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Study of Energy Efficient Operation Modes by Construction of Energy Characteristics of the Main Technological Units of Oil Extraction Plants

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ABSTRACT: The article presents the results of studies carried out by the author, on the example of "YEVROSNAR" limited liability community, on the development of energy-saving measures in order to select the most energy-efficient modes of operation of equipment at fat-and-oil enterprises.

KEY WORDS: Power Supply System, Oil Press Unit, Disc Peelers, Roller Mills, Efficient Operation Mode, Power Consumption, Specific Power Consumption, Energy Characteristics.

I. INTRODUCTION

One of the possible ways to solve the problem of improving the reliability and accuracy of forecasts of energy and energy-economic indicators in the power supply systems of industrial enterprises is their forecasting, taking into account the relationship with other indicators characterizing the production process. When implementing this method, the basics of probability theory and mathematical statistics are used [1, 2].

The modes of electrical loads of individual units form the basis for the formation of electric power indicators, consumption levels and the nature of changes in electrical loads of industrial production. The study and correct assessment of the power consumption indicators of these units, taking into account their technical condition, mechanical and physicochemical features of the technological process, make it possible to correctly analyze the dynamics of the electrical load of the enterprise, identify reserves for saving electricity, and improve the accuracy of planning and forecasting [3, 7, 8].

Energy characteristics that express the dependence of energy consumption on output for a calendar period of time are built taking into account that the main indicator of industrial production, according to which planning, accounting and control is carried out, is the volume of output, in accordance with which the need for electricity should be determined [5, 6]. This is also justified by the fact that a change in the program in terms of output has the most systematic and significant impact on the specific power consumption and that these characteristics play an important role in choosing the most energy-efficient modes of equipment operation.

II. METHODOLOGIY

To build the energy characteristics of power consumption and specific power consumption, depending on productivity and other indicators, experiments were carried out on operating equipment.
Since the machines have different idling power due to different adjustment and lubrication, the studies were carried out on machines with average idling power values.
In the production of cottonseed oil, machines and devices specific to this industry are used - various types of seed cleaners, disc hullers, bitter separators, roller machines, prepress units, extractors, various filters and oil separators, and others [12].

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The most energy-intensive are the oil pre-extraction units - forpresses, which consume more than 19.3% together with braziers, and disk peelers with rollers, consuming 13.9% and 6.5%, respectively, of the total plant power consumption. The paper presents the results of our experimental studies of the energy characteristics of individual units, including not only the formal results of the experiments, but also the physical dependencies arising from the essence and properties of each equipment.

Processing of experimental materials for the construction of energy characteristics was carried out using the methods of mathematical statistics and probability theory [9, 10]. It is established that the performance of the aggregates obeys the law of normal distribution.

Energy characteristics of the oil press unit.

The oil press unit is designed for pre-pressing oil. Studies of the energy characteristics of power consumption (P) and specific energy consumption (d) depending on the hourly productivity (A). The dependence of the power consumption of the press on various technological factors is expressed as

$$P=f\,(b, n, w, \varepsilon_{pr}, V_k, A_k) \qquad (1)$$

where b is a coefficient depending on the temperature of the kernel and its humidity;
n - frequency of rotation of the screw shaft, rpm;
w - kernel moisture content, %;
ε_{pr} - practical degree of pulp compression in the press;
V_k - the speed of movement of the pressed kernel, m/s;
A_k - the amount of kernel entering the press, t/h.

According to technological requirements, the temperature and humidity of the kernel must have a constant value with narrow limits of deviations, therefore, the coefficient (b) and (w) within the regulated limits does not have a significant effect on the deviation of power consumption.

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Under production conditions, the number of revolutions of the screw shaft (n), the practical degree of kernel compression (V_{pr}) and its speed (V_k) for a certain press design and each specific mode are also relatively constant values.

Thus, all indicators of formula (1), except for (A_k) for each type of press are relatively constant, the power consumption of the press depends to the greatest extent on the amount of kernel entering the press, i.e. from loading the press with goods. However, the construction of energy characteristics, taking into account the weight of the kernel, is difficult due to the complexity of determining the amount of kernel entering the press.
The recalculation of the productivity of the press to the indicator for seeds can be simplified, but with sufficient accuracy for practical purposes, using the cake yield coefficient K_c according to the formula [7]:

$$A_s = \frac{A_c}{K_c} \ \text{t/h} \qquad (2)$$

Based on this, we consider the energy characteristics of the press as a function of the produced cake, i.e. $P=f(A_c)$ and $d=f(A_c)$.
Power demand equation

$$P_P = 6,3 - 2,26 \cdot A_c + 16,76 \cdot A_c^2 \qquad (3)$$

The specific power consumption for the production of a ton of cake is determined from the expression

$$d_P = -2,26 + 16,76 \cdot A_c + 6,3 \cdot \frac{1}{A_c} \qquad (4)$$

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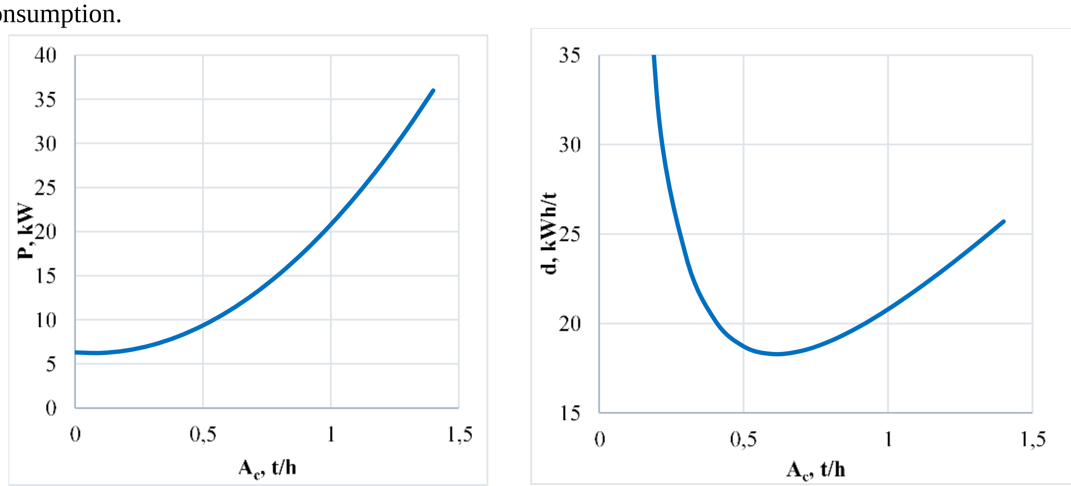
Figure 1 shows the characteristics built according to equations (3) and (4). It can be seen from the $P=f(A_c)$ curve that upon reaching 0.6 t/h (43%), the power begins to grow faster than the productivity, resulting in an increase in the specific power consumption.



a) b)

Fig. 1. Energy characteristics a) $P=f(A_c)$ and b) $d=f(A_c)$ of the oil press unit with cake thickness δ = 9 mm.

The most energy-efficient mode for this unit is 43% load, at which the minimum level of specific electricity consumption of 16.4 kWh/t is achieved.
With a decrease or increase in load, the specific consumption increases. At maximum load, the specific consumption increases by 55% and is equal to 25.5 kWh/t.

Energy characteristics of disk peelers and rolling machine. At oil plants, disc hullers are used for hulling cotton seeds, and roller mills are used for kernel grinding. The equations for the energy characteristics of the consumed power and the specific power consumption for the first peeling peelers are obtained.

$$P_{pe1} = 4,82 + 3,12 \cdot A_s \quad (5)$$

$$d_{pe1} = 3,12 + 4,82 \cdot \frac{1}{A_s} \quad (6)$$

second peeling

$$P_{pe2} = 8,32 + 6,5 \cdot A_s - 0,47 \cdot A_s^2 \quad (7)$$

$$d_{pe2} = 6,5 - 0,47 \cdot A_s + 8,32 \cdot \frac{1}{A_s} \quad (8)$$

and for grinding the kernel

$$P_r = 7,4 + 10,83 \cdot A_s - 2,772 \cdot A_s^2 + 0,285 \cdot A_s^3 \quad (9)$$

$$d_r = 10,83 - 2,772 \cdot A_s + 0,285 \cdot A_s^2 + 7,4 \cdot \frac{1}{A_s} \quad (10)$$

Recalculation per ton of seeds is made through the kernel yield coefficient K_k according to the expression [7]:

$$A_s = \frac{A_k}{K_k} \quad (11)$$

The yield coefficient of the kernel is determined taking into account the yield of litter of K_{lit} and husks of K_h

$$K_k = 1 - \left(K_{lit} + K_h\right). \quad (12)$$

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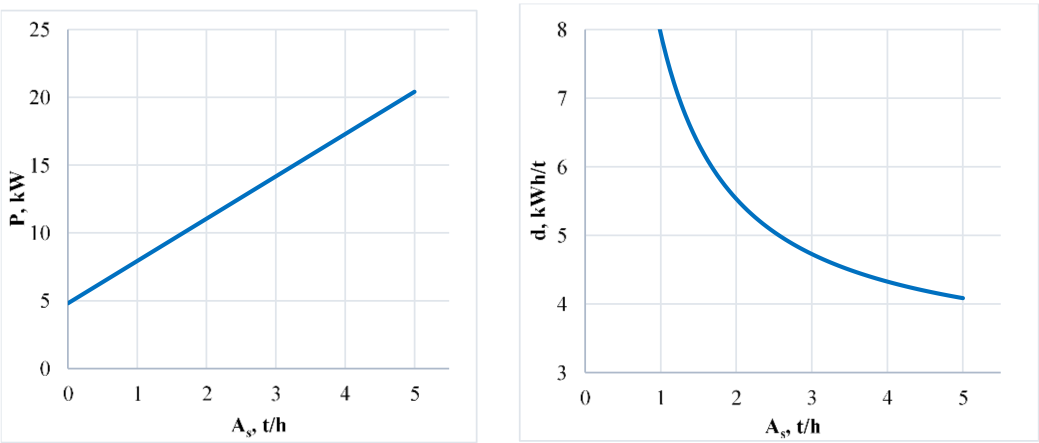
With K_{lit}=0.019; K_h=0.321; K_k=0.66. Calculations made according to the data of operation of "Yevrosnar" oil extraction plant coincide with the data of technological maps.

The analysis shows that the power consumption of the disk peeler of the first peeling changes according to a straight-line law - the crushing force is the greater, the more of them enter the peeler (Fig. 2).

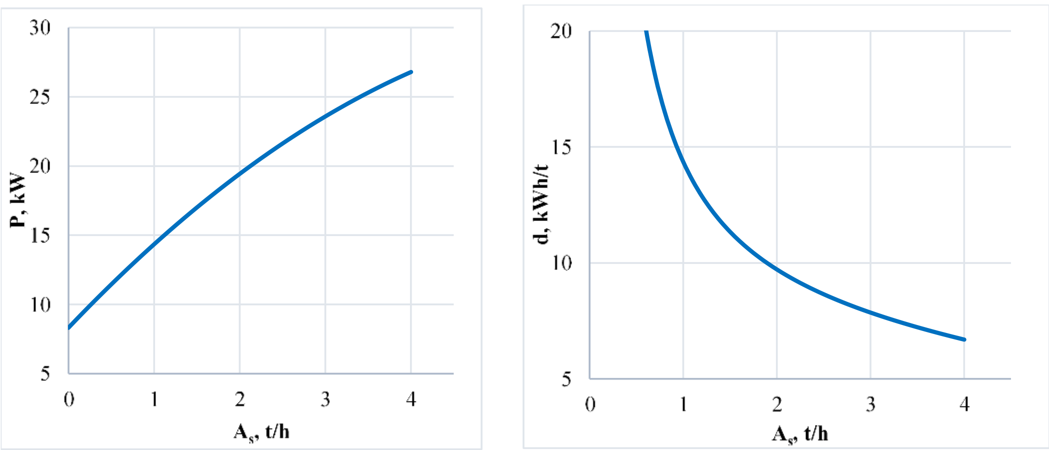


a) b)

Fig. 2. Energy characteristics a) $P=f(A_s)$ and b) $d=f(A_s)$ of the disc peeler of the first peeling.

The pattern of load changes depending on the number of seeds remains the same over the entire range of productivity due to the fact that the disc gaps are not clogged when seeds of regulated moisture and pubescence are supplied.

The power consumption curve of the hullers of the second hulling has a convex shape (Fig. 3). The straightness of the characteristic is maintained up to 90% of the performance. This can be explained by the fact that, firstly, the gap between the knives is smaller compared to the huller of the first peeling, since the rest of the seeds collapse and, secondly, the rushanka has a lower bulk weight compared to the seeds. A further increase in productivity leads to a slight increase in energy consumption, as the knives become clogged and incomplete caving occurs. The inflection point $P=f(A_s)$ characterizes the critical situation, at which the loss of oil with the husk increases (the removal of the kernel with the husk due to the poor performance of the shakers).



a) b)

Fig. 3. Energy characteristics a) $P=f\ (A_s)$ and b) $d=f(A_s)$ of the disk peeler of the second peeling.

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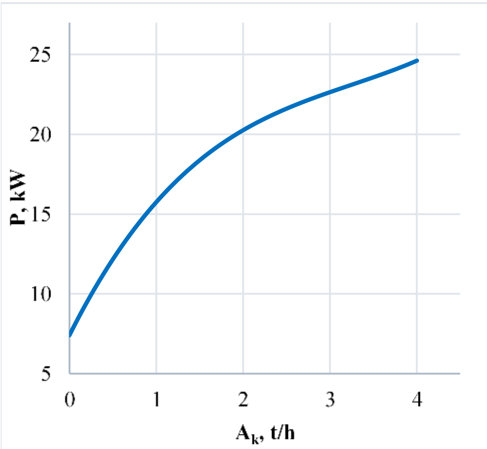
The increase in power at the load of the sheller of the second peeling compared to the first is due to the reduced gap and greater efforts to peel the remaining seeds and rushanka.

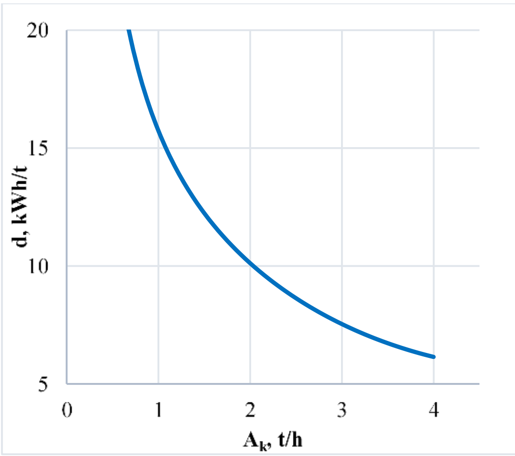
In the load zone from 2 to 3 t/h, for each percentage increase in productivity, the power consumption of the huller of the first peeling increases by 0.92%, and for the hullers of the second peeling - by 0.43%.

The most advantageous mode of operation of the hullers of the first hulling is the maximum load corresponding to the minimum specific consumption equal to 4.1 kWh/t (at A_s=5 t/h).

For hullers of the second hulling, it is desirable to work at 90% load with the best quality indicators and a slightly increased (by 10%) specific power consumption equal to 6.8 kWh/t (at A_s=3.6 t/h).
On fig. 4 shows the energy characteristics of the roller mill.



a)



b)

Fig. 4. Energy characteristics a) $P=f(A_k)$ and b) $d=f(A_k)$ of the roller mill.

For this equipment, the most energetically favorable mode will be at maximum load, however, according to the conditions of the permissible level of grinding the kernel, the productivity should not exceed 85-90% (see Fig. 4), which corresponds to an increased level of specific power consumption compared to the minimum by 36-40% .

III. CONCLUSION

1. The most favorable energy mode for oil presses is 43% load, at which the minimum level of specific power consumption of 16.4 kWh/t is achieved. With a decrease or increase in load, the specific consumption increases.
2. The most advantageous mode of operation of the hullers of the first hulling is the maximum load corresponding to the minimum specific consumption equal to 4.1 kWh/t (at A_s=5 t/h).
3. The most advantageous mode of operation of second peeling hullers is desirable to operate at 90% load with the best quality indicators and slightly increased (by 10%) specific power consumption equal to 6.8 kWh/t (at A_s=3.6 t/h).
4. For a roller mill, the most energetically favorable mode will be at maximum load (6.1 kWh/t), however, according to the conditions of the acceptable level of core grinding, the productivity should not exceed 85-90%.

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