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Analytical Modeling of the Breaking of Small Dry Fruits Between a Pair of Rollers

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ABSTRACT: The breaking of small dry fruits between a roller pair in an updated and improved form is analytically modeled. A design scheme for capturing dry fruits between rolls has been developed. The operability of the analytical model was proved and, using this, the length of the working part of the roll was found.

KEYWORDS: breaking; dry fruit; roll; roller pair; working part of the roll; roller drum.

I.INTRODUCTION

During the rolling process, spacer forces arise that tend to push the rolls apart. They must be taken into account, since with excessively large amounts of effort, the safety device fails and bending of the rolls is observed. The values of expansion forces and power consumption during rolling in pre-stationary and stationary modes are different. However, experimental data on spacer forces and power consumption show the presence of only a stationary process characterized by constant values of these power and energy characteristics.

Theoretical studies of the work of a roller pair when breaking small dry fruits have not been studied. Researches and calculations of the equation are inaccurate and incomplete [1-3]. To improve this study, we have analytically simulated the breaking of small dry fruits between a roller pair of an updated and improved form.

II.RESEARCH METHODS

Based on the theory of plastic elastic deformation, the breaking force of dry fruit is found. When compiling systems of equilibrium equations of the working process of the system, the general equations of dynamics were used.

III. RESEARCH RESULTS.

To simplify the calculation, we make the following assumptions: we assume that there are no fine teeth above the surface of the rollers; rollers will work without impact.

Breaking performance of small dry fruits in the roller section of the machine, kg/h $\Pi = k_n \psi \omega h_0 b \rho$, (1)

wherek_n- coefficient (with gear ratio$i = 1:4, k_n = 2509$, at$i = 1:3, k_n = 2717$,);ψ- the coefficient of completeness of the removal of dry fruit from the roll, equal to 0,7÷0,9; ω-circumferential speed of the roll with the largest number of revolutions, m/s;h_0-gap size between rolls, m; h-length of the working part of the roll, m; ρ-dry fruit density, kg/m^3.

Based on the theory of strength, two types of deformation: a - plastic and b - elastic deformation, the breaking force is determined [4,5]:

a)based on the laws of plastic deformation of the material between the rolls, the magnitude of the breaking force is determined

$$P = \frac{1 L \chi \sigma_t h_{ns}}{\delta - 1} \sqrt{\frac{2R}{h_n - h_k}} \left[\left(\frac{h_{ns}}{h_k} \right)^{\delta} - 1 \right], \qquad (2)$$

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where$L$- swath working length, m: -coefficient, taken equal 1< χ >1,25;σ_t- yield strength, N/m^2;$\delta = \frac{f_1}{tg\frac{\alpha}{2}}$-coefficient determined by the ratio, $(1-2) < \delta > 10$;f_1-coefficient of friction of the material on the surface of the roll,$f_1 = tg\varphi$ (φ −angle of friction);α- angle of grip;h_{ns}- thickness of the neutral section, determined by the formulas

$$h_{ns} = h_k\left[\frac{1+\sqrt{1+\left(\frac{h_n}{h_k}\right)^{\delta}(\delta^2-1)}}{\delta+1}\right]^{\frac{1}{\delta}} (3)$$

or$h_{ns} \approx \sqrt{h_k h_n}$(4)

where $\delta = \frac{2f_1 y}{h_n - h_k}$ h_n-initial material thickness, m;h_k- material thickness after rolling, equal to the gap between the rolls, m; R -roll barrel radius, m

b) the equation for determining the expansion force in the case of elastic deformation between the rolls

$$P = \frac{ED^2 bsin\alpha}{H}(-cos\alpha),\ cos\alpha = 1 - \frac{H-h_0}{D}, \qquad (5)$$

This group of methods finds limited use in engineering calculations of roll equipment, due to the fact that it cannot satisfactorily explain the physical essence of the process of rolling and calendaring of polymeric materials, since it does not take into account the features of the process of their deformation and flow.

The power required to drive both rolls is determined if thetorqueon them is known. The torque at the site dx of the roll is

$$dM = \tau_b LdxR\ , \qquad (6)$$

where τ_b- the shear stress, which is equal to

$$\tau_b = \frac{dP}{dx}h = \frac{h_0}{\sqrt{2Rh_0}}(1+X^2)\frac{dP}{dX}. (7)$$

The distance from the symmetry plane to the roll surface h is a function of the X coordinate and is related to it by the following relation

$$h = h_0(1+X^2)(8)$$

Taking (7) and (8) into account, we obtain: $X = \frac{x}{\sqrt{2Rh_0}}$, $Y = \frac{y}{\sqrt{2Rh_0}}$.

Roller torque is determined by the expression

$$\frac{dM}{dx} = \tau_b LR = \frac{h_0}{\sqrt{2Rh_0}}(1+X^2)LR\frac{dP}{dX} = \tau_b LR = \frac{h_0}{\sqrt{2Rh_0}}(1+X^2)LR\sqrt{2Rh_0}\frac{dP}{dx}.$$

The power of the rollers is determined by the expression $N_n = 2M\omega$

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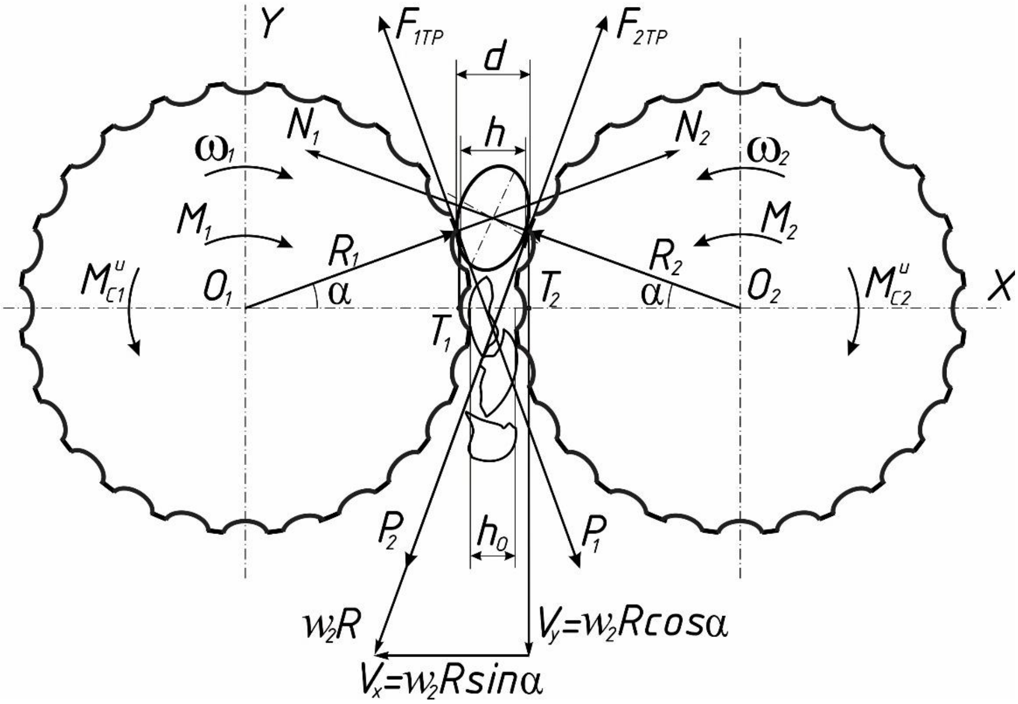

Figure 1 - Scheme of capture of the mixture by rolls

The friction forces of the material on the surface of the first and second rolls (respectively F1 and F2) depend on the magnitude of the normal forces N1 and N2 and (Fig. 1) and the friction coefficients of the mass on the surface of the rolls (f1 and f2).

As it exits the gap, the material sticks to the work roll, which is hotter and spins at a slower speed.

$F_{1tr} = N_1 f_1 = N_1 tg\rho_1$,

$F_{2tr} = N_2 f_2 = N_2 tg\rho_2$.

Friction coefficients$f_1 = f_1 = 1 - 2{,}5$.

Reduction ratio of rear roll circumferential speed $\omega_z$to the circumferential speed of the front rollω_p

$$i = \frac{\omega_z}{\omega_p} = \frac{D_z n_z}{D_p n_p}$$

where$D_z D_p$ rear and front roll diameters, mm; n_z,n_p- number of revolutions of the rear and front rolls, rpm.

By$D_z = D_p$be$i = \frac{n_z}{n_p}$.

The rolls act on a narrow driving wedge of the material, which is subjected to intense shear deformation and simultaneously pushed into the gap. Passing through the gap between the rolls, the fruit passes into a viscous state.

The pattern of fruit movement in the gap between two rotating rolls is as follows. With the same circumferential speeds of both rolls near their surface, the material flows more or less parallel to the rolls towards the minimum working gap. In the center of the gap, at the beginning of the wedge movement, a countercurrent is observed. The rolls act on a narrow driving wedge of material, which is subjected to intense shear deformation and simultaneously pushed into the slot. Passing through the gap between the rolls, the fruit passes into a viscous state.

The radius of the rollers is determined depending on $R_{min} = \frac{hcos\varphi - h_o}{2(1-cos\varphi)}$.

Capture angle$\alpha = arccos\frac{D+h_o}{D+h}$,

whereh_o-working gap between rollers;h-gap between rollers;D- roller diameter.

The supply of a roller pair in steady state is determined by the dependence$Q_m = l\delta_p V_n \rho\psi$.

The gap between the rollers rotating towards each other $\delta_l$changes according to the dependence$h_l = 2R[1 - cos(\alpha\ \omega_0 t)] + h_0$,and at the axis level OX, $(\alpha\omega_0 t)$becomes equal h_0- working clearance.

Moment of inertia two rolls $M_{c1}^{in} = I_{c1}\varepsilon_1 = \frac{p_1}{2g}r_1^2\frac{\omega_1}{r_1}$,

$$M_{c2}^{in} = I_{c2}\varepsilon_2 = \frac{p_2}{2g}r_2^2\frac{\omega_2}{r_2}$$

Equilibrium equations for roller drums [6-8]

$$(N_1 - P_{1d})r\delta_{\varphi 1} + (P_1 - F_{tr1})r\delta_{\varphi 1} - M_{c1}^{in}\delta_{\varphi 1} + M_{dv1}\delta_{\varphi 1} = 0$$

$$(N_2 - P_{2d})r.\delta_{\varphi 2} + (P_2 - F_{tr2})r\delta_{\varphi 2} - M_{c2}^{in}\delta_{\varphi 2} + M_{dv2}\delta_{\varphi 2} = 0 \qquad (9)$$

here M_{dv1}-driving torque on the drive side; M_{dv2}-torque from the drive shaft.
Deformation forces from dry fruits to rolls

$$P_d = \psi l\frac{\sigma_\varphi - \sigma_0}{2}Rsin\alpha$$

whereσ_φ, σ_0 – normal stress influencing from the side of dry fruits to the rollers at the entrance and exit of the working gap; ψ-=0,30-0,35-slot fill factor, l- slot length.

We divide equations (9)by$\delta_{\varphi 1}$and equations 2 by$\delta_{\varphi 2}$, in total we get

$$(N_1 - P_{1d})r_1 + (P_1 - F_{tr1})r_1 - M_{c1}^{in}. + M_{dv1} = 0$$

$$(N_2 - P_{2d})r_2 + (P_2 - F_{tr2})r_2 - M_{c2}^{in}. + M_{dv2} = 0$$

From these expressions we can find the torque of the rollers M_{dv}.

Let us give an example to prove the developed model. Determine the performance of a two-roll drum according to the following data: the diameter of the rolls is 0.45 m; length 0.1 m; the number of revolutions of the roll rotating at the highest speed, 2.5 rpm; the ratio of the number of revolutions of the rolls is 1:2; (the size of the gap between the first and second rolls

h_0 =0,0001 m;)dry fruit density ρ=1800 kg/m^3, $k_n = 2509$- coefficient(with gear ratio $i = 1:4$, at$k_n = 2717$ $i = 1:3$,);$\psi = 0,7 \div 0,9$ –coefficient of completeness of dry fruit removal from the swath.

Circumferential speed of the roll with the highest number of revolutions, m/s: $\omega = \pi Dn$ =3,14 0,45 2,5 = 3,53 m/s. where D – roll diameter, m; n – number of revolutions, rev/s.

The performance of the ink grater is calculated by the formula

$\Pi = k_n\psi\omega h_0 b\rho$ =2509 0,8 3,53 0,01 0,1 1800 = 12753,8 kg/h.

where $k_п$ = 2509; ψ= 0,8; h_0= 0,01 m; b = 0,1 m; ρ= 1800 kg/m^3;

$h = (\Pi/k_n\psi_0\omega b_0\rho_0)$ = 12753,8 ⁄2509 0,7 3,53 0,015 0,1 1900=0,51sm.

Here n in the process of breaking changes the values ψ_0=0,7,$b_0 = 0,015, \rho_0 = 1900$.

IV. CONCLUSION

Analytically simulated breaking of small dry fruits between roller pairs in an updated and improved form makes it possible to calculate the real working condition. A design scheme for capturing dry fruits between rolls with specified geometric and power parameters has been developed. The operability of the analytical model was proved and using this model, the length of the working gap between the rolls was found, which has a value of 0.51 sm.

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