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MATHEMATICAL MODEL OF THE EFFECT OF MODIFIERS ON GRAY CAST IRON ALLOYS

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Abstract
This article presents a research analysis of the effect of the CuP2 element as a modifier on the wear resistance of the gray cast iron low – alloyed liquid cast iron alloy. Based on the obtained results, the increase in the number of crystallization centers of the cast alloy and the formation of a fine granular structure led to a significant increase in the wear resistance property of the cast product.

Keywords: modifier, wear resistance, low – alloyed, crystallization centers, Lagrange's interpolation polynomial, CuP2, Cramer's method, matrix.

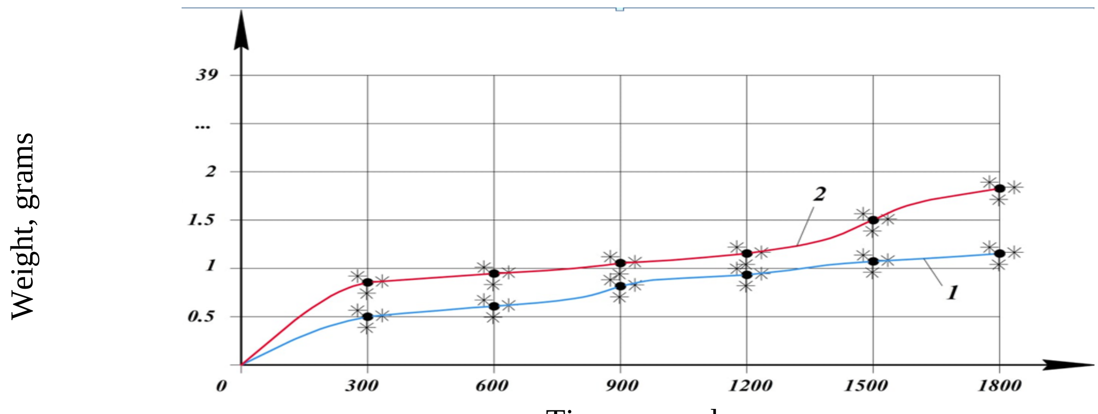
Introduction

Today, thin-walled parts are the main used and very cheap parts in manufacturing enterprises. During work, they faced various stresses and strains. In addition, the geometric dimensions and material of the thin-walled details must ensure that they can withstand the heaviest loads that occur during the shear sequence. Another important factor related to the service life of the shaft is the wear resistance of its material.

Main part

The diagram shown in Picture 1 was used as a basis for creating a mathematical model of the effect of copper phosphide added as a modifier to gray cast iron alloys on the wear resistance property .

In the experiments, we make a mathematical expression of the corrosion of copper phosphide cast samples in the same conditions, which are determined in a special device for up to 30 minutes [1 – 3].



Picture 1. Wear resistance 1 – the sample poured with the addition of modifier, 2 – the sample taken without adding the modifier, the graph of the weight change over time

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This device can be used to determine the wear resistance of all types of metals. It's easy to use, with the option to control the speed of the diamond disc with automatic power-off at a selected number of revolutions. It is designed to carry out studies of special grinding disk speeds of 400, 525, 650, 775 and 900 revolutions per minute.

Picture 2. General view of a special device with a diamond disc for determining the wear resistance of samples

The problem is brought to the system of algebraic equations, and by determining the unknown coefficients, it can be expressed in the form of a polynomial with the help of the decay function, that is, we construct the interpolation polynomial of Lagrange.

m=f(t) in the function;

t – minute

m – gram

$$\begin{cases} 5^6 t_1 + 5^5 t_2 + \ldots. + 5t_6 = 0.8 \\ 10^6 t_1 + 10^5 t_2 + \ldots. + 10t_6 = 0.9 \\ 15^6 t_1 + 15^5 t_2 + \ldots. + 15t_6 = 0.8 \\ 20^6 t_1 + 20^5 t_2 + \cdots. + 20t_6 = 1.3 \\ 25^6 t_1 + 25^5 t_2 + \ldots. + 25t_6 = 1.5 \\ 30t_1 + 30^5 t_2 + \ldots. + 30t_6 = 1.8 \end{cases}, \qquad (1)$$

We find the unknown values by bringing the system of equations (1) into matrix form and using Cramer's method of solving a system of complex linear equations. Initially, the determinants of the matrix formed using the system of equations were determined $\Delta, \Delta_1, \Delta_2, \Delta_3, \Delta_4, \Delta_5, \Delta_6$.

$$\Delta = \begin{vmatrix} 15625 & 3125 & 625 & 125 & 25 & 5 \\ 1000000 & 100000 & 10000 & 1000 & 100 & 10 \\ 11390625 & 759375 & 50625 & 3375 & 225 & 15 \\ 640000000 & 3200000 & 160000 & 8000 & 400 & 20 \\ 244140625 & 9765625 & 390625 & 15625 & 625 & 25 \\ 729000000 & 24300000 & 810000 & 27000 & 900 & 30 \end{vmatrix} = -1.186523437499922e + 22, \qquad (2)$$

$$\Delta_1 = \begin{vmatrix} 0.8 & 3125 & 625 & 125 & 25 & 5 \\ 0.9 & 100000 & 10000 & 1000 & 100 & 10 \\ 1.1 & 759375 & 50625 & 3375 & 225 & 15 \\ 1.3 & 3200000 & 160000 & 8000 & 400 & 20 \\ 1.5 & 9765625 & 390625 & 15625 & 625 & 25 \\ 1.8 & 24300000 & 810000 & 810000 & 900 & 30 \end{vmatrix} = -1054687500000000, \quad (3)$$

$$\Delta_2 = \begin{vmatrix} 15625 & 0.8 & 625 & 125 & 25 & 5 \\ 100000 & 0.9 & 10000 & 1000 & 100 & 10 \\ 11390625 & 1.1 & 50625 & 3375 & 225 & 15 \\ 64000000 & 1.3 & 160000 & 8000 & 400 & 20 \\ 244140625 & 1.5 & 390625 & 15625 & 625 & 25 \\ 729000000 & 1.8 & 810000 & 27000 & 900 & 30 \end{vmatrix} = -110742187499996930, \quad (4)$$

$$\Delta_3 = \begin{vmatrix} 15625 & 3125 & 0.8 & 125 & 25 & 5 \\ 100000 & 10000 & 0.9 & 1000 & 100 & 10 \\ 11390625 & 759375 & 0.1 & 3375 & 225 & 15 \\ 64000000 & 3200000 & 1.3 & 8000 & 400 & 20 \\ 244140625 & 9765625 & 1.5 & 15625 & 625 & 25 \\ 729000000 & 24300000 & 1.8 & 27000 & 900 & 30 \end{vmatrix} = 4535156250000302000, \quad (5)$$

$$\Delta_4 = \begin{vmatrix} 15625 & 3125 & 625 & 0.8 & 25 & 5 \\ 1000000 & 100000 & 10000 & 0.9 & 100 & 10 \\ 11390625 & 759375 & 50625 & 1.1 & 225 & 15 \\ 640000000 & 3200000 & 160000 & 1.3 & 400 & 20 \\ 244140625 & 9765625 & 390625 & 1.5 & 625 & 25 \\ 729000000 & 24300000 & 810000 & 1.8 & 900 & 30 \end{vmatrix} = -913623046687499840000, \quad (6)$$

$$\Delta_5 = \begin{vmatrix} 15625 & 3125 & 625 & 125 & 0.8 & 5 \\ 1000000 & 100000 & 10000 & 1000 & 0.9 & 10 \\ 11390625 & 759375 & 50625 & 3375 & 1.1 & 15 \\ 640000000 & 3200000 & 160000 & 8000 & 1.3 & 20 \\ 244140625 & 9765625 & 390625 & 15625 & 1.5 & 25 \\ 729000000 & 24300000 & 810000 & 27000 & 1.8 & 30 \end{vmatrix} = 930102539062443800000, \quad (7)$$

$$\Delta_6 = \begin{vmatrix} 15625 & 3125 & 625 & 125 & 25 & 0.8 \\ 1000000 & 100000 & 10000 & 1000 & 100 & 0.9 \\ 11390625 & 759375 & 50625 & 3375 & 225 & 1.1 \\ 640000000 & 3200000 & 160000 & 8000 & 400 & 1.3 \\ 244140625 & 9765625 & 390625 & 15625 & 625 & 1.5 \\ 729000000 & 24300000 & 810000 & 27000 & 900 & 1.8 \end{vmatrix} = -4.765869140624638e+21, \quad (8)$$

2 – 8 functions by solving the expression of the matrices, the following values of the unknowns were determined [4 – 6],

$$t_1 = \frac{\Delta_1}{\Delta} = \frac{1054687500000000}{-1.186523437499922e+22} = -\frac{4119873046875}{46348571777340700000}$$

$$t_2 = \frac{\Delta_2}{\Delta} = -\frac{-110742187499996930}{-1.186523437499922e+22} = \frac{144195556640621}{15449523925780234000}$$

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$$t_3 = \frac{\Delta_3}{\Delta} = \frac{4535156250000302000}{-1.186523437499922e+22} = -\frac{79086848667695}{206913266863128130}$$

$$t_4 = \frac{\Delta_4}{\Delta} = -\frac{-913623046687499840000}{-1.186523437499922e+22} = \frac{278815627098083}{3620982170104742 0}$$

$$t_5 = \frac{\Delta_3}{\Delta} = \frac{930102539062443800000}{-1.186523437499922e+22} = -\frac{1774029806256187}{22631138563154640}$$

$$t_6 = \frac{\Delta_4}{\Delta} = -\frac{-4.765869140624638e+21}{-1.186523437499922e+22} = \frac{1136271748691711}{2828892320394330}$$

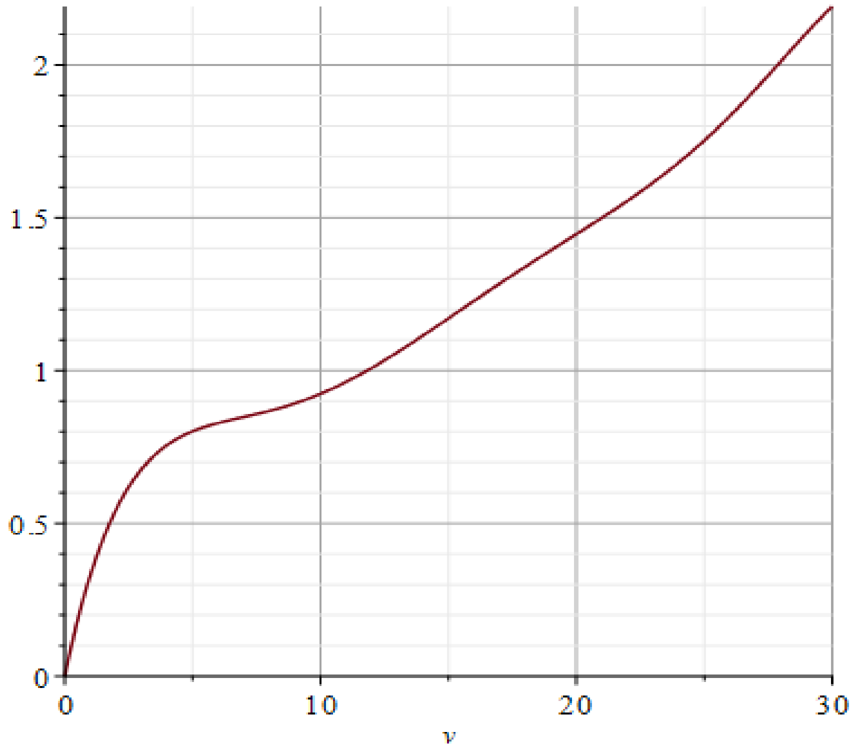
The following values were calculated from the equations:

$$t_1 = -8.89{\cdot}10^{-8},\ t_2 = 9.33{\cdot}10^{-6},\ t_3 = -3.82{\cdot}10^{-4},$$
$$t_4 = 7.7{\cdot}10^{-3},\quad t_5 = -0.078,\quad t_6 = 0.4$$

Using the found values, we construct the function of the dependence of the amount of wear on the front surface without introducing copper phosphide as a modifier in gray cast iron as follows:

$$m = (-8.89{\cdot}10^{-8})t^6 + (9.33{\cdot}10^{-6})t^5 - (-3.82{\cdot}10^{-4})t^4 + (7.7{\cdot}10^{-3})t^3 - 0.078t^2 + 0.4t \quad (9)$$

Using the given values, the graph shown in Picture 1 was created using the Maple 2017 program,



Pic 3. Mathematical model based on research results correspondence to actual results.

Conclusio

Based on the results of the research, it was found that the wear resistance was significantly improved under the influence of the copper phosphide element added as a modifier to the alloy composition in the amount of 0.1 – 0.5%. The results obtained based on the results of practical research were compared with the results obtained based on mathematical models. The results are confirmed to be compatible.

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