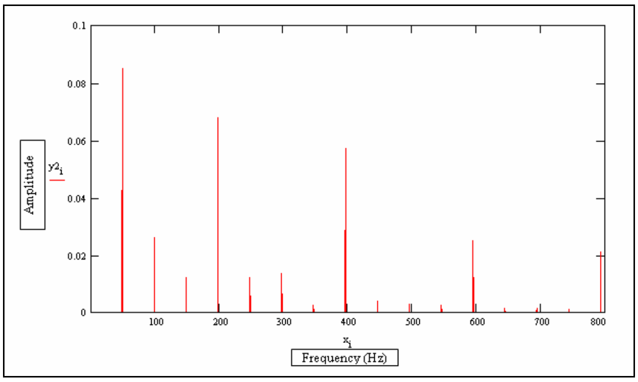

Figure 8. Frequency spectrum. Barley. Charging 100 A

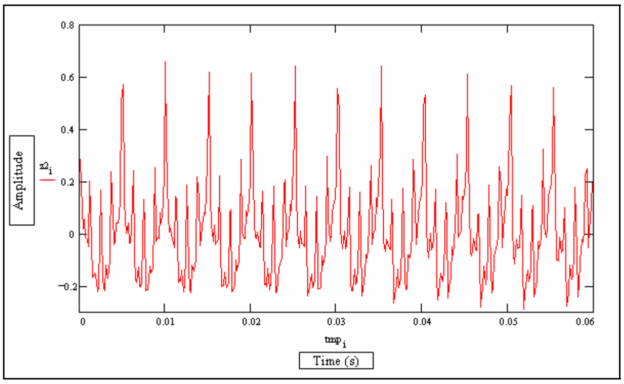

Figure 9. Signal in time domain. Barley. Charging 100 A

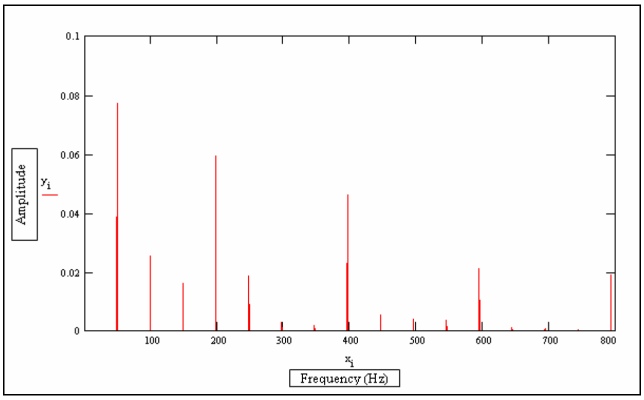

Figure 10. Frequency spectrum. Barley. Charging 120 A

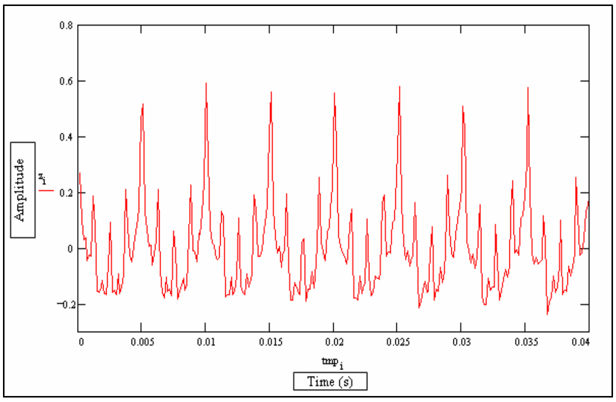

Figura 11. Signal in time domain. Barley. Charging 120 A

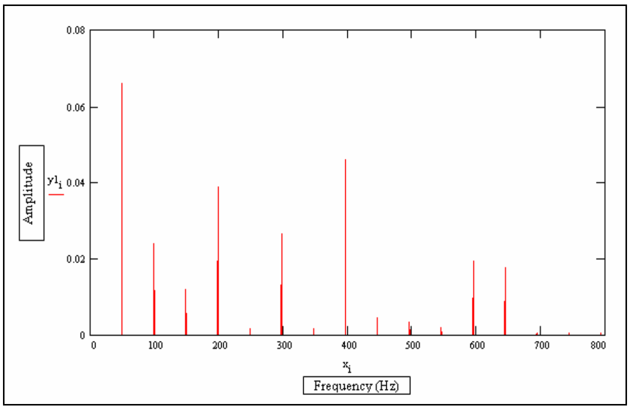

Figure 12. Frequency spectrum. Barley. Charging 140 A

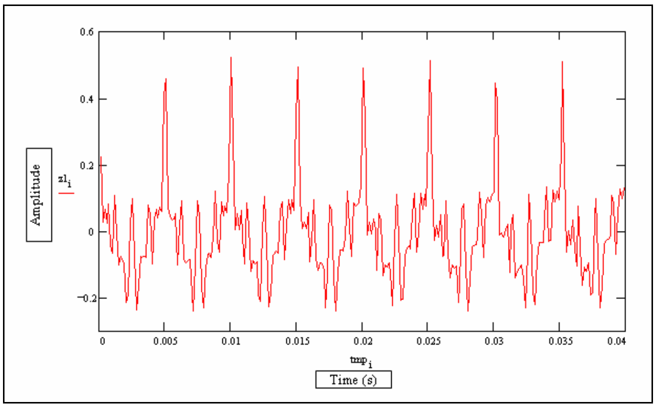

Figure 13. Signal in time domain. Barley. Charging 140 A

4 Conclusions

The striking interactions between the hammer and the material produce additional perturbations which generate irregularities in functioning. The transmission ratios of the percussion express the value of perturbations owed to the collisions and represent the source of the high level of vibrations.

For the improvement of the crumbling process the loss of energy of the hammer during percussion must not outrun a limited value. This loss of energy is function to the nature of the material to grind, the same material having a high humidity, acting as a real vibration absorbent, leading to an important loss of energy of the hammer during the crumbling process and implicit to the decrease of the productivity of the mill. For an efficient crumbling the active working surface (the plates with scores) must not have marked wear.

As a measure of the increase of the productivity of the mill the supply mode must be taken to consideration so that the losses of energy in the percussion between the particles of material are minim.

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