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Research on Impact of Technological Factors on Electric Power Loads of Cement Production

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ABSTRACT: The article discusses the influence of technological factors on the electrical load of cement production. A multifactor correlation and regression analysis is used to highlight the main factors affecting the electrical load of cement production. An analytical power formula was obtained by which it is possible to calculate and analyze the electrical load in all modes of operation of the pipe mill. Estimated wear of grinding bodies, its effect on the electrical load, proposed a rational schedule of loading.

KEYWORDS: cement industry, electric load, electric power, pipe mills, grinding bodies, grinding, clinker, cement, wet method, multivariate regression analysis.

I. INTRODUCTION

Electric power indicators of cement production – power (P), consumption (W) and specific power consumption (d) indicators, the level of which depends on many random, both energy and technological factors. These factors (x_i) act on the resulting trait, i.e. the function (P, W, d), not separately in isolation, but together, and have a complex effect.

The decomposition of the level of electric power indicators by factors and the determination of the influence of each of them could be carried out using well-known statistical methods: the grouping method, the index method, the method of separate study of factors, or the method of sequential - chain decomposition of factors.

II. METHODS

The above methods have a number of disadvantages, which are considered in the specialized literature. The most acceptable is the use of multiple correlation and regression analysis, which makes it possible to determine the complex effect of all factors.

Thus, it is necessary to find an analytical model expressing the dependence of the function (d, P, W) on the factors (arguments) determining it, i.e. find function

$$Y=f\,(x_1,x_2\ldots x_n)\,, \qquad (1)$$

Reveal the nature and degree of influence of arguments on the function to identify the main (most significant) factors and exclude minor, insignificant of them. The organization of passive experiments should consist of the following list:

I. Baseline information gathering:
- time sampling;
- reliability of the baseline data;
- quantitativeness (each phenomenon should be expressed single-valued, by a certain number or system of numbers);
- sufficiency in quantity;
- studying the structure of selected objects;
- exclusion of sharply distinguished (abnormal) observations;
- uniformity of input data.

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II. Primary processing of baseline information (checking the normality of the distribution and the absence of autocorrelation, etc.).

III. Selection of communication form.

IV. Calculations according to probability theory and mathematical statistics.

Studying the available operational information, on the basis of the research results and qualitative analysis, to analyse the influence of factors on average power (Y_1) and electric energy consumption (Y_2), time factors of cement mills (x_1) rotary kilns (x_2) compressors (x_3), raw mills (x_4), smoke exhausters (x_5) and the fill factor of cement mills with grinding bodies (x_6) were selected.

The time between two measurements in connection with the all-day continuous operation of cement plants can be taken equal to 24 hours (day). The possibility of such time quantization is confirmed by the availability of operational information in reporting data, operational journals, etc.

The necessary number of tests, taking into account the correlation of related values, accounting defects, possible anomalous values, calculated according to [1, 2, 3, 4] amounted to:

$$\frac{N-H}{H} \geq 20 \qquad (2)$$

from which $$N \geq 2/H \qquad (3)$$

where H – number of factors.

The normalcy of distribution hypothesis was tested by the Pearson criterion $\chi 2$, which allows to judge more strictly the normalcy of distribution of the considered set of values than other generally accepted criteria.

When testing the normalcy of distribution hypothesis, the observed empirical distribution of the statistical series is compared with the expected theoretical distribution and, depending on the deviation of the empirical distribution from the theoretical distribution, the normalcy of distribution hypothesis is either accepted or rejected. The conformity assessment of the empirical distribution and theoretical distribution is checked by the formula:

$$\chi^2 = \sum \frac{(m_э - m_т)^2}{m_т} \qquad (4)$$

For values of $\chi^2_t \geq \chi^2_e$, the discrepancies between empirical and theoretical frequencies ($m_т$) are not random and the hypothesis of normal distribution is rejected, and for $\chi^2_e < \chi^2_t$ the discrepancies are random, and the empirical distribution obeys the normalcy law.

III. RESULTS

The number of degrees of freedom K is equal to the number of groups in the empirical distribution (there are 14 in this problem) without the number of links superimposed on frequencies in the process of constructing a theoretical distribution. In this problem 3, such relations (equality of the sum of frequencies, arithmetic mean variance).

$$k=14-3=11 \qquad (5)$$

From tables VIII [6] the value of χ^2 while k=11 is:

$$\chi^2_{т.0,05} = 19,67$$

The calculated values of $\chi^2_{расч.}$=1,02 are much smaller than the tabulated values. Therefore, the empirical distribution is in good agreement with the theoretical one, i.e. our assumption that the distribution of average power obeys the normal law has been confirmed. The agreement of the empirical distribution of function and theoretical is clearly visible in Figure 1.

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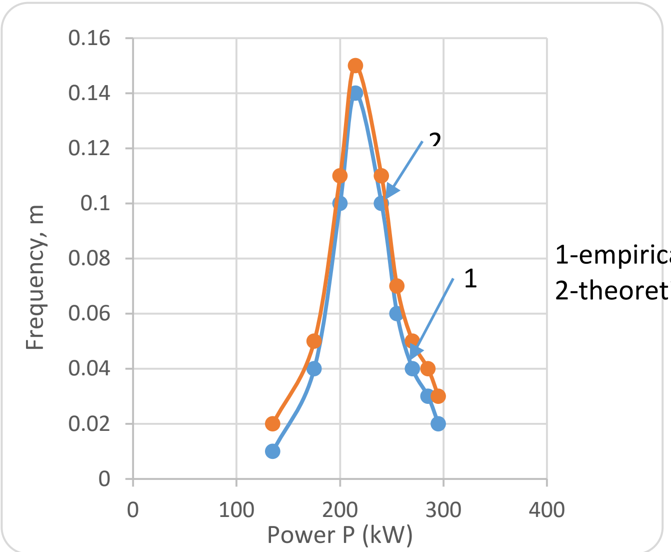
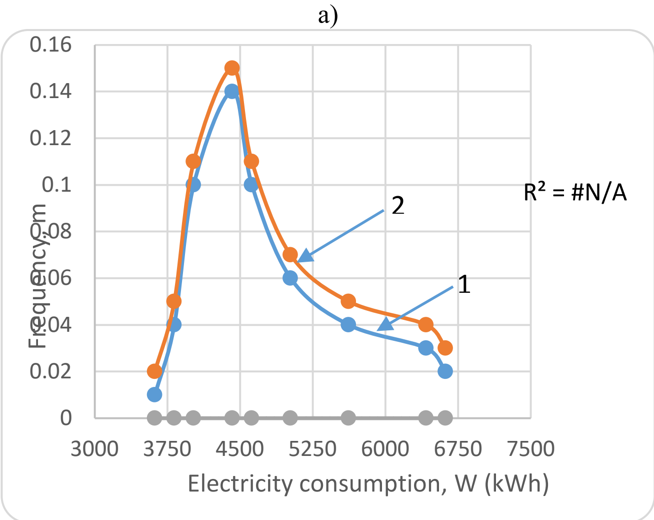
IV. DIAGRAMMATIC REPRESENTATION



a)



b)

Figure 1. Average power distribution curves

a) electric power consumption, b) cement production

The normalcy of distribution is confirmed in the same way as for other functions (average power, specific energy consumption, etc.), and for the arguments included in the analysis.

There is no autocorrelation between adjacent values of a function and influencing factors. The linearity of the mathematical model of power and electric power consumption is proven by researches.

Therefore, the function can be most fully described by the following polynomial of the first degree

$$Y=a_0+a_1x_1+a_2x_2+\dots a_nx_n \qquad (6)$$

Due to the linearity of the mathematical model, the solution of the problem is simplified, and the possibility of its practical use is increased.

In general, for cement production, due to the relative stationarity and smooth functioning of the technological regimes of energy-intensive units, the postulation of a multidimensional normal distribution for process factors is valid, and thus a correlation model of energy consumption is possible.

The use of multiple correlation and regression analysis made it possible to identify the main factors affecting the electrical loads of cement production – time factor of cement mills, rotary kilns, raw mills, compressors to obtain a polynomial model of cement production capacity with sufficient accuracy for practical use.

V. CONCLUSION

The results of our studies of the modes of electric load of cement production are as follows:

1. The daily graphs of the electrical loads of the cement enterprise are stable, straightforward, the load factor is quite high: in the shops - 0.85, and in the enterprise - close to one.

2. The electrical load of the main energy-intensive units (rotary kilns, cement and raw mills), as well as the main shops of the enterprise, are almost independent of productivity.

3. An analytical power formula is obtained, according to which it is possible to calculate and analyze the electric load for all operating modes of the tube mill.

4. The wear of grinding bodies, its effect on the electric load is estimated, a rational loading schedule is proposed.

5. The dependency of the group electrical load of the utilization coefficient of the main units is established.

6. Computer-based research using multiple correlation and regression analysis identified:

a) the most significant factors - the utilization rate of rotary kilns, compressors of cement and raw mills, affecting the electrical load of the enterprise.

b) a polynomial model in the first degree of average power with sufficient accuracy for practical use in cement production.

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PROFESSIONAL SKILLS AND FIELDS OF SCIENTIFIC INTEREST

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• Study on energy saving and efficiency in buildings and industrial plants
• Prediction of energy consumption
• The use of modern information approaches (fuzzy logic, artificial neural networks, etc.) in the energy sector
• Experience in the use of necessary instruments (electric and gas analyzer, thermal, and others), regulations, the technical and design documentation to conduct energy audits