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EVALUATION OF PHYSICO-MECHANICAL PROPERTIES OF HIGH-CHROMIUM TOOL STEELS MODIFIED WITH HARRINGTON METHOD

S.A. Atroshenko[1*], I.A. Korolyov[2], N. Didenko[3]

[1]Institute of Problems of Mechanical Engineering of Russian Academy Sciences,

Bolshoj pr. 61, V.O., St. Petersburg, 199178, Russia,

[2]Saint-Petersburg State Economic University, Sadovaya str.21, St. Petersburg, 191023, Russia

[3]Peter the Great St. Petersburg Polytechnic University,

Politekhnicheskaya str. 29, 195251, St. Petersburg, Russia

*e-mail: satroshe@mail.ru

Abstract. The qualimetric evaluation of high-chromium tool steels with application of modified desirability function was performed. It was shown that high qualitative performance was demonstrated by low carbon steels additionally alloyed with rare-earth metals, as well as optimally heat-treated steels. The methodologies for assessing the economic characteristics of high-chromium tool steels were proposed. The first technique is an assessment of the production cost of high-chromium tool steels in its early stages. The second technique is a value analysis of technological equipment, whose manufacturing needs high-chromium tool steels.

1. Introduction

The most important issues related to the development of cold stamping processes are the tools, technological equipment and the materials from which they are made, whereas they form the basis, which provides quality at the initial stages of manufacturing of any product. Therefore the most important role in mechanical engineering plays tooling, equipment and their functionality. Especially important task is increasing the tool durability while processing new and difficult deformable materials. Increased tool durability reduces the downtime of the equipment and the time for necessary adjustments as well as costs for production and repair. Also it reduces product costs and improves the quality of the produced parts.

The research is based on high chromium instrumental steel type Cr-12, obtained through optimization of alloying and heat treatment [1]. The quality of these steels was evaluated by specially modified desirability function method.

2. The economic evaluation of high-chromium tool steels

The usage of high chromium tool steel in the enterprise should be justified not only by the strength, technical and operational properties of steel, but also must be economically justified.

The cost of production of the alloy steel depends on the chemical composition of steel, the type of semi-finished product and its size. To a first approximation, the comparative cost of production of the alloy steel {L1X1, L2X2, … , LnXn} can be estimated, based on data of A.P. Gulyaev [2]. The comparative production costs are proposed to estimate by the formula:

$$C_{st} = 0{,}01[C_{Fe}(1-\sum X_i) + \sum C_i X_i], \quad (1)$$

Table 2. Indicators of desirability and non-dimensional auxiliary indicators.

Steel grade, thermal treating mode	Hardness HRC		Average tool durability T, min.		Carbide grade of steel	
	y	Q	y	Q	y	Q
According to the experimental data						
70Cr12VNbZr	4.5	0.80	2.453	0.67	4.5	0.80
110Cr12VNbZr	4.5	0.80	3.029	0.72	3.33	0.74
60Cr9Mo2WVZr	1	0.37	4.5	0.8	4.5	0.80
According to the regulatory specifications						
Cr12V1	2.75	0.70	1	0.37	1	0.37

The modification of the method. The formula for the calculation of complex desirability has been modified by the introduction of economic expedience coefficients of the researched material. The formula of complex desirability is as follows:

$$\mathbf{Q} = \sqrt[n]{\prod_{i}^{n} q_i k_i},$$

where n – the number of single desirabilities; q – the indicator of single desirability; k_i – the coefficient of economic expedience of the property of the material.

Taking the mechanical properties of high-chromium tool steels (tool durability, hardness, carbide grade) and related factors of economic expedience of these properties as an example, the following results were obtained:

$$\mathbf{Q}_{70Cr12VNbZr} = \sqrt[3]{0,67 \cdot 2,37 \cdot 0,80 \cdot 0,98 \cdot 0.80 \cdot 3,8} = 1,55;$$

$$\mathbf{Q}_{110Cr12VNbZr} = \sqrt[3]{0,72 \cdot 2,85 \cdot 0,80 \cdot 0,97 \cdot 0,74 \cdot 1,9} = 1,3;$$

$$\mathbf{Q}_{60Cr9Mo2WZr} = \sqrt[3]{0,80 \cdot 3,83 \cdot 0,37 \cdot 0,82 \cdot 0,80 \cdot 3,4} = 1,36;$$

$$\mathbf{Q}_{Cr12V1} = \sqrt[3]{0,37 \cdot 1,0 \cdot 0,70 \cdot 1,0 \cdot 0,37 \cdot 1,0} = 0,46.$$

Table 3. Single and complex indicators of desirability of the researched steels.

Steel grade, thermal treating mode	Single desirability indicators of various properties			Complex desirability index
	Average tool	Hardness HRC	Carbide grade	
70Cr12VNbZr	0.67 (good)	0.80 (excellent)	0.80 (excellent)	1.55
110Cr12VNbZr	0.72 (good)	0.80 (excellent)	0.74 (good)	1.3
60Cr9Mo2WVZr	0.80 (excellent)	0.37 (satisf.)	0.80 (excellent)	1.36
Cr12V1	0.37 (satisf.)	0.70 (good)	0.37 (satisf.)	0.46

The analysis of the desirability indicators shows that the highest indicator of hardness was obtained with the steels 70Cr12VNbZr and 110Cr12VNbZr. The steel Cr12V1 shows good performance whereas the steel 60Cr9Mo2WZr performs only satisfactory. But when such mechanical property as tool durability is analyzed the steel 60Cr9Mo2WVZr performs somewhere between “excellent” and “superior”. The steels 70Cr12VNbZr and 110Cr12VNbZr demonstrated also excellent performance, while the steel Cr12V1 performed poorly with grade “satisfactory”. While analyzing the carbide grade the steels

60Cr9Mo2WVZr and 70Cr12VNbZr show excellent performance. The same result with the steel 110Cr12VNbZr, while the steel Cr12V1 performed poorly with grade "satisfactory". The modified complex desirability index shows that the best combination of properties demonstrate the steels 70Cr12VNbZr and 110Cr12VNbZr, where the complex desirability function has its maximum values of 1.55 and 1.3. The steel 60Cr9Mo2WZr has the value of 1.36, which is a good combination of properties. The steel Cr12V1 shows substantially worse results with complex desirability index of 0.46.

4. The economic evaluation of the properties of the tools and equipment made of high chromium tool steels

The evaluation of the economic properties of tooling and equipment made of high-chromium tool steels along with the physical and mechanical properties of steels is the most important stage of analysis of high-chromium instrumental steels. The evaluation of economic properties of tooling and equipment made of high-chromium tool steels includes 2 methodical approaches: (A) The evaluation of production cost of tooling and equipment made of high-chromium tool steels on the early stages, which is actually forecasting of production cost of high-chromium tool steels. (B) The economic evaluation of tools and equipment that are produced with high chromium tool steels is normally carried out with value analysis [5].

5. Conclusion

On the basis of the performed research we can conclude that the modification in the calculations of the composite desirability indicator has substantially improved the objectivity and sufficiency of the qualimetric evaluations of high-chromium tool steels. The qualimetric evaluation has shown the advantages of new high-chromium tool steels 70Cr12VNbZr, 60Cr9Mo2WVZr and 110Cr12VNbZr over the steel Cr12V1 not only in mechanical properties, but also in economic expedience of usage of these steels. The modification of the integrated desirability index is one of the aspects of improvements of the high chromium steels evaluation technology.

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