The study of the moment of resistance of the grinder of legumes

G G Klasner, V S Tarasov and V P Baranov
Kuban State Agrarian University named after I.T. Trubilina

E-mail: egor.klasner.91@mail.ru

Abstract. The paper presents experimental studies of the determination of the flywheel masses and the moment of inertia along the coastline, the mechanical characteristics of the shredder are constructed depending on the abrasive roughness, the direction of curvature of the groove and the size of the gap between the disks.

1. Introduction

The most effective way to use seeds of leguminous crops for agricultural animals is to prepare a protein emulsion, which makes it possible to improve the absorption of vegetable protein by the animal's body.

There are many technologies [1, 2], allowing to obtain a protein emulsion. The main technological operations in the preparation of the extractant are: grinding, extraction, separation into liquid and solid fractions, heat treatment, cooling and storage. All this leads to the need to purchase a whole complex of large-scale, energy-intensive and expensive machines, which are often beyond the capacity of small businesses that produce today more than 50% of livestock and poultry products.

Thus, there is a need to develop a universal constructive-technological scheme of technical equipment, combining the following technological operations: grinding, protein extraction, separation of the suspension into fractions.

2. Materials and methods

As a result of a patent search for structures for preparing fodder for agricultural animals and poultry on a protein basis under the conditions of conducting personal subsidiary farming and peasant farming, we developed a device for obtaining a protein suspension from grain of leguminous crops (patent for invention of the Russian Federation No. 2614777).

The main element of the proposed technology for the preparation of high-protein feed based on soybean grain is a soybean grain chopper.

In the proposed device, the main technological operation is the abrasion of soaked soybean grain to a fine state, by means of a truncated cone with curvilinear grooves and an applied abrasive over its entire surface.

A prototype was fabricated [3], (figure 1), on the basis of which a number of multifactorial experiments were carried out with the aim of experimentally substantiating the design-mode parameters of the shredder.
Figure 1. General view of the shredder soaked soybean grain.

Figure 2. Abrasive discs with curved grooves.

Experimental installation in a proper measure allows to vary in the required limits by the values of selected factors that affect the process of grinding soaked soybean grain, followed by extraction of soy protein. The frequency of rotation of the lower abrasive disc was changed by the switch frequency of the installation. The switch works in three modes [3-5].

Replaceable abrasive discs with curved grooves were also made (figure 2). Curved grooves are made in the form of grooves at different angle of intersection of the grooves (α=60°, α=90°, α=120°). The gap between the abrasive discs was exposed by overlaying washers between the upper abrasive cone and the cover of the chopper housing (thus, during the experiment, the gap between the abrasive discs 3, 4, and 5 mm was set.) The roughness of the abrasive surface of the discs was achieved by applying corundum on the abrasive stone, the roughness value was chosen Ra = 50, Ra = 250, Ra = 450 microns [5].

To determine the mechanical characteristics of the shredder, the calibrated AC collector machine method is used, the essence of which is to calculate the idle time of the electric machine to determine the constant C due to the design features of the machine and the adopted value of the magnetic flux. Then the electric motor is connected to the grinder and the grinding process is carried out with different directions of grooves, abrasive roughness and the gap between the discs, since these factors significantly affect the amount of mechanical torque. It should be noted that this shredder starts at idle speed [6]. On the basis of the results of experiments and the calculation of the moment of the working machine, the mechanical characteristic of the working machine, reduced to the motor shaft, is built. For rotation of the shredder, a single-phase collector-ac motor of the JUICERCT-1206 type is used, the passport (nominal) data: nominal power – Ph = 0,8 kW; nominal voltage – Un= 220 V; rotation frequency (speed) nominal – nn= 1500 min – 1; rated current – Ih = 3 A. The installation diagram is shown in figure 3.

![Installation diagram](attachment:image.png)

**Figure 3.** Scheme of the test setup.  
QF - automatic switch; # A1 – microcontroller voltage regulation circuit;  
TA – current transformers 15/5; PS - Resource-UF2M-3T52-5-100-1000.

The single-phase voltage of the 220 V network is fed through the QF circuit breaker to the microcontroller voltage regulation circuit # A1. After that, the regulated voltage is supplied to the armature of the
collector electric motor of alternating current M, which causes the working body of the chopper to rotate. Voltage and current are recorded with an interval of 160 ms by the Resource-UF2M-3T52-5-100-1000 power quality analyzer, the current transformer is used with a rating of 15/5 A. The tests are carried out on an electric machine at a steady-state temperature [7].

Constant C is found from the experience of the idling speed of the calibrated machine in engine mode. To do this, let the car idling at selected different voltages at the terminals of the armature circuit and record the armature voltage $U_u$, idle current $I_u$ and the angular velocity of the engine armature $\omega_u$.

Voltage regulation is carried out using a microcontroller voltage control circuit. Recording the readings of the ammeter, voltmeter and rotational speed, we obtain the data for the construction of the mechanical characteristics [8, 9].

3. Results and discussion
The characteristic of idling establishes a qualitative and quantitative connection between the magnetic and electrical circuits. The characteristic of idling shows that the voltage of the autonomous generator can be smoothly adjusted in the range from zero to 1.35 $U_n$ by changing the excitation current.

Calculate the electromotive force by the formula:

$$E = U_u - \Delta U_u$$

Voltage drop in the armature circuit

$$\Delta U_u = I_u R_u + 2\Delta U_i$$

where $R$ is the resistance of the armature circuit.

$\Delta U_u$ - voltage loss in the brush contact.

The voltage loss in the brush contact $\Delta U_i$ is usually taken equal to 1.5 ... 2 V.

Measured armature resistance = 2.5 ohm. Constant C is calculated as the average value based on the data obtained when adjusting the voltage at the engine anchor

$$C = 1/K \cdot (E1/\omega 1 + E2/\omega 2 + E3/\omega 3 + \ldots + Ek/\omega k)$$

where $K$ is the number of experiments.

After calculating C, we determine the idle time of the calibrated machine

$$M_xtm = C I_u$$

According to the columns $\omega_u$ and $M_{crm}$ build the mechanical characteristic of the working machine, reduced to the motor shaft.

The moment of breaking the car is determined by the value of the armature current of the engine. Increasing the voltage at the anchor, determine the motor current at which the chopper shaft begins to rotate. For reliability, the experiment is carried out with a triple repetition and calculate the average value of the starting current $I_{tr}$.

![Figure 4](image1.png)  **Figure 4.** Mechanical characteristics of the shredder depending on abrasive roughness.

![Figure 5](image2.png)  **Figure 5.** Mechanical characteristics of the shredder depending on the direction of the grooves.
This current corresponds to the armature current. In this case, the moment of starting is calculated by the formula:

\[ M_0 = C I_{tr} = P_n I_{tr} / (I_n \cdot \omega_n) \]  

(5)

where \( P_n, I_n, \omega_n \) - passport nominal data of the electric motor.

Next, we build the mechanical characteristic of the moment of resistance of the chopper, depending on the direction of the grooves, the roughness of the abrasive and the gap between the disks.

It should be noted a significant inertial component of the chopper. This parameter affects the starting and braking times of the electric drive. The moment of inertia of the drive can be expressed as [9]:

\[ J = m \rho^2 = \frac{G D^2}{4 g} \]

where \( D \) is the radius and diameter of inertia, m;
\( G \) - gravity, H;
\( g \) is the acceleration of gravity, \( g = 9.8 \text{ m/s}^2 \);
\( GD^2 \) - flywheel moment.

General view of the equation of motion:

\[ \pm M + M_c = J \frac{d\omega}{dt} \]

(6)

where \( M \) - the torque of the engine;
\( M_c \) - the moment of static resistance of the drive.
When self-braking, when \( M = 0 \), the last equation has the form:

\[ M_c = J \frac{d\omega}{dt} \]

(7)

To obtain the inertial characteristics or values of the moment of inertia of the shredder, we remove the coasting curve.
Ad hoc:

\[ \tan \alpha = \frac{\omega}{t} = \frac{d\omega}{dt} \]  

(8)

The static moment of resistance \( m_s \) is selected from the mechanical characteristics (figures 4-6) at the nominal speed.

Based on the formula obtained in expression 7, we obtain:

\[ J_{nr \text{ min}} = \frac{m_s}{\omega_0} = \frac{0.75 \times 8.9}{157} = 0.042, \text{ kg} \cdot \text{m}^2 \]

\[ J_{nr \text{ max}} = \frac{0.9 \times 8.9}{157} = 0.051, \text{ kg} \cdot \text{m}^2 \]

4. Conclusions

Thus, the mechanical characteristics at start-up without load have a fan-like appearance, and when the product arrives at increased rotational frequencies, it leads to an increase in the moment of resistance. Increasing the angle of the grooves, roughness of the abrasive and reducing the gap between the discs can lead to an increase in the moment of resistance to 20%. The chopper mechanism has a significant moment of inertia, which is confirmed by the overrun curve.

References

[1] Frolov V Yu, Barakin N S and Klasner G G 2018 Investigation of the moment of resistance of the soybean shredder *Rural mechanic* **10** 24-6

[2] Aret V A, Nikolaev B L, Zabrovsky T P and Nikolaev L K 2006 *Fundamentals of Calculation of Equipment of Production of Fat-Containing Food Product* (St.Petersburg.: St.Petersburg State University Low-Temperature and Food Technologies) p 435

[3] Baturin A K 2006 *Chemical Composition and Energy Value of the Food Products* (St.Petersburg: Profession) p 416

[4] Frolov V Ju, Klasner G G and Kremyansky V F 2019 Justification of design-mode parameters of the chopper soaked soybean grain *IOP Conference Series: Earth and Environmental Science* **315**(6) 062014

[5] Frolov V Ju, Klasner G G and Sysoev D P Substantiation of design and standard parameters of chopper of soaked grain of leguminous plants (as an example of the Soya Grain) *Periodico Tche Quimica* **16**(31) 258-67

[6] Frolov V Ju, Kurasov V S, Sysoev D P and Klasner GG Theoretical and experimental aspects of the grinding process the soaked soybean grain *Dusunen Adam* **10**(1) 972-81

[7] Frolov V Ju, Klasner G G and Kremyansky V F 2019 Justification of design-mode parameters of the chopper soaked soybean grain *IOP Conference Series: Earth and Environmental Science* **315**(6) 062014

[8] Frolov V Ju, Klasner G G and Sysoev D P Substantiation of design and standard parameters of chopper of soaked grain of leguminous plants (as an example of the Soya Grain) *Periodico Tche Quimica* **16**(31) 258-67

[9] Frolov V Ju, Kurasov V S, Sysoev D P and Klasner G G 2019 Theoretical and experimental aspects of the grinding process the soaked soybean grain *Dusunen Adam* **10**(1) 972-81