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Methods of regulating the work of units at irrigation pumping stations

D Alijanov[1]*, Sh Abdurokhmonov [1] and N Umirov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan

abduroxmonov.shavkatjon@bk.ru

Abstract. The article shows that the process of grain crushing is not sufficiently studied. A practical way to control the quality of grain grinding. The crushing process was studied by various scientists, but they did not consider the module for the quality of grain grinding in a rotary crusher. The article is devoted to assessing the quality of grain grinding by compiling a module. For a qualitative analysis of the grinding of the experimental crusher, the experimental plan was adopted for various values of the working chamber clearance and rotor rotation frequencies. The experimental results were examined in wheat at 750 rpm and a working chamber gap of 1.5 mm. The results obtained allow us to determine the average size of the grinding particles. For the analytical description of processes according to experimental data, various standard distribution functions of a random variable were used. To determine the appropriate case of the form of the distribution of the discrete function for various gaps. The technique of determining the coefficients of models in the form of linear equations by the least squares method is considered. The technique can also be used to find the coefficients of nonlinear functions. The distribution density of random variables is determined which allows to determine the probability of a random variable falling into the range of values. The degree of correspondence between empirical and theoretical distributions was estimated based on a hypothesis at a significance level. The grinding quality of the experimental machine, with serial hammer crushers shows the average grinding value, the particle density distribution of hammer machines is much lower.

1. Introduction

An analysis of world and domestic experience in livestock breeding shows that only in conditions of a high level of supply of farms with complete feeds and modern machines, the genetic potential of animals and birds can be realized. Without the use of resource-saving machine technologies, highly efficient sets of machines and production lines, it is impossible to solve the vital market problems of modern animal husbandry [1-12].

Recent studies indicate the possibility of a significant increase in the efficiency of feeding concentrated feed by fractionating it during grinding for each animal species. Grinding grain negatively affects the productivity of animals and their health, up to an increase in mortality, significantly worsens working conditions throughout the entire process from preparation to distribution of feed, and also increases the energy intensity of the process [13-17].

One of the promising areas in the field of grain grinding in recent years is the development of centrifugal rotor disk choppers, which are currently widely used.

Zootechnical science recommends crushed feed with particles of a certain size for each type of animal and bird. The size of the entire mass of bulk material as a statistical population is estimated by the content in it of classes or fractions of certain sizes, i.e., by granulometric composition.
The object of research is the process of influencing the operating parameters of a rotary crusher with grains.
An analysis of the works shows that the crushing process was studied by various scientists, but they did not consider the model of the quality of grain grinding in a rotary crusher [18-21].
The aim of the article is to compile a model for assessing the quality of grinding grain.
Putting the issue
Introduction The object of research is the technological process of the influence of the operating parameters of a rotary crusher with grains.
An analysis of world and domestic experience in animal husbandry shows that only in conditions of a high level of supply of full-fledged feeds to farms.
An analysis of the works shows that the crushing process was studied by various scientists, but they did not consider the model of the quality of grain grinding in a rotary crusher.
The aim of the article is to compile a model for assessing the quality of grinding grain.
In practice, sieve analysis is performed using sieve analysis with standard sieve sets. At the same time, the grinding module (average value of grain particle sizes after destruction):

$$M = \frac{\sum x_i \cdot m_i}{\sum m_i} = \sum x_i \cdot p_i$$

Where mi is the mass of product on i ohm sieve;
$\sum m_i$ is grinding mass total for one sieving;
$P_i = \frac{m_i}{\sum m_i}$ is the relative part of the grinding on the i-th sieve (frequency);
$x_i = \frac{d_i + d_{i+1}}{2}$ is the average value of sieves with diameters of a random particle size between two adjacent holes di and d_{i+1}; it is assumed that the accepted random values xi correspond to the normal distribution.
Since the results of experiments on xi and pi are discrete, the dispersion of the distribution is also determined by the formula [4, 5, 6, 7, 8, 9]

$$D = \sum (x_i - M)^2 \cdot p_i$$

2. Solution method

To analyze the qualitative characteristics of grinding the experimental crusher, we adopted the experimental plan for various gaps of the working chamber and rotational speeds n of the rotor. For the specified clearance, grinding was performed at least 5 times, and the reliability of the pi results was checked according to criterion 3 σ . The processing of the experimental results will be examined using the example of grinding in wheat at a rotor frequency of 750 min^{-1} and a working chamber gap of δ=1,5 mm Table 1. shows the average data of five repeated grindings of the same weights (1 kg each). For the sieve analysis, we took the grinding mass obtained during the stationary operation of the crusher (i.e., the mass obtained during the transitional regime was excluded).

Table 1. Size distribution of grinding particles at n = 750 min^{-1} and δ = 1.5 mm

Particle size x_i, mm	1.1	1.35	1.75	2.25	2.75
Frequencies, p	0.04	0.06	0.1	0.3	0.5
Sum of accumulated frequencies $F = \sum p\xi$	0.04	0.1	0.2	0.5	1.0

Given in Table 1, numerical data of a discrete (experimental) distribution make it possible to determine the average value of grinding particles [10, 11, 12, 13, 14]

$$\overline{x} = \sum_{1}^{5} x_i \cdot p_i = 2.35mm$$

and variance

$$D = \sum_{i}^{5} \left(x_i - \overline{x}\right)^2 \cdot p_i = 0.2415$$

From the table. 1 it also follows that pi show the probability of equality of a random variable x to a specific value xi, i.e.

$$P_\xi = P(X = x_i)$$

respectively for the accumulated frequencies

$$\sum P_\xi = P(X \leq x_i)$$

For the analytical description of processes according to experimental data, various types of standard distribution functions of a random variable are used (normal distribution, gamma distribution, exponential distribution, etc.). To determine the type of distribution suitable for our case, we consider a discrete function $P_i = f(x_i)$ on the graph (Fig. 1), constructed for various gaps.

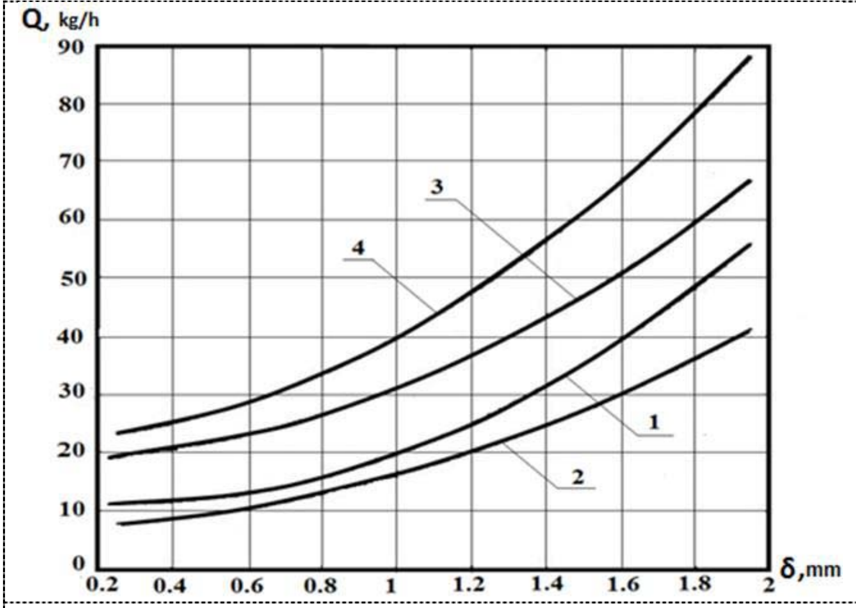

Figure 1. Dependence of productivity on the gap in the working chamber at the rotor speed: 1-750; 2-1000; 3-1500; 4-2000 min^{-1} (grain wheat W = 18%).

Obviously, the most appropriate is the exponential distribution of the form

$$p_m = A \cdot x^a \cdot e^{bx}$$ or

here the index m- means the equation of the model, and A, a, b are the coefficients that must be determined on the basis of experimental data.

The methodology for determining the coefficients of models in the form of linear equations by the least squares method is considered. This technique can also be used to find the coefficients of nonlinear functions. To do this, they must be replaced by variables to expressions linear with respect to unknown coefficients. In the table. Figure 2 shows the transformations of some linear functions that may be useful when performing practical transformations. So, having $z = \ln(P);$ $a_0 = \ln A,$ $a_1 = b,$ accepted we get the equation $z = a_0 + a_1 x$ (this is for the equation $P_m = A \cdot e^{bx}$). The calculation of the model coefficients was performed in the MatLAB system in the direct calculation mode:

matrix s= [1 1 1 1 1; 1.1 1.35 1.75 2.25 2.75];
vector z= ln(p);
odds pa=s"\z'= [a0=-4.9659, a1=1.5867];
coefficient A=exp(-4.9659)=0.007; Since a1 = b, we obtain the frequency model

$$P_m = 0{,}007 \cdot e^{1{,}5867 \cdot x}$$

The calculation of Pm at xi gives the vector Pm= [0.0401 0.00596 0.1125 0.2486 0.5497], error vector P-Pm = [-0.0001 0.0004 -0.0125 0.0514 -0.0497], t.s. the maximum error is 0.0514.
Similarly, we obtain the coefficients of the model of the function of the accumulated frequencies:
z= ln(F), here is the vector F=[0.04 0.1 0.2 0.5 1.0];
matrix s=[1 1 1 1 1; 1.1 1.35 1.75 2.25 2.75];
from here
odds A=exp (-5.026)=0.0066;
F_m= 0.0066·e1.8811·x;
F_m at the points xi gives the vector
F_m=[0.0523 0.0836 0.1775 0.4547 1.0646];
error vector F-F_m= [-0.0123 0.0164 0.0225 0.0453 -0.0646] with a maximum error value of 0.0646.
It is known that the distribution density of a random variable

$$\phi_m = F_m^{/}$$

$$\phi_m = \frac{dF_m}{dx} = 0.0124 \cdot e^{1.8811 \cdot x}$$

The density distribution allows you to determine the probability of a random variable X falling into the range of values x_1-x_2.

$$P(x_1 \le X \angle x_2) = \int_{x_1}^{x_2} \varphi_m dx$$

If you take x_1=1.1; x_2=2.75, then the probability should be equal to one. To check the accuracy of the model, we calculate using the quad file ($\varphi_m, 1.1, 2.75$) integral $F_m = \int_{1.1}^{2.75} 0.012 \cdot exp(1.8811 \cdot x) dx = 1.0123$, which is close enough to unity. Accordingly, we obtain the mathematical expectation of a random variable

$$X_m = \int_{1.1}^{2.75} x \cdot \phi_m \cdot dx = 2.5537 мм$$

and variance 2.75

$$D_m = \int_{1.1}^{2.75} (x - x_m)^2 \cdot \phi_m \cdot dx = 0.2393$$

The degree of correspondence between empirical and theoretical distributions was estimated based on the H_0 hypothesis with a significance level of α-0.05

3. Results and Samples

Table. 3 shows the results of processing the experimental data, and Fig. 2 shows the dependencies in the form of continuous curves P_m (*x*) and points of the discrete series *P (x)*. The nature of the curves in Fig. 3 shows a high distribution density for cases 1, 2, 5, 6. So for curves 1.2, all particles (at *P = 1*)

are at a length of 0.98 mm with dispersions D_1 = 0.082 ... 0.094; D_2 = 0.0408 ... 0.0339. For cases of 5.6, the particle weight is on a length of 1 mm with the corresponding dispersions D_3 = 0.1337 ... 0.11; D_6 = 0.0688 ... 0.0719, which indicates a high mass uniformity of grinding. So at δ = 0.25, $\bar{x} = 0.9 \pm 0.2$ about 70% of the crushed mass falls into the range and the possible amount of dust fraction x <0.1 is not more than 3%. The presence of a dust fraction is possible only δ = 0.25; 0.5; 1 mm with large gaps of the dust fraction is not. With an average grinding (with δ = 1, 1.5 mm), a large variation in particle sizes is observed. In particular, at δ = 1 mm, an insignificant amount of dust fraction (not more than 2%) may be present and the dispersion D_3 = 0.5209 ... 0.5067 is the largest in the considered example, and the amount of crushed particles in the range $\bar{x} = 2.05 \pm 0.7$ is about 70%. The difference in the values $\bar{x}$ and δ are explained by the features of the process in the working chamber at the moment of grinding particles from the chamber. At δ = 1.75 ... 2.25 mm, the average particle sizes are hardly distinguishable, although the distribution density at δ= 2.25 is much higher. This is explained by an increase in the yield of non-crushed particles having a thickness of less than δ.
An analysis of similar results for wheat at n = 1000, 1500, 2250 min^{-1} shows that there are no significant differences in the quality of grinding for the same gaps δ. It is also impossible to find stable relationships between the model coefficients between themselves or with the distribution parameters x_m, D_m. Comparison of the grinding quality of the experimental machine with serial hammer crushers shows that with the same average grinding values, the distribution density of particles in hammer machines is much lower (1.5 ... 2 times). Also, with any grinding modules, the hammer mill will produce flour fractions, and with fine grinding, the amount of flour fraction can exceed 10%, which violates the zootechnical requirements for the quality of grinding of feed grain.

Table 2. Transformation of some nonlinear functions for determining the coefficients by the least squares method according to experimental data.

Original nonlinear function	What kind of form	Variable Replacement
$У = A \cdot e^{вx}$	$z = a_0 + a_1 x$	$z = \ln У$, $в = a_1$, $a_0 = \ln A$
$У = B \cdot x^{в}$	$z = a_0 + a_1 u$	$z = \ln У$, $u = \ln x$, $a_0 + \ln в$, $a_1 = в$
$У = A \cdot x^{a} \cdot e^{вx}$	$z = a_0 + a_1 \ln x + a_2 x$	$z = \ln У$, $a_0 = \ln A$, $a_2 = в$
$У = A \cdot x^{a} \cdot e^{ax^2}$	$z = a_0 + a_1 \ln x + a_2 x^2$	$z = \ln У$, $a_0 = \ln A$, $a_1 = a$, $a_2 = в$
$У = A \cdot e^{\frac{(x-a)^2}{2\sigma^2}}$	$z = a_0 + a_1 x + a_2 x^2$	$z = \ln У$, $a_1 = \frac{a}{\sigma^2}$, $a_1 = \frac{1}{2\sigma^2}$
$У = A \cdot a^{x} \cdot e^{bx^2}$	$z = a_0 + a_1 x + a_2 x^2$	$z = \ln У$, $a_0 = \ln A$, $a_1 = \ln a$, $a_2 = b$

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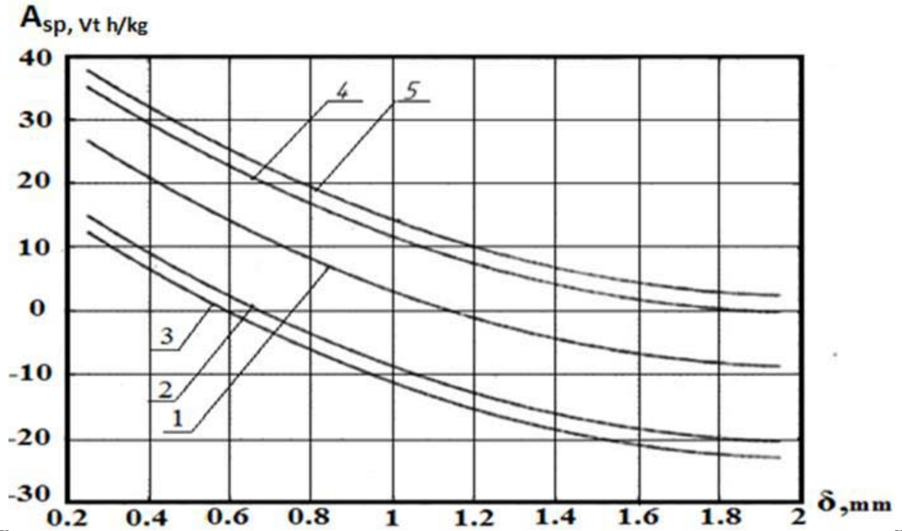

Figure 2. Dependence *A (δ)* at the fifth productivity level *Q* (kg/h): 1-19; 2-21; 3-32; 4-45; 5-70 rotor speed of 1500 min^{-1}

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Table 3. Experimental and theoretical distribution of a random value x of particle size after grinding wheat at n = 750 min^{1}

The clearance in the working chamber	Experiment Results	Arithmetic mean x	Dispersion D	Theoretical models	Mathematical expectation x_m	Dispersion D	Error value
δ=0.25 mm	Particle size x=[0.12 0.325 0.75 1.1] ; Frequencies P=[0.05 0.1 0.2 0.65]; Distribution function F=∑P$_i$=[0.05 0.15 0.35 1];	0.9035	0.094	$P_m = 0.0387 \cdot \exp(2.4653 \cdot x)$; $F_m = 0.0439 \cdot \exp(2.8591 \cdot x)$; Density distribution $\phi_m = F_m^1 = 0.1255 \cdot \exp(2.8591 \cdot x)$;	0.8501	0.082	$\max\{P - P_m\} = 0.064$; $\max\{F - F_m\} = 0.065$; $(\bar{x} - x_m) = 0.0534$; $(D - D_m) = 0.012$
δ=0.5 mm	Particle size x=[0.12 0.325 0.75 1.1] ; Frequencies P=[0.01 0.02 0.15 0.82] ; Distribution function F=∑P$_i$=[0.01 0.03 0.18 1];	1.022	0.0339	$P_m = 0.0052 \cdot \exp(4.5572 \cdot x)$; $F_m = 0.0061 \cdot \exp(4.6192 \cdot x)$; Density distribution $\phi_m = F_m^1 = 0.0282 \cdot \exp(4.6192 \cdot x)$;	0.9801	0.0408	$\max\{P - P_m\} = 0.038$; $\max\{F - F_m\} = 0.018$; $(\bar{x} - x_m) = 0.042$; $(D - D_m) = -0.007$
δ=1 mm	Particle size x=[0.12 0.325 0.75 1.1 1.35 1.75 2.25 2.75] ; Frequencies P=[0.01 0.02 0.05 0.6 0.12 0.15 0.2 0.39]; Distribution function F=∑P$_i$=[0.01 0.03 0.08 0.14 0.26 0.41 0.61 1];	2.05	0.5067	$P_m = 0.0138 \cdot \exp(1.2877 \cdot x)$; $F_m = 0.074 \cdot x^{0.9856} \cdot \exp(0.5999 \cdot x)$; Density distribution $\phi_m = F_m^1 = 0.0444 \cdot x^{-0.0144} \cdot \exp(0.5949 \cdot x)$;	2.1081	0.5209	$\max\{P - P_m\} = 0.086$; $\max\{F - F_m\} = -0.044$; $(\bar{x} - x_m) = -0.058$; $(D - D_m) = -0.0142$

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δ=1.5 mm	Particle size x=[1.1 1.35 1.75 2.25 2.75] ; Frequencies P=[0.04 0.06 0.1 0.3 0.5]; Distribution function F=∑P$_i$=[0.04 0.1 0.2 0.5 1];	2.35	0.2415	$P_m = 0.007 \cdot \exp(1.5867 \cdot x)$; $F_m = 0.0066 \cdot \exp(1.8811 \cdot x)$; Density distribution $\phi_m = F_m^1 = 0.0124 \cdot \exp(1.8811 \cdot x)$;	2.5537	0.2393	$\max\{P-P_m\} = 0.0514$; $\max\{F-F_m\} = 0.064$; $(\bar{x}-x_m) = -0.2$; $(D-D_m) = 0.049$
δ=1.75 mm	Particle size x=[2.25 2.75 3.25] ; Frequencies P=[0.1 0.2 0.7]; Distribution function F=∑P$_i$=[0.1 0.3 1];	3.05	0.11	$P_m = 0.0011 \cdot \exp(1.9459 \cdot x)$; $F_m = 5.5253 \cdot 10^{-4} \cdot \exp(2.3026 \cdot x)$; Density distribution $\phi_m = F_m^1 = 1.2723 \cdot 10^{-3} \cdot \exp(2.3026 \cdot x)$;	3.153	0.1337	$\max\{P-P_m\} = 0.086$; $\max\{F-F_m\} = 0.017$; $(\bar{x}-x_m) = -0.103$; $(D-D_m) = -0.024$
δ=2.25 mm	Particle size x=[2.25 2.75 3.25] ; Frequencies P=[0.05 0.15 0.8]; Distribution function F=∑P$_i$=[0.05 0.2 1];	3.12	0.0719	$P_m = 8.8722 \cdot 10^{-5} \cdot \exp(2.7726 \cdot x)$; $F_m = 5.6952 \cdot 10^{-5} \cdot \exp(2.9957 \cdot x)$; Density distribution $\phi_m = F_m^1 = 1.6881 \cdot 10^{-4} \cdot \exp(2.9957 \cdot x)$;	3.113	0.0688	$\max\{P-P_m\} = 0.0863$; $\max\{F-F_m\} = 0.0366$; $(\bar{x}-x_m) = 0.007$; $(D-D_m) = 0.031$

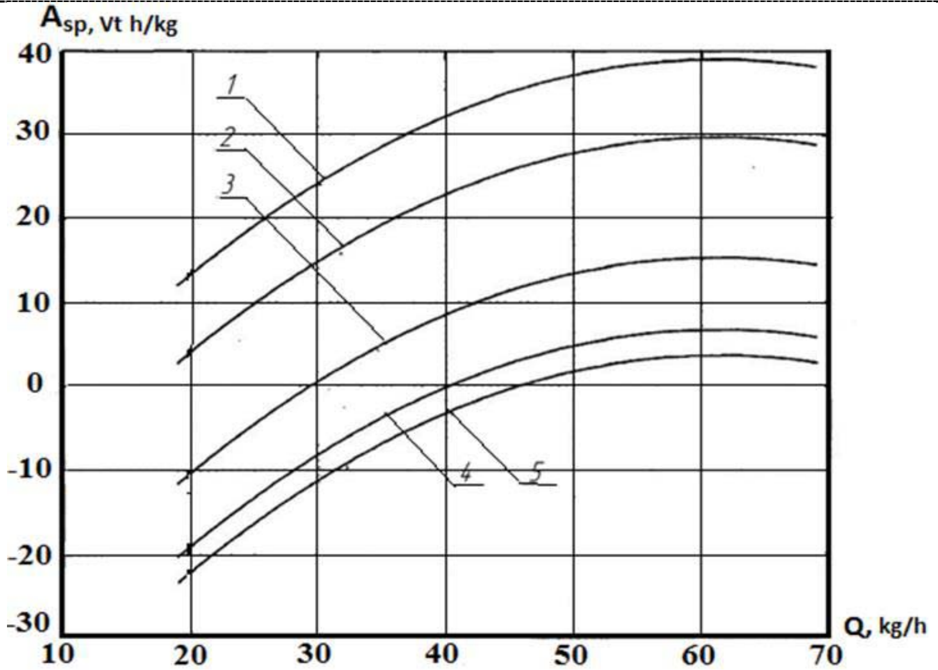

Figure 3. Dependence A (δ) at the fifth productivity level Q (kg / h): 1-19; 2-21; 3-32; 4-45; 5-70 rotor speed of 1500 min^{-1}

4. Conclusions

1. The process of destruction of indicators by grain materials and the resulting model of positive intervals of *Q (δ)* and (*Q, δ*) values and non-positive intervals of *Q* and *δ* values.
2. The method of determining the coefficients of models in the form of linear equations by the least squares method can also be used to find the coefficients of nonlinear functions.
3. The grinding quality of the experimental machine, with serial hammer crushers shows the average grinding value, the particle density distribution of hammer machines is much lower.

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