Application of the knife machine’s operation elements with inertia bodies force to fiber

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Abstract. This article considers a shear force impact on fiber during the contact of inertia body's knives with drum knives.

In papers [1,2] it was discussed that the inertia force J was the main force providing fiber crushing during machine grinding with inertia motivating bodies. It was proved that the force of sliding friction and the force of rolling friction also influenced fiber crushing.

Hereby we consider conditions of intensive impact on the pulp of grinding machine operation elements. Under the force $P_1$ an inertia body located on the internal surface of the drum is tentatively deformed whereupon it leans not on one point, but on areas of bigger or smaller sizes [2]. It results in that during rolling of the body, the point A (figure 1) of the bearing reaction application moves a bit forward from the vertical line passing through the body's gravity center, while the action line of the bearing reaction $R_n$ deviates a bit backward from this vertical line. At that the normal component $R_n = N$ of the bearing reaction compensates the inertia force $J$ (i.e. $R_n = -J$) and that not compensated tangential component $R_t$ of the bearing reaction plays the role of rolling friction force $T_{fr}$ or the force of friction against the drum wall [2].

![Figure 1. Scheme of inertia bodies' impacts on fiber due to sliding friction and rolling friction forces](image)

The modulus of rolling friction force against the drum wall $T_{fr}^r$ is calculated using the formula:

$$T_{fr}^r = \frac{f_r \cdot P_1}{r},$$

where $f_r$ is the friction coefficient of the body sliding on the drum wall, $P_1$ is the force of the body's impact on the drum wall, and $r$ is the radius of the drum wall.
where $f_r$ is a coefficient of rolling friction equal to 0.0005 m [3];

$r$ is a radius of an inertia body equal to 0.045 m.

The sliding friction force $T_{sl}^{fr}$, Н, against the drum wall is calculated using the formula:

$$T_{sl}^{fr} = f_{sl} \cdot P_1.$$  (2)

Hereby we consider the condition of the inertia body at various rotational speeds of the inertia body and the change in circumferential force $N_{cir}$ [2]:

a) inertia body rolls without sliding, if $T_{r}^{fr} < N_{cir} < T_{sl}^{fr}$;

b) inertia body rolls with sliding, if $N_{cir} > T_{sl}^{fr}$

Hereby we determine the circumferential force affecting the inertia body $N_{cir}$, Н

$$N_{cir} = \frac{P_{motor} \cdot \eta}{V_0},$$  (3)

where $P_{motor}$ is the power of motor, kW;

$\eta$ is the efficiency coefficient of mechanical transmission form the engine [3];

$V_0$ is circumferential speed of rotation of the inertia body, m/sec.

Efficiency coefficient of mechanical transmission from the engine is calculated using the formula:

$$\eta = \eta_1^2 \cdot \eta_2 \cdot \eta_3 \cdot \eta_4,$$  (4)

where $\eta_1$ is roller bearing friction loss;

$\eta_2$ is friction losses in V-belt drives;

$\eta_3$ is friction losses in bevel drive;

$\eta_4$ is losses in shaft bearings of the apparatus drive.

$$V_0 = \frac{\pi \cdot D_c \cdot n}{60},$$  (5)

where $D_c$ is a diameter of the inertia body, m.

The results of calculation of forces affecting fiber are summarized in Table 1.

Table 1 shows that within the change in the rotational speed of the inertia body up to 883.5 rpm, the latter rolls down the inner drum surface generatrix with sliding as $N_{cir} > T_{cir}^{fr}$. With further increase in inertia body rotational speed, it rolls without sliding [3], since from that moment an increase in the value of the rotational speed of the inertia body causes a decrease in the value of circumferential force $N_{cir}$ and an increase in the force of sliding friction against the drum wall $T_{sl}^{fr}$, which provides fulfillment of the condition $T_{r}^{fr} < N_{cir} < T_{sl}^{fr}$. At the same time, the inertia force $J$ keeps incrementing together with the increase in the rotational speed of the machine’s operation bodies.
Table 1. Forces affecting fiber in case rotational speed of the inertia body changes

| The rotational speed of inertia body n, rpm | Inertia force J, Н | Circumferential stress of inertia body N_{cir}, Н | The force of rolling friction against the drum wall T_{fr}, Н | The force of sliding friction against the drum wall T_{sl}, Н |
|-------------------------------------------|------------------|---------------------------------|-----------------|-----------------|
| 85.5                                      | 11.61            | 2497.05                        | 0.13            | 2.32            |
| 114                                       | 20.64            | 1872.78                        | 0.23            | 4.13            |
| 142.5                                     | 32.26            | 1498.23                        | 0.36            | 6.45            |
| 171                                       | 46.45            | 1248.52                        | 0.52            | 9.29            |
| 199.5                                     | 63.22            | 1070.16                        | 0.71            | 12.64           |
| **228**                                   | **82.58**        | **936.39**                     | **0.93**        | **16.52**       |
| 256.5                                     | 104.51           | 832.35                         | 1.17            | 20.90           |
| 285                                       | 129.03           | 749.11                         | 1.45            | 25.81           |
| 313.5                                     | 156.12           | 681.01                         | 1.75            | 31.22           |
| 342                                       | 185.80           | 624.26                         | 2.09            | 37.16           |
| 370.5                                     | 218.05           | 576.24                         | 2.45            | 43.61           |
| 399                                       | 252.89           | 535.08                         | 2.84            | 50.58           |
| 798                                       | 1011.56          | 267.54                         | 11.37           | 202.31          |
| 826.5                                     | 1085.10          | 258.32                         | 12.19           | 217.02          |
| 855                                       | 1161.23          | 249.70                         | 13.05           | 232.25          |
| **883.5**                                 | **1239.93**      | **241.65**                     | **13.93**       | **247.99**      |
| 912                                       | 1321.22          | 234.10                         | 14.85           | 264.24          |

Taking into consideration that the crashing capability of the machine provides the maximum value of rotational speed of inertia bodies corresponding to 228 rpm, the latter move in the machine with sliding, which corresponds to the fulfillment of the condition $N_{cir} > T_{fr}$. Thus, if the machine functions within its technical characteristics with the maximum speed of inertia bodies rotation of 228 rpm, the dominant forces of impact on the fiber while grinding are the forces of inertia $J$ and sliding friction $T_{sl}$. Hereby we consider the dependence of sliding friction and rolling friction forces on circumferential force (Figure 2).

![Figure 2. Dependence of sliding friction and rolling friction forces on circumferential force](image)

1 is the force of rolling friction against the drum wall $T_{fr}$, Н
2 is the force of sliding friction against the drum wall $T_{sl}$, Н

Figure 2 presents the diagram which shows that when circumferential force increases, the force of rolling friction and sliding friction decrease. The force of sliding friction against the drum wall is the maximum force providing the maximum crushing effect on fiber. The diagram also shows that the decrease in circumferential...
force (increase in the rotational speed of inertia bodies) results in a sharp increment of sliding friction force. It may be supposed that when the rotation speed of the inertia body increments, the critical grinding process is slowing down.

Conclusions
When the inertia body moves in the grinding drum, fiber is mostly affected by the force of inertia $J$ and sliding friction $T_{sl}^{fr}$ against the drum wall, which is the maximum force providing the maximum crushing effect on fiber. The force of rolling friction $T_{r}^{fr}$ exerts an insignificant effect.

References
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