# THE INFLUENCE OF HAMMERS' PERIPHERAL SPEED ON THE PERFORMANCE OF THE HAMMER MILLS

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## ABSTRACT

*Cereal milling is a complex process resulting in a wide variety of particles that differ in size, surface or composition. Ensuring a rational regime regarding the technological process of hammer mills operation, actually refers to the correlation of the indices to ensure the functioning of the mills at optimal values. The peripheral speed of hammers is one of the decisive factors in the milling process. Speed limitation is determined by fodder resistance, the construction of working parts and their durability. In the paper we study the influence of hammers' peripheral speed on the product subjected to milling, through a series of experiments under exploitation conditions.*

## INTRODUCTION

Fodder milling, as a component of technological processes for feed preparation, is one of the basic operations. The milling operation produces physical (form, structure, granulation) and chemical changes that increase the nutritional value of the fodder, increase digestibility, improve taste, allow obtaining varied and complete assortments of fodder receipts. In a given process, the grinding is usually accomplished by the interaction of several grinding principles, in which one of the following principles has the decisive weight (Păun, 2004, 2008, 2009):

- compression with flat roller type active part;
- splitting with corrugated roller type active part;
- bending with active part of stellar breaker type, with fingers and discs;
- friction with stone type active part;
- hitting with hammer rotor type active part.

The grinding of concentrated fodder according to the grinding principles mentioned above may be carried out by means of stone mills, in the case of dry seeds, of corrugated roller mills in the case of dry or wet cereal seeds (when we want to obtain cereal flakes), stellar and disc breakers for oilseeds and briquettes, finger breakers for corn cobs processing and hammer mills for all cases.

Being known the fact that fodder made of cereal seeds represent elastic, plastic and viscous bodies, but in the same time complicated colloidal, capillary-porous bodies where each part of the seed behaves differently, determining the resistance to grinding under different working regimes, allows establishing properly the constructive and functional parameters of the hammer mills.

Fodder (cereal seeds) as plant material consists of two structural elements; skeleton (coat) characterized by elastic and plastic properties and filling (endosperm) characterized by viscosity properties.

When applying a short-term external load, it is found that the resistance of the filling and the support action of the skeleton are high.

When the active parts of the machine hit the material, its resistance to destruction is determined by the resistance of the whole complex, the skeleton-filling. This process (the appearance of plastic deformations in the seed structure during the action of the external forces) takes place over time with an increasing speed which leads to the conclusion that the destruction is practically momentary.

In the process of milling machines, cereal seeds are subjected to various actions of the active parts but also to the influence of the environment (humidity, temperature, air pressure, etc.).

These actions result in a change in the mechanical structure and physicochemical properties of the seeds.

The dynamic system of the hammer mill, Figure 1, can be imagined as a physical model composed of three elements (Păun A., Gângu V., Cojocaru I., Schilacci G., 2007):

- 1-the rotor as a hitting impulse generator which results in a multitude of ground particles;
- 2-a product-air layer as a volume (or mass) that supports the equality between two simultaneous processes of "multiplication" (hammer rotor capacity) and "evacuation" (hole sieve capacity);
- 3-the useful surface (perforated) of the grinding chamber (sieve with holes as a screen) that can limit the flow of material passing through the hammer mill.

The working process of the mill must be regarded as a stochastic process described by pseudo-static methods. In this case, the established working regime of the mill is a continuous, incidental, stationary process.

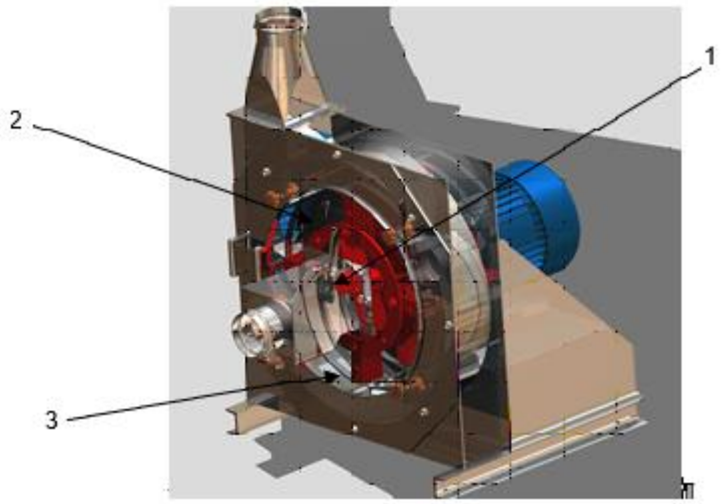



***Figure 1. Hammer mill construction***

## MATERIAL AND METHOD

Material and method. The milling process is particularly complex due to the large number of factors that occur during its deployment and is a large energy consumer that can be characterized by three indices:

- grinding degree;
- grinding modulus, *M;*
- specific energy consumption, *L;*

The process of grinding, in the case of hammer mills, is influenced by the following factors: technological, mechanical, constructive, functional.

The main mechanical factors influencing the grinding process in hammer mills are: percussions applied by hammers to the fodder particles, loss of deformation energy during shock, peripheral speed of hammers, fodder layer speed in the grinding chamber, the fan effect produced by the hammer rotor, the moment of inertia of the hammer rotor (Paun A., 2004) and (Voicu Gh., David L., Safta V., 1998).

The constructive factors that influence the grinding process are: the size of the grinding chamber, the constructive shape of the hammers, the size of the distance between the hammers and the sieve, the constructive shape of the corrugations, the feed method of the machine, the discharge way of the grinding.

Seeds grinding in hammer mills can be considered as having three phases:

- Phase 1: fodder particles grinding due to collision with the rotating rotor hammers when entering the grinding chamber;
- Phase 2: grinding the particles in uneven motion resulting from the first collision and projected by hammers on the corrugated counterweight plates and the edges of the sieve holes, which surround the grinding chamber;
- Phase 3: fodder particles grinding as a result of collisions in the milling chamber. Ensuring a rational regime regarding the technological working process of hammer mills actually refers to the correlation of the indices to ensure the functioning of the mills at optimal values.

The parameters that influence the performance of hammer mills it is inflenced by the pharameters from equation (1), (Păun A., Ivancu B., Ioniță Gh., Zaica A., 2014).

$$P = f(Q, q, D, v, z, b, e, d, l, A, M, G, F, E, \rho, g) \quad (1)$$

Where: *Q* – the feed flow of the mill, [kg/h]; *vc* – peripheral speed of the hammers, [m/s]; *D* – diameter of the rotor with hammers, [m]; *vds* – the movement speed of the seed layer in grinding chamber, [m/s]; *z* - number of hammers; *b* – hammer width, [mm]; *e* - distance between the top of the hammers and the sieve, [mm]; *d* - diameter of the sieve holes in the grinding chamber, [mm]; *β* - the coverage angle of the grinding chamber, [$^0$]; *l* – hammer length, [mm]; *qa* - air quantity required to evacuate the material from the grinding chamber, [$m^3$/min]; *A* - total area of sieve holes, [$mm^2$]; *M* - fineness modulus of the grinding, [mm]; *G* - grinding granulation, mm; *F* - crushing resistance of the seeds, [kgf/$cm^2$]; *E* - elastic modulus of the seeds, [kgf/$cm^2$]; *ρ* - the density of the material that is being ground, [kg/$m^3$]; *g* - rotor - hammers dynamic system.

The peripheral speed of the hammers is the most important factor because it influences the hitting speed and the flow of the material layer in the grinding chamber. Grinding of the fodder particles takes place at a peripheral speed of hammers higher than the rate of material destruction. The rate of destruction when seeds are ground by hitting is given by the relation (2), where:

Ρ is density, [kg/$m^3$]; and $\sqrt{\frac{E}{\rho}} = c_0$ is propagation velocity of the elastic waves, [m/s] (Melnicov S.V. s.a., 1979).

$$v_{dsl} = \sigma_{ds}\sqrt{\frac{E}{\rho}}E \quad (2)$$

Analyzing relation (2) we find that the limit rate of destruction depends on the physical-mechanical properties of the material undergoing hammer hitting.

Therefore, a correlation between the hammer speed and the physical-mechanical properties of the milled product must be made.

To determine the optimum value of hammer speed, must be used the equations (3) and (4), (Revenko V., 1971):

$$v_c = v_p \frac{1}{1-k} = \alpha v_d \quad (3)$$

$$v_d = \frac{v\sigma_p}{E} \quad (4)$$

Where: $v_d$ - destruction rate by hitting, [m/s]; $v$ - rate of diffusion of the material deformation, [m/s]; $\sigma_p$- effort to destroy the material, [N/cm$^2$];$E$ - material elastic modulus, [N/cm$^2$];$v_c$ - peripheral speed of the hammer, [m/s]; $k = \frac{v_s}{v_c}$ - coefficient that takes into account the influence of the speed of layer in the grinding chamber;$v_s$ - speed of the layer on the working surface of the grinding chamber, [m/s];$\alpha$ - proportionality coefficient determined in practice as having a value between 4÷ 5.

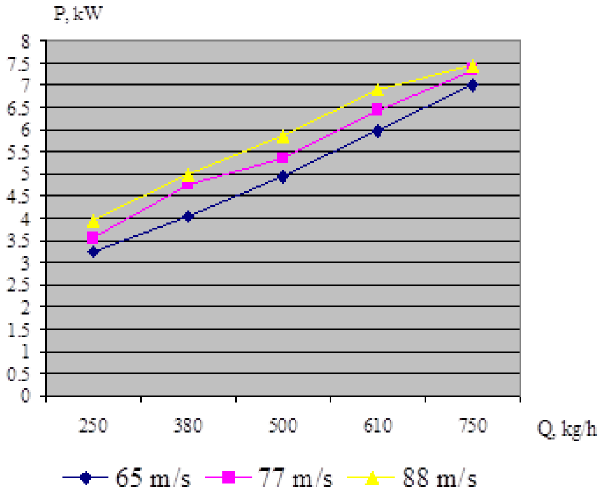
## RESULTS AND DISCUSSIONS

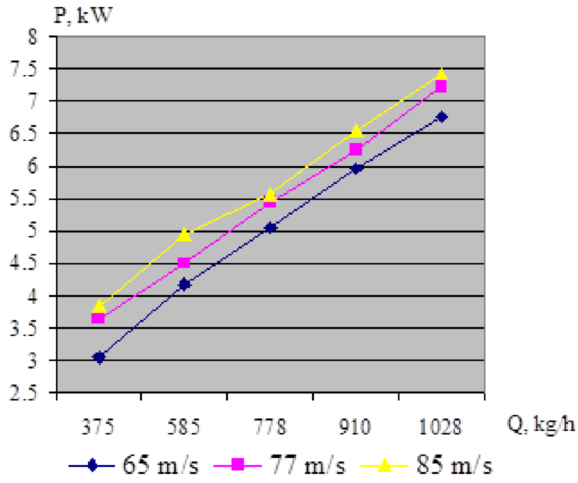
In order to determine the influence of the hammer peripheral speed on the grinding flow Q, the specific energy consumption q and the grinding modulus M, determinations were made according to Tables 1. Based on the results obtained in the experiments, a series of diagrams was made, figure 1, 2, 3.

*Table 1*

**Table with experimetnal data**

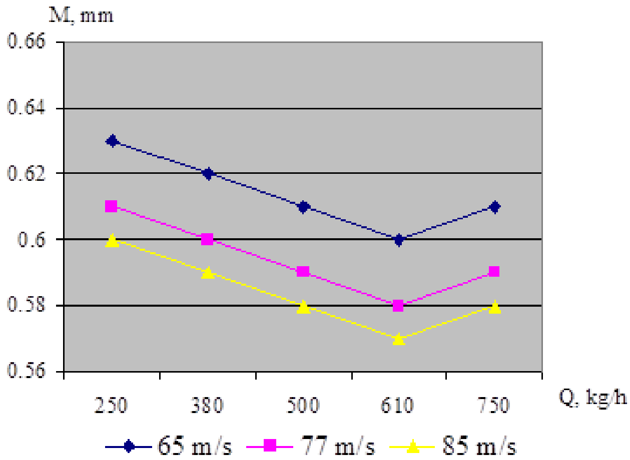
| No. Crt. | Processed product | mill's sieve holes diameter [mm] | Peripheral hammers speed $v_c$, [m/s] | Grinding flow Q, [kg/ h] | Power absorbed P, [kW] | Specific energy consumption q, [kWh/t] | Grinding modulus M, [mm] |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | Maize | 3 | 65 | 250 | 3.25 | 13.00 | 0.64 |
| 2 | | | 65 | 380 | 4.04 | 10.60 | 0.63 |
| 3 | | | 65 | 500 | 4.94 | 9.88 | 0.62 |
| 6 | | | 77 | 250 | 3.55 | 14.2 | 0.62 |
| 7 | | | 77 | 380 | 4.75 | 12.5 | 0.61 |
| 8 | | | 77 | 500 | 5.35 | 10.24 | 0.60 |
| 11 | | | 85 | 250 | 3.95 | 15.8 | 0.60 |
| 12 | | | 85 | 380 | 4.99 | 13.1 | 0.59 |
| 13 | | | 85 | 500 | 5.85 | 11.7 | 0.58 |
| 16 | | 5 | 65 | 375 | 3.28 | 8.75 | 0.96 |
| 17 | | | 65 | 585 | 4.25 | 7.26 | 0.97 |
| 18 | | | 65 | 778 | 5.05 | 6.49 | 0.98 |
| 21 | | | 77 | 375 | 3.65 | 9.73 | 0.81 |
| 24 | | | 77 | 910 | 6.25 | 6.87 | 0.85 |
| 25 | | | 77 | 1028 | 7.22 | 7.02 | 0.87 |
| 26 | | | 85 | 375 | 3.85 | 10.27 | 0.76 |
| 27 | | | 85 | 585 | 4.95 | 8.46 | 0.77 |
| 28 | | | 85 | 778 | 5.75 | 6.32 | 0.77 |
| 31 | Barley | 3 | 65 | 250 | 3.95 | 15.8 | 0.51 |
| 32 | | | 65 | 300 | 4.71 | 15.70 | 0.52 |
| 33 | | | 65 | 405 | 6.01 | 14.83 | 0.53 |
| 35 | | | 77 | 250 | 4.25 | 17.00 | 0.59 |
| 36 | | | 77 | 300 | 5.00 | 16.66 | 0.60 |
| 37 | | | 77 | 405 | 6.28 | 15.50 | 0.61 |
| 39 | | | 85 | 250 | 4.45 | 17.8 | 0.55 |
| 40 | | | 85 | 300 | 5.25 | 17.5 | 0.56 |
| 41 | | | 85 | 405 | 6.55 | 16.17 | 0.57 |
| 43 | | 5 | 65 | 500 | 4.01 | 8.02 | 0.63 |
| 44 | | | 65 | 610 | 5.05 | 8.28 | 0.64 |
| 45 | | | 65 | 700 | 6.10 | 8.71 | 0.65 |
| 47 | | | 77 | 500 | 4.20 | 8.4 | 0.65 |
| 48 | | | 77 | 610 | 5.25 | 8.61 | 0.66 |
| 49 | | | 77 | 700 | 6.45 | 9.21 | 0.68 |
| 51 | | | 85 | 500 | 4.50 | 9.00 | 0.67 |
| 52 | | | 85 | 610 | 5.65 | 9.26 | 0.68 |
| 53 | | | 85 | 700 | 6.70 | 9.57 | 0.7 |

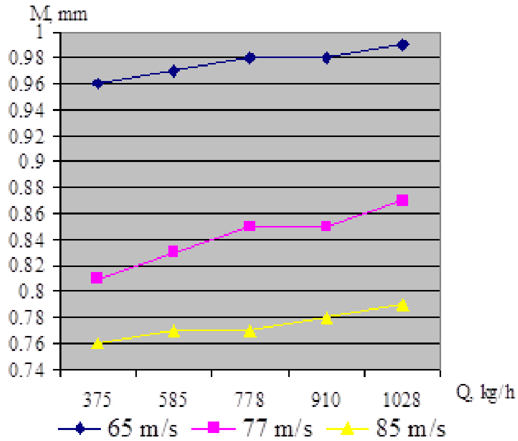



sieve holes diameter of ø= 3 [mm]

sieve holes diameter of ø= 5 [mm]

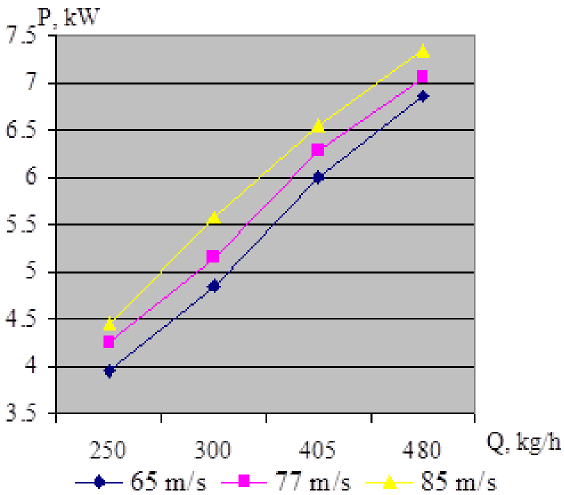


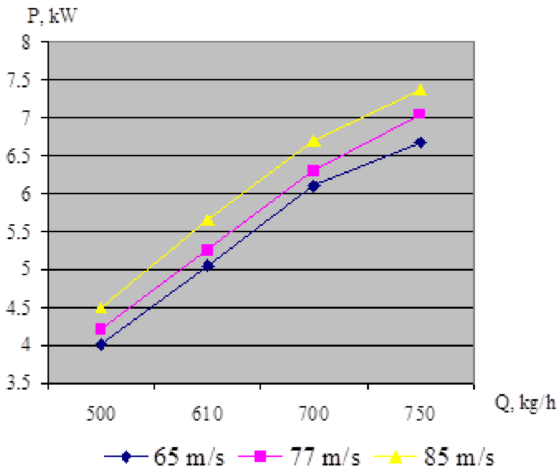




sieve holes diameter of ø= 3 [mm]

sieve holes diameter of ø= 5 [mm]

***Figure 1. Influence of hammer speed on mill's performance in maize seed milling***




sieve holes diameter of ø= 3 [mm]

sieve holes diameter of ø= 5 [mm]

***Figure 2. Influence of hammer speed on mill's performance in barley seed milling***

## CONCLUSIONS

Research has shown that for each product undergoing the milling process, an optimal peripheral speed of the hammers is required to obtain the necessary grinding degree. Analyzing the graphs in Fig. 1 and 2, made for the maize and barley seed milling with sieves having hole size of ø = 3mm and ø = 5mm, it is found that in both products the increase of the peripheral speed of the hammers, to a power required to operate within very close limits, the capacity the milling decreases, and the grinding modulus decreases. The most advantageous indices are obtained with the peripheral speed of the hammers of 65 m/s.

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