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The Process of Moving Grain Particles Along the Bottom and Side Edge of the Rotor Groove

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Abstract: This paper examines the working chamber of a crusher with a horizontal rotor arrangement, on which there are rectangular cross-section grooves used to move and crush grain material; for the same purpose, there are grooves on the upper disk. To study the movement of a grain particle along a lateral face and along a groove, differential equations were compiled. After the corresponding statements on these equations, the corresponding systems of equations were obtained. For the numerical and graphical implementation of the system of equations, the corresponding machine programs were compiled in the system "matlab". The prepared programs allow for the study of particle movement along the side surface and bottom of the rotor groove in numerical and graphical forms.

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1 INTRODUCTION

Research and development work is being carried out around the world aimed at creating new types of resource-saving technologies and technical means for preparing feed by grinding grain materials in livestock farms and substantiating their technological work processes (Konoshin, Zvekov, 2014; Erdieva, 2016; Savinykh, Palitsyn, Ivanov, 2017; Mishkhozhev, Teshev, Kazdokhov, Kurmanova, Mishkhozhev Kan, Mishkhozhev Kaz, 2020; skenderov, Lebedev, Zacharin, Lebedev, 2018; Lebedev, Iskenderov, Zhevora, Lebedev, Marin, Pavlyuk, Zaharin, 2020).

In this regard, it is considered necessary to develop and justify the parameters of a rotary grain grinder that ensures minimum specific energy consumption for obtaining ground grain products that meet the zootechnical requirements for the type and age of livestock and, on this basis, ensure a dust fraction not exceeding 5%.

In machines grinding grain material with a horizontal rotor arrangement, the study of processes in the working chamber is necessary to obtain dependencies of design and operating parameters with energy and quality characteristics. In this paper, a number of possible movements of grain material in the working chamber are considered (Freudenberger, Vernes, Fotiu, 2023; Benjumea, Laniado, Combita, 2023; Wills, Finch, 2016; Oduori, Mutuli, Munyasi, 2018; Sinnott, Cleary, 2015).

2 MATERIALS AND METHODS

If the rotor slots are located at a significant angle α to the vertical axis of the rotor, then the movement of the grain particle may depend on the speed modes of the rotor and the design parameters of the slot.

Let us consider this case, which is of both theoretical and practical interest (Fimbinger, Kemper, 2022; Alijanov, Abdurokhmonov, Jumatov, Bozorboev, 2020; Dyakonov, 1993; Alijanov, Abdurokhmonov, Umirov. 2020; Abdurokhmonov, Umirov, Ismaylov, 2024).

From Fig. 1 it is evident that a moving particle located on the surface of the side face and not resting on the bottom of the rotor groove can perform two movements: along the x axis and in the radial direction along the rotating r axis. In this case, the particle will be acted upon by the forces of weight – mg, centrifugal force $F_c = mrw^2$, rotational force. $Fk = 2m\frac{dS}{dt}w \cdot sin\beta$, friction force on the lateral face $F_{fr} = 2mf\frac{dS}{dt}w \cdot sin\beta$.

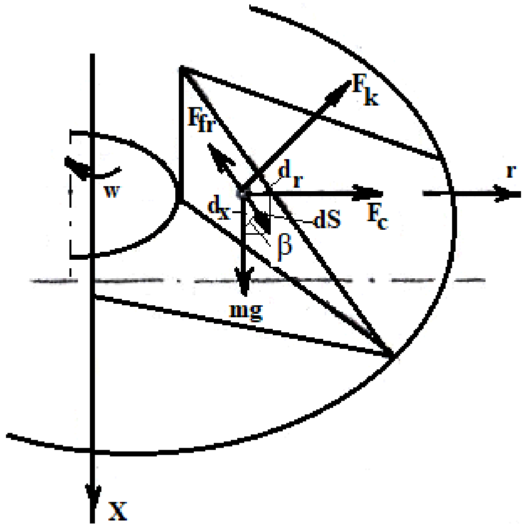

Figure 1: Scheme of forces during the movement of a particle along the lateral edge of a groove.

To study the motion of a particle along a lateral face, we will compose a differential equation taking into account two degrees of freedom of the system under consideration:

$$\begin{cases} m\ddot{x} = mg - 2mf \cdot \frac{dS}{dt} \cdot w \cdot cos\beta \\ m\ddot{r} = mrw^2 - 2mf \cdot \frac{dS}{dt} \cdot w \cdot sin\beta \end{cases} \quad (1)$$

Because

$$dS = \sqrt{(dx)^2 + (dr)^2}\,, sin\beta = \frac{dr}{dS}, cos\beta = \frac{dx}{dS},$$

then after the appropriate substitutions in (1) we obtain a system of equations in the form:

$$\begin{cases} \ddot{x} = g - 2fw\dot{x} \\ \ddot{r} = rw^2 - 2fw\dot{r} \end{cases} \quad (2)$$

If the angle β≥α, then contact of the particle with the bottom of the rotor slot is impossible, and movement can only be carried out along the lateral face. Since the angle β is a variable quantity, the above condition can be written as:

$$Sin\alpha \leq \frac{\dot{r}}{\sqrt{(\dot{r})^2 + (\dot{x})^2}}$$

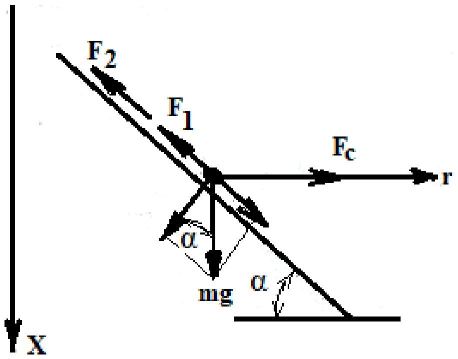

Figure 2: Scheme of forces when a particle moves along the bottom of a groove.

For the case α>β we have the particle moving along the bottom of the rotor slot. Here (Fig. 2) the equation of motion has the form:

$$\begin{cases} m\dot{r} = F_c - F_1 - F_2 \\ mx = mg \cdot sin^2\alpha - (F_1 + F_2) \cdot sin\alpha \ , \end{cases} \quad (3)$$

where Fc=mrw2, friction force along the bottom of the groove $F_1 = fmg \cdot \cos\alpha$, friction force along the side face $-F2 = 2fmw \cdot \dot{r} \ \cos\alpha \cdot sin\alpha$ Making the appropriate substitutions into system (3), we obtain

$$\begin{cases} \dot{r} = rw^2 - fgcos\alpha - 2f \cdot w\dot{r}cos\alpha \cdot sin\alpha \\ \dot{x} = g \cdot sin^2\alpha - sin\alpha(fgcos\alpha + 2fw\dot{r}cos\alpha \cdot sin\alpha \end{cases} \quad (4)$$

Let us represent the system (2) and (4) in matrix form.

Let us lower the order of the system of equations (2). We accept $r = r(1), \dot{r}(1) = r(2), x = r(3), \dot{r}(3) = r(4)$.

Then we get:

$$\begin{cases} \dot{r}(1) = r(2) \\ \dot{r}(2) = r(1) \cdot w^2 - 2fw \cdot r(2) \\ \dot{r}(3) = r(4) \\ \dot{r}(4) = g - 2fw \cdot r(4) \end{cases} \quad (5)$$

Similarly for system (4):

$$\begin{cases} \dot{r}(1) = r(2) \\ \dot{r}(2) = r(1) \cdot w^2 - fg \cdot cos\alpha - 2fw \cdot r(2)cos\alpha \cdot sin\alpha \\ \dot{r}(3) = r(4) \\ \dot{r}(4) = g \cdot sin^2\alpha - sin\alpha(fg \cdot cos\alpha - 2fw \cdot r(2)cos\alpha \cdot sin^2\alpha) \end{cases} \quad (6)$$

System (5) in matrix form:

$$\begin{bmatrix} \dot{r}(1) \\ \dot{r}(2) \\ \dot{r}(3) \\ \dot{r}(4) \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 \\ w^2 & -2fw & 0 \\ 0 & 0 & 1 \\ 0 & 0 & 2fw \end{bmatrix} * \begin{bmatrix} r(1) \\ r(2) \\ r(3) \\ r(4) \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} * g \quad (7)$$

System (6) in matrix form:

$$\begin{bmatrix} \dot{r}(1) \\ \dot{r}(2) \\ \dot{r}(3) \\ \dot{r}(4) \end{bmatrix} + \begin{bmatrix} 0 & 0 & 0 & 0 \\ w^2 & -A_1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & -A_2 & 0 & 0 \end{bmatrix} * \begin{bmatrix} r(1) \\ r(2) \\ r(3) \\ r(4) \end{bmatrix} - \begin{bmatrix} 0 & 0 & 0 & 0 \\ A_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ A_4 & 0 & 0 & A_5 \end{bmatrix} * \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix} \quad (8)$$

Here

$A_1 = 2fw \cdot cos\alpha \cdot sin\alpha,$

$A_2 = 2fw \cdot cos\alpha \cdot sin^2\alpha,$

$A_3 = -fg \cdot cos\alpha,$

$A_4 = g \cdot sin^2\alpha$

$A_5 = -fg \cdot cos\alpha \cdot sin\alpha.$

3 RESULTS AND DISCUSSION

For the numerical and graphical implementation of (7) and (8), we will compose machine programs in the "matlab" system, respectively. For (7), using the "Vas 3.m" file, we obtain

Function yprime = Vas 3(t,r);

yprime =[0100; 22.5· 1000 − 111 00; 00 01; 000 111] ∗

*[r(1)r(2)r(3)r(4)]′ − [0001]′ ∗ 9.81.

The program for solving this system with graph output looks like this:

clc

t0=0

t final = 0.5;

YO = [0.014 0.01 0 0.01];

to1 = 1.c – 3;

t race = 1;

[t,r] = odc 23 (“Vas 3”, to, t final, YO, tol, t race);

Plot (t,r(:, 1), t,r (;,2), t,r (:3), t,r(:4))grid, rauce).

For (8), using the file "Vas 4,m", we get:

Function yprime = Vas 4(t,r);

yprime =[0100; 22.5· 1000 − A_1 00; 0001; 0 − $A_2$00] ∗

*[r(1)r(2)r(3)r(4)]′ − [0000; A_3 000; 0000; A_4 00 A_5] ∗ [1001]′.

The program for solving this system with the output of graphs on the screen looks like this:

clc

t0=0

t final = 0.5;

YO = [0.014 0.01 0 0.01];

to1 = 1.c – 3;

t race = 1;

[t,r] = jde 23 («Vas 4», t0, t final, YO, tol, t race);

Plot (t,r(: 1), t,r (:.2), t,r (:.3), t,r (:,4))grid, pause.

In the equations, take the values of the coefficients:

$$w^2 = (150\frac{P}{c})^2 = 22.5 \cdot 10^{-3};$$

$$2fw = 2 \cdot 0.37 \cdot 150 = 111;$$

$$g = 9.81.$$

4 CONCLUSION

The prepared programs allow to conduct studies of particle motion in numerical and graphical forms along the side surface and bottom of the rotor slot, depending on the angular velocity of the rotor, the angle of inclination of the rotor slot α, the friction coefficients f of the initial and final diameters r of the rotor.

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