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# GRAPHICAL METHOD FOR POWER-QUALITY ASSESSMENT OF MILLING MACHINE FEED

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SUMMARY

The problem of fodder processing has always been a hot issue from the perspective of energy and qualitative evaluation. A method has been proposed for graphic determination of energy consumption depending on the degree or module of grinding that can be applicable for preliminary energy and qualitative evaluations of fodder grinding machines. A construction of a multifunctional device with combined working component has been justified and a range (group, series) of machines has been designed for cutting, grinding and shelling various fodders for small and medium-size farms.

**Key words:** cutting, shredding, shelling, corn cobs, shelled cobs, multifunctional device

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# ГРАФІЧНИЙ МЕТОД ОЦІНКИ ЕНЕРГОЗАТРАТ І ЯКОСТІ КОРМІВ ПІСЛЯ ПОДРІБНЕННЯ

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РЕЗЮМЕ

Проблема переробки фуражу завжди була важливою проблемою з точки зору енергії та якісної оцінки. Запропонований метод для графічного визначення енергоспоживання у залежності від ступеня або модуля помелу, який може бути застосований для попереднього розрахунку енергії і якісних оцінок кормових агрегатів для подрібнення та машини. Створений багатофункціональний подрібнювач, який поєднується з комбінованим робочим компонентом для подрібнення стебел і фуражного зерна, для малих і середніх фермерських господарств.

**Ключові слова:** різка, подрібнення, корм, енергозатрати, якість корму, багатофункціональний пристрій.

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# ГРАФИЧЕСКИЙ МЕТОД ОЦЕНКИ ЭНЕРГОЗАТРАТ И КАЧЕСТВО КОРМА ПОСЛЕ ИЗМЕЛЬЧЕНИЯ

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РЕЗЮМЕ

Проблема переработки фуража всегда была острой проблемой с точки зрения энергии и качественной оценки. Предложен был метод для графического определения энергопотребления в зависимости от степени или модуля помола, который может быть применим для предварительного расчета энергии и качественных оценок кормовых агрегатов для дробления и машины. Создан многофункциональный измельчитель, сочетанный с комбинированным рабочим компонентом для дробления тела стебель и фуражного зерна, для малых и средних фермерских хозяйств.

**Ключевые слова:** резка, измельчение, корм, энергозатрат, качество корма, многофункциональное устройство

## INTRODUCTION

The operational efficiency of the particular device is of prime importance in the production of agricultural and livestock products.

Devices for mechanical processing of fodder are generally specialized in purpose and type of working components. Rough (stem) fodder is cut by straw-ensilage cutters with disk or drum cutting apparatuses, grain fodder is ground by fodder grinders with hammer working components respectively, juicy fodder from the root-tuber group is cut by beet cutters and corn cobs are shelled by maize shellers [3,7,8].

Cutters and grinders most commonly used by farmers are not always effective since substantial energy is spent in the process of grinding. The nature of that energy usually remains hidden to the lay minds and its cost is paid for indirectly. The cost of the finished product is largely influenced by the market price of the different types of machines (cutters, fodder grinders, maize shellers and beet cutters) [5].

**Objectives.** It is known that obtaining quality fodder (as per zoological technical requirements) with minimum specific energy consumption relates to the implementation of a relevant principle of operation and working components along with theoretically and experimentally justified sizes and modes of operation. Classic apparatuses (disk and hammer) are not always suitable for efficient grinding of fodder especially for the needs of private and small-size farmers regardless of their permanent improvement [6, 7, 8]. Intensifying the process of grinding by applying new principles and working components that would provide sufficient productivity with low specific energy consumption and a possibility for comb-ined processing of grain, rough and juicy fodder is needed. Combining cutting, grinding and shelling with ejection of the mass features into a single compact construction of a universal machine might prove useful and cost effective for private farmers in market economy and competition.

Research on the process of grinding [1, 3, 5, 6] has found that the classic type and most common hammer fodder grinders with single stage grinding in a closed type working chamber (with screen) are not effective for processing rough fodder. This is of particular importance in grinding cornstalks and straw of higher moisture during the autumn-winter period. More efficient for the purpose would be the principle of cutting in an open type working chamber with preliminary rough grinding of the stems. Concerning energy, cutting is substantially influenced by the coefficient of sliding which depends on the way the edge of the cutter is formed and its positioning on the rotor. Hammers of particular thickness (2-10 mm) do not cut the stems but shred them, the result being lower productivity and higher energy consumption [3, 7, 8].

On the other hand, the principle of multiple hammer effect on the particles performed by blunt cutters (hammers) in a closed working chamber (with screen) is power efficient for grinding grain fodder. Thus specific quality indexes regarding particle size are also achieved.

Research on constructions with vertical shaft has found [3, 4, 8] that a higher intensification of the process of grinding is present due to the better utilization of the working components.

**Procedure.** Contemporary theories for grinding materials and particularly fodder are based upon the renowned «voluminous» and «surface» hypotheses explaining the relation between energy consumption and decreasing the volume $V$ or increasing the surface $S$ of the particles obtained. The physical picture of the process of destruction of materials might be viewed as a sequence of stages identical to Hooke's Law. At first, elastic deformations of particles appear, then plastic, and then their division to smaller ones, i.e. formation of new surfaces. Therefore the «voluminous» hypothesis is valid until the stage of destruction, i.e. in the field of elastic deformations while the «surface» one is valid after the stage of destruction, i.e. in the field of plastic deformations. Our research [1, 3, 6] has shown that the dependency obtained by R. Charles representing the relation between energy consumption and the result from the fodder grinding process summarizes the different hypotheses. It could successfully be applied for theoretical and practical justification of the basic parameters of working components and machines for grinding rough as well as grain fodder. For instance from R. Charles's differential equation:

(1) $dA = -C\dfrac{dx}{x^n}$,

By integrating is obtained

(2) $A = -C\dfrac{x^{1-n}}{1-n} = -C\dfrac{M^{1-n}}{1-n}$,

Or respectively

(3) $A = k\dfrac{\lambda^{n-1}}{n-1}$,

where $A, dA$ is the work for shredding and its change, respectively;

$x, dx$ – the initial particle size and its change;

$M, \lambda$ – the module and degree of grinding;

$C, k, n$ – coefficients characterizing the process.

## RESULTS AND DISCUSSION

A graphic method is proposed for building a hyperbole by one known point – Lм by means of the auxiliary rays 1, 2, 3, 4, 5, 6, 7, etc. (random number) drawn from the beginning of the coordinate system N. Straight lines parallel to the coordinate axes are drawn through the rays' crossing points with the straight lines parallel to the coordinate axes and passing through point Lм. The crossing points of these straight lines 1', 2', 3', 4', 5', 6', 7', etc. are the points of the sought hyperbole justifying the dependency q = *f*(M). The specific energy consumption $q$ for grinding, presented as the ratio of power required in *kW* to productivity in *t/h* is a basic criterion for optimization and comparison of various types of working components and machines. A way of fast and practical definition of its values for different particle sizes is shown on Figure 1. The figure shows that building the two dependencies $q = f(\lambda)$ и $q = f(M)$ requires knowing only one point $T_M$ or $L_M$, i.e. performing only one test under certain conditions after which the values for the required work with other modules or degrees of grinding could be determined fast and easily. The basic parameters of the new machines could be optimized for the same conditions. Point $N$ with ordinate $A$, corresponding to the energy consumption at idle, serves for beginning of the coordinate system.

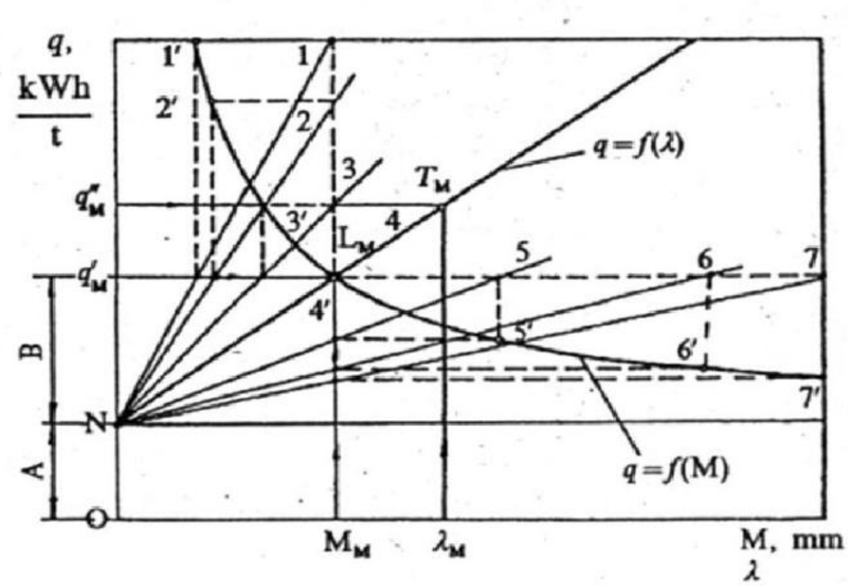



**Fig. 1.** Graphic building of the change of specific energy consumption $q$ depending on the module of grinding M or the degree of grinding $\lambda$ and method for determining it in other working conditions.

The exponent $n$ for the grinding process is defined at values $n>1$, which confirms the «surface» hypothesis of Rittinger as closest to its physical nature, i.e. with the decreasing of the module M and the increasing of the degree of grinding $\lambda$, the required work A will grow up. The experimentally obtained values of $n = 1{,}72 \div 2{,}17$ determine the general character of the dependencies (1) and (2) close to a hyperbole of the $A.M = const$ type and a straight line of the $A = a.\lambda + b$ type respectively [3,4].

Out of the power balance at grinding the efficiency $Eff$ could be determined by the known dependencies of Rebinder and Melnikov where

$$(4)\ Eff = \frac{A_s}{A_s + A_{ел}} = \frac{A_s}{A_s + A_v},$$

That can also be presented as

$$(5)\ Eff = \frac{C_s(\lambda - 1)}{C\left[C_s(\lambda - 1) + C_v.\lg\lambda^3\right]},$$

where $C, C_s, C_v$ are coefficients.

For cutting stem (rough) fodder by analogy

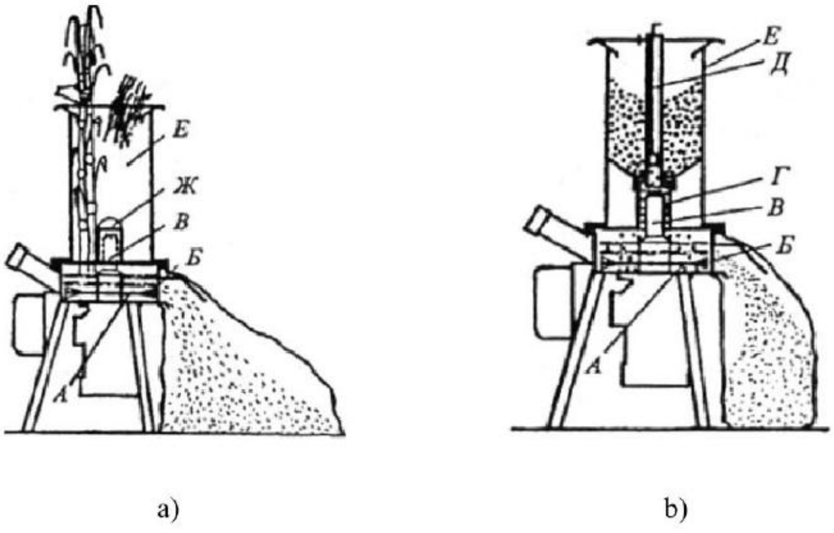
$$(6)\ Eff = \frac{A_p}{A_{уп} + A_p},$$

where the yield is $A_p$ (for cutting), and the loss is – $A_{уп}$ (for stuffing).

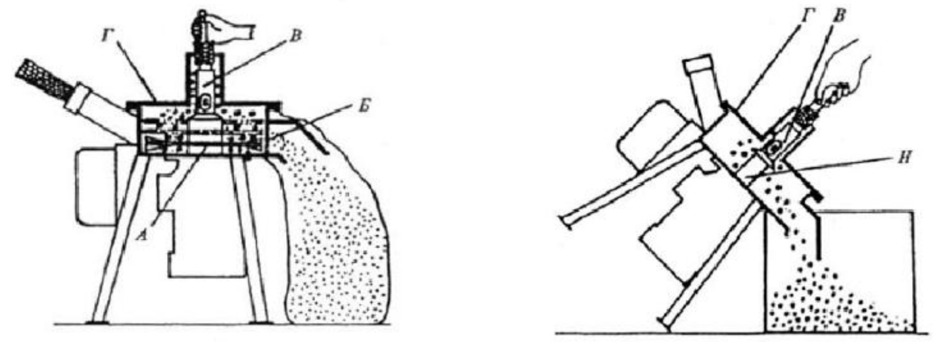
Out of the dependencies (4) and (6) the conclusion can be drawn that using working components only for elastic and plastic deformations (crushing, stuffing), i.e. destruction by hammers where $A_{уп}$ grows substantially, is ineffective. For zoological technical reasons using cutters in combination with hammers proves effective for softening the ground particles.

Based on known constructions and on many years' research [2, 3, 4, 5], a combined working component has been justified and designed for cutting, grinding and shelling various types of fodder. Especially for the needs of private farmers, a universal fodder cutter has been constructed with a number of different features such as cutting rough fodder, grinding grain and corn cobs, shelling corn cobs with or without simultaneous grinding of the grain, cutting root-tuber fodder as well as grinding plant debris and twigs of bushes and vines. It has been designed mostly for private livestock breeding and small livestock farms. The combined rotor makes it applicable also as a maize sheller. Maize grain can be ground simultaneously with shelling the cobs. There is also an option for grinding whole peeled or unpeeled cobs along with the shelled cobs. A range of models of various sizes with the justified multifunctional working component has been developed [4, 5]. The universal fodder grinder with multifunctional working component has been tested and approved by the Tractors and Agricultural Machines Testing Centre, Ruse.

The separate types of operations when working with the designed machine are shown with technological diagrams on Figure 2 (a, b, c, d).




a) b)




c) d)

**Fig. 2.** Technological diagrams for different modes of work with the universal machine with combined working component designed to perform several different operations:

a) grinding grain fodder; b) cutting rough and green fodder; c) grinding whole corn cobs or shelling them with simultaneous grinding of the grain; d) corn cobs shelling

As a result from the tests of the designed machine, the following key parameters have been justified:

- Rotor frequency – 2 880 $\text{min}^{-1}$;
- Installed power – 2,2 *kW* (220 *V*);
- Weight – 63 *kg*;

Productivity has been obtained as follows:

- For grinding maize grain with 4 *mm* screen – 400 *kg/h;*
- For grinding whole corn cobs with 5 *mm* screen – 180 *kg/h*;
- For simultaneous shelling and grinding the grain with 3 *mm* screen – 150 *kg/h*;
- For cutting straw – 200 *kg/h*.

An overview of the mass-produced fodder grinder ФУ-330 А is shown on Figure 3.

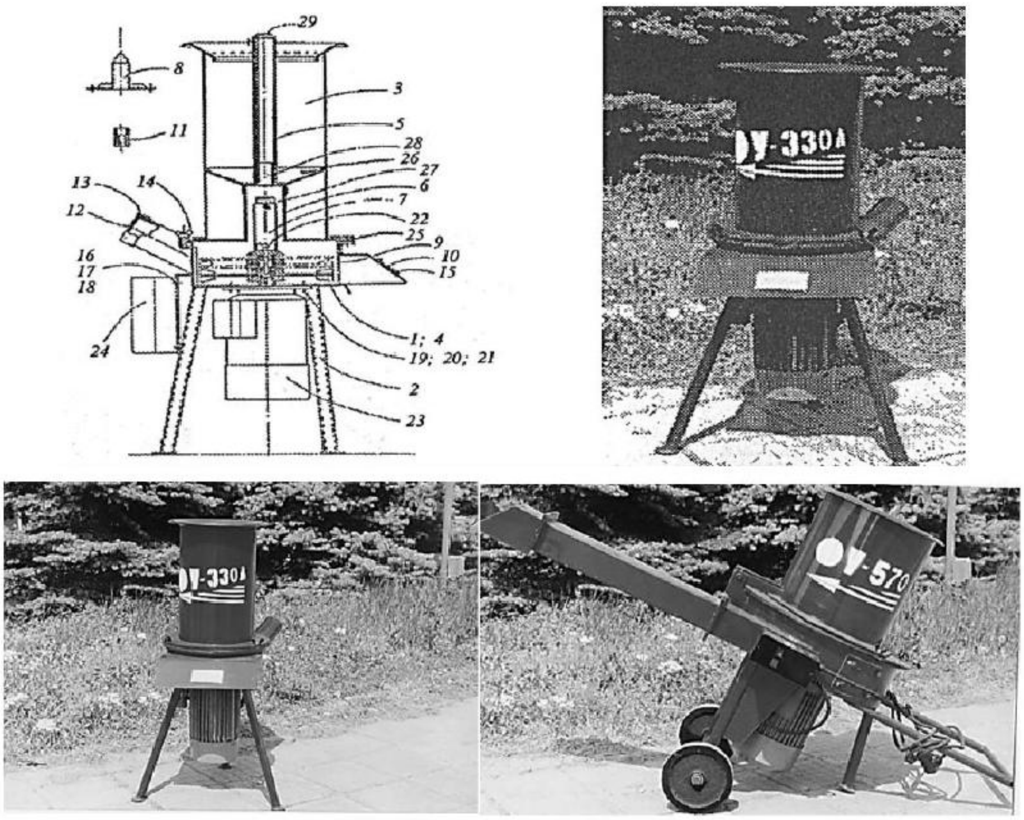



**Fig. 3.** Overview of the designed constructions FU-330 A and FU-570 with combined working component:

1;4 – combined working component with cutters, hammers and fan blades; 2 – frame with telescopic leg; 3 – receiving chamber (tank); 5 – air duct; 6 – lid with a cup; 7 – shelling apparatus with a set of nozzles 27; 8 – cone; 9 – screen; 10 – exhaust pipe with hatch 15; 11 – socket; 12 – pipe for whole cobs with cap 13; 14 – wing nut; 16,17,18 – fasteners for the electric starter 24; 19,20,21 – fasteners for the electric motor 23; 25 – sealing gasket; 26 – bottom for the grain; 28 – grain adaptor; 29 – valve

## CONCLUSIONS

A method has been justified for graphic determination of energy consumption depending on the degree or module of grinding that can be applied for preliminary power and qualitative evaluations of fodder grinding machines.

A construction of a multifunctional device has been justified and a range of grinding machines designed for cutting, grinding and shelling of various types of fodder that can be effectively implemented for the needs of small, medium-size and large livestock farms.

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