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Considerations Concerning the Dynamics of Vibratory Mills Used in Powders' Mechanical Milling Process

Dynamic mechanical milling process in a powder mill was studied by analyzing the vibratory effects of vibration and shock phenomena on the material microstructure ground. During the milling process, there were noticed both distinct modes of ball motion: the one generated by the periodic vibration and the one produced by chaotic vibration.

***Keywords**: vibration phenomena, collision, impact force.*

1. Introduction

Mechanical grinding process is characterized by repeated clashes between grinding media, mill body and crushed material.

A mill performance is influenced both by the oscillating system's macrodynamics participating in the grinding process (body mill and grinding media movement) as well as its microdynamics (broken material deformation and microstructural evolution).

Ground collisions material properties changes during the previous individual collisions, can influence the production following the collision events, default macro dynamics mill development implicitly.

During the milling process, the mill microdynamics strongly influences, controls both the microstructural evolution and the final structure of the obtained material. As a result, macro and microdiyamics are closely interrelated.

The paper was studied the macrodynamics of a vibratory mill by analyzing the mechanical vibration and by performing shock measurements and some computer simulations.

To achieve the target, a vibratory mill with a simple construction was used, which allows the quantitative study of the mechanical grinding process, having an easily controllable dynamic and based on simple principles.

Previous researches [1] showed that grinding body movement is made by overlapping two distinct modes of vibration: a periodical vibration and a chaotic vibration. Since the energy evolved in individual collisions during milling can be controlled and quantified, specialists studies have focused specifically on periodic vibration.

Determinations were made on the effect of system dynamics on microstructural development of several powdery material types.

2. Experimental determination

2.1. Vibratory mill

The vibratory mill on which some measurements have been made is of the type shown in Figure 1, being used for the preparation of pharmaceutical powders. This mill transforms the material into particles of 125-250 μm, resulting in increasing its total surface area of 5 to 10 times that of an ordinary powder [4].

Mill body *3* is mounted on support plate *2* related to vertical platform *1*. Inside the body there is one grinding mill *4* with diameter of $\phi = 70\,mm$. Accelerometers *5* and *6*, and force transducer *7* transmit signals to computerized data acquisition system *11* through the charge amplifiers *8*, *9* şi *10*.

Note that the frequency and amplitude of the vertical platform can be modified independently.

Experiments were conducted under conditions with the amplitude $A = 2\,mm$, and frequency $\nu = 10{,}1....20{,}86\,Hz$.

The equipment system used for data acquisition consists of accelerometers, preamplifiers, vibrometers, recorder, computer and AT2150 4-channel acquisition board. Signal processing uses Lab VIEW 4.1 software. [2].

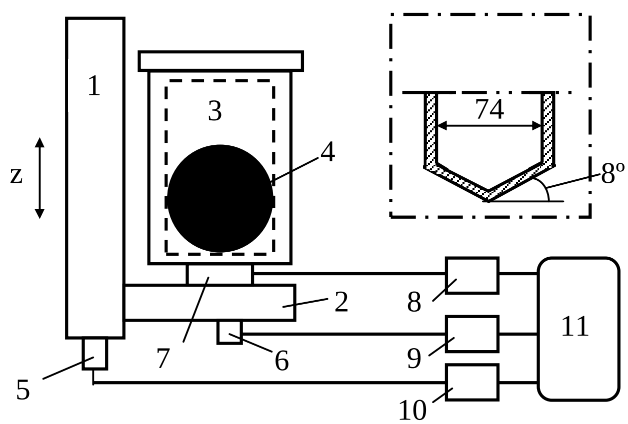

Figure 1

2.2. Mechanical vibration and shock measurements

Mill body movements and accelerations were monitored using accelerometers. In Figure 2 there is a chart of curves $d = d(t)$ and $A = A(t)$. Displacement signal represents enclosure movement, while maximum points present on the acceleration signal correspond to the collision moments between the ball and the body mill. To assess the intensity of individual collision intensity, the impact force is measured directly using a force transducer. The average impact force was established after recording 50 collisions. Experiments were performed on several batches of potassium chloride powder, a substance frequently used in the thoroughfare manufacture of pharmacy prescriptions. Two sets of experiments were held. The first used a load of 10 g of powder at different frequencies of body mill, while the second took place at a constant frequency of 15 Hz, using different loads of 10, 15 and 20 g.

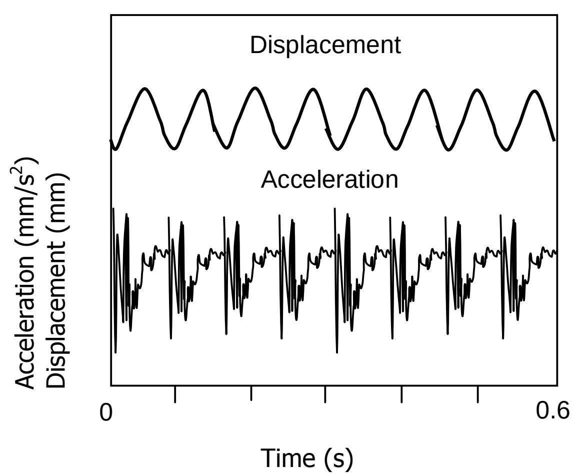

Figure 2

3. System dynamics varied

Because the experiments were conducted only in the periodical vibration production area, il must be noted that the oscillating system microdynamics study was lined out only for this area.

3.1. Grinding media movement

Generally, ball movement takes place over three stages: the regular vibration, irregular vibration (chaotical), regular relaxation (detention).

Critical frequency of the ball required for the occurrence of a relative vibration to the body mill can be determined as follows [1]:

$$f_{cr} = \frac{1}{2 \cdot \pi} \cdot \sqrt{\frac{g}{A}} \tag{1}$$

where A is the vibration amplitude [mm], and g is the gravitational acceleration [m/s^2].

For a buffered oscillatory system, much kinetic energy is dissipated during ball - mill body collision and at low frequencies, the energy transmitted by the mill body is insufficient to maintain the ball at a continuous vibration.

Ball and mill body trajectories generated by computer simulation and described during the periodic motion are shown in Figure 3 (frequency of the mill body is 10,1 Hz).

Once the increase of mill body frequency over the critical frequency value ($f_{cr} = 11{,}15\,Hz$), a transition from regularly relaxation stage (detention) to regular periodic vibration stage appears. Thus, the ball comes back in vibrational motion after each collision with body mill and the interval between two collisions is constant (Figure 4). In the Figure 4 representations were made to a mill body frequency of 12.87 Hz.

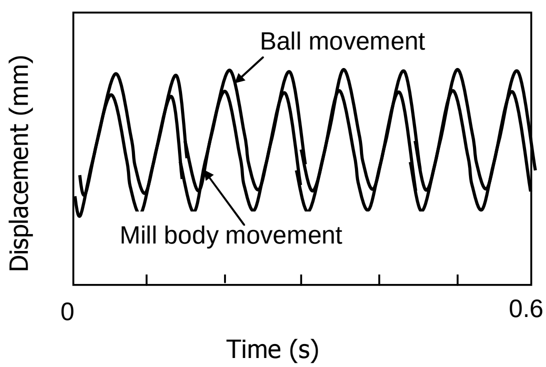

Figure 3

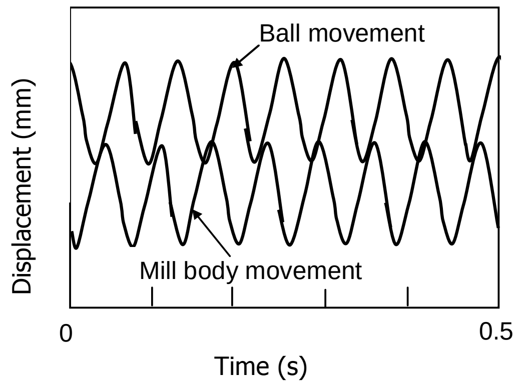

Figure 4

Increasing even more the applied frequency (18,1 Hz) over another critical value f_m, the periodical vibration becomes unstable motion, consisting of two periodic vibrations (Figure 5). To a greater frequency value ($\nu = 20{,}32\,Hz$) a division of the two periodic motions in four and then eight movements results, emphasizing the tendency to transform itself into a chaotic motion (Figure 6).

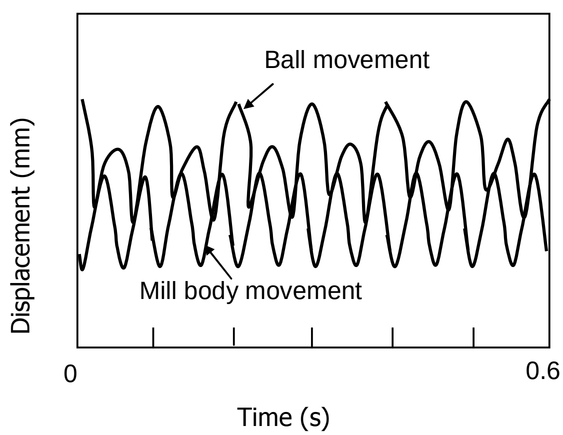

Figure 5

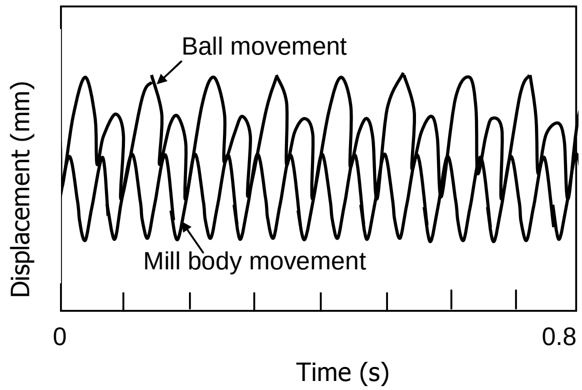

Figure 6

When the frequency increases above a maximum critical value f_m (in our case for $\nu = 20{,}86\,Hz$**)** irregular or chaotic vibration appear (Figure 7).

In Figure 8 it is shown the synthetic effect of the mill body frequency and amplitude values exerted on the values of critical frequencies (f_{cr}, f_m şi f_u). There are three areas of vibratory ball milling system highlighted (Zone I - no vibration, Zone II - regular vibration, zone III - chaotic vibration).

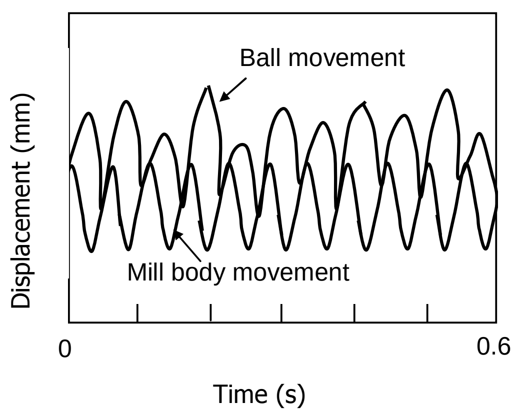

Figure 7

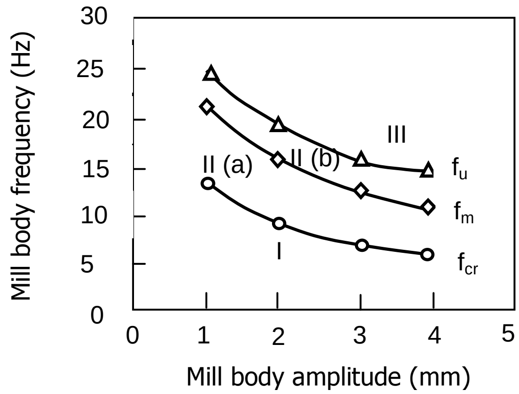

Figure 8

3.2. Determination of impact force

Collision between two bodies is characterized by the appearance of high intensity forces (contact or impact forces) in a very short time. These forces depend on the velocities of colliding bodies, the material properties of these objects are made, but also – in this case - the size and mechanical behaviour of the powder layer between the two bodies. Figure 9 shows how the powder acts as a viscous layer between the ball and body mill. Measurements are presented in graphical form expressing the mill body frequency effect on the average values of impact force (for three different values of the masses of powder).

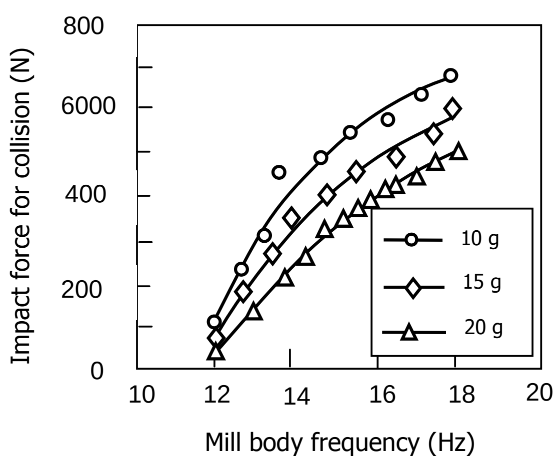

Figure 9

4. Conclusions

If the grinding process takes place in periodical vibration mode, the energy absorbed by milled powders during each collision remains constant for a set of imposed grinding conditions. However, it was found that in the case of a vibratory grinding process, one of its important features is the impact force generated during the collision phenomenon.

References

[1] Huang, H., Pan, J., Mc. Cormick, P.G., *On the dynamics of mechanical milling in a vibratory mill*, Materials, Science & Engineering, A232, pag. 55 – 62, 1997.

[2] Pavel, Cr., Legendi, A., *Consideraţii asupra dinamicii morilor vibratoare utilizate în procesul de măcinare mecanică a pulberilor,* Analele Universităţii din Oradea, Fascicula Management şi Inginerie Tehnologică – secţiunea S1, mai 2005, Editura Universităţii din Oradea.

[3] Pavel, Cr., *Dinamica morilor vibratoare utilizate în industria materialelor de construcţii*, Conspress, Bucureşti, 2000, ISBN 973-99571-2-9.

[4] Stănescu, V., *Tehnică farmaceutică*, Editura Medicală, Bucureşti, 1983.

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