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TERMITE HIGH-SPEED STEELS

У результаті проведених теоретичних та експериментальних робіт встановлена можливість синтезу інструментальних швидкорізальних сталей металотермією. Виявлено вплив металотермічного методу синтезу на особливості мікроструктури і фазового складу термітних швидкорізальних сталей. Встановлені для синтезованих термітних аналогів промислових марок швидкорізальних сталей Р18л, Р12л, Р9л, Р6М3л, Р9К5л, Р10К5Ф5л механічні та технологічні властивості, а саме теплостійкість, відносна шліфовність, період стійкості під час точіння залежно від швидкості різання та виявлено вплив зерна сплаву на його властивості.

Ключові слова: швидкорізальні сталі, металотермія, властивості, період стійкості.

The possibility of synthesis of instrumental high-speed steel by metallothermy is set as a result of theoretical and experimental work. The influence of the method of synthesis on metallothermic features of the microstructure and phase composition of the thermite high-speed steel was found. The mechanical and technological properties such as heat resistance, relative sanding, period of stability in turning depending on the cutting speed and impact of grain alloy's properties synthesized analogues of industrial steel grades "Р18л", "Р12л", "Р9л", "Р6М3л", "Р9К5л", "Р18л", "10К5Ф5" are investigated.

Key words: high-speed steel, metallothermy, properties, period of stability.

Introduction. Special attention is paid to the properties of materials that meet the stringent requirements of the tool alloys at the present level of development of engineering products. The need for the manufacture of tool materials requires research as one of the possible directions thermite cast speed steels, that do not have mechanical properties, heat resistance, wear resistance [1]. At the same time, it is well known that the use of metalothermic methods for the synthesis of materials allows to obtain almost any alloy cast in technology that have clear benefits for specific conditions of casting.

Analysis of recent research and publications. Synthesis of high-speed steel cast by metalothermic methods can be carried out in the absence of powerful sources of electricity, complicated equipment for traditional melting alloy and its fill, providing high performance and speed of technological cycle [2, 3]. The alloy is synthesized in foundry ladle lining in the simplest version of metallothermy. Last but not least advantage metalothermic process is the use of thermal waste, foundry and metal industries (iron scale, grinding aluminium shavings, crushed stone ligatures, dust from the air filters in foundries, flour burned parts of graphite electrodes, etc.). It is important to note that thermite alloy can be used for thermite welding cutting plate to the base metallurgy tool [4].

Purpose. Elaboration of technologies of the synthesis of cast thermite speed steels, studies of their mechanical and technological properties and installation process for the impact of high speed steel on structure and properties.

Tasks. 1. Install the possibility of synthesizing cast thermite speed steels. 2. Identify the mechanical properties of high-speed steels thermite – industrial analogues brands R18l, R12l, R9l, R6M3l, R9K5l, R10K5F5l. 3. Identify the influence of the structure of obtained alloy on its properties.

The starting materials and methods of preparation of exothermic mixture. Such materials as aluminium powder brands ПА-3 – ПА-4 "ГОСТ" 6058-73 (or sifted grinding swarf aluminium), chrome metals "ГОСТ" 5905-79; ferrochrome ФХ65-7А "ГОСТ" 47570-79; silicocalcium С40Л10 "ГОСТ" 4762-71; siliconmanganese СМн26 "ГОСТ" 4756-77; ferrosilicon ФС65Ал3,5 "ГОСТ" 1415-78; ferromanganese ФМн70 "ГОСТ" 4761-80; acetylene soot (carbon ТУ 14-7-24-80); titanium powder chemical PTH-1, PTH-2 TU 48-10-78-83; chromium powder ПТХ-1, ПТХ-2 ТУ 14-1-14-77-75; iron slag (blacksmith and rolling mills) with an average chemical composition (% by weight): 0.05 C; 0,10–0,35 Si; 0,10–0,35 Mn; 0,01–0,03 S; 0,01–0,03 P; 40–50 Fe_2O_3; 50–60 FeO are used for layout of metalothermic charge.

Powdered ingredients of metalothermic charges, the share of which was produced from waste foundry, forging and metal industries (iron slag, sifted grinding graphite electrodes, grinding aluminium shavings, etc.) have been used in the studies. Powder charge has been dried at 150–180 °C, mixed and then placed in metalothermic reactor [5] with diameter 80 mm with varying percentages ratio of components in the mixture. The initiation of the combustion process has been performed by a special titanium lighting made from titanium powder. Charge previously has been calculated by the stoichiometric ratio of the reaction components [6]. Further assimilation of separate components of reaction by appropriate coefficients has been into account. After synthesis process alloy has been separated from the slag, assessing the structure of slag, control weighing and setting out of the quantity of the metal charge has been made and then synthesized ingot has been explored.

Theoretical study. Proposed in the study [1] model explains the interaction in the system (Fe_2O_3, Al, WC) with such mechanism: under the influence of the heat pulse aluminium melts and it spreads by the capillary channel of dispersion medium components, along with spreading the dissolution of Fe_2O_3 and saturation with it solution to the temperature of the beginning of combined processes that unites stage of metallothermy and SHS. Due to the exothermicity of the dissolution process a melt temperature increases it's, which in turn leads to an increase in the solubility of titanium carbide in melt steel of thermite until a peritectic temperature. This process is accompanied by the beginning of the particles in the solid solution phase FeWC. Endothermic decay formed earlier in the melt phase Al_2O_3 embryos is observed after reaching the peritectic temperature. Later the formation of the given germ is main phase and determines the course of the temperature profile of the combustion wave to reach a critical concentration embryos [1]. The study of process of combustion has been performed on metalothermic process thermograms obtained using two-channel mikropirometer. They show that the temperature in the interaction of the reaction components is transient in nature. Periods of growth temperature change by periods of stabilization or even its rising. One-step tool to obtain a composite alloy technology, combining metalothermy and SHS process is a complex macroscopic task that should take into account processes such as heat transfer, mass transfer, phase formation and etc. The patterns combustion reaction mixture formation of the chemical and phase composition of the final product, the mode of crystallization of the alloy must be considered for dense material with high physical-mechanical and technological properties. Such alloys contain at least two metals and non-metals as a result of crystallization they can form a so-called mixed crystal lattice in which alloying elements form a solid solution rooting and replacement. Further studies of given alloys will allow to get information about the structure of the alloy and its behaviour during heating, melting and solidification and predict not only the structure of alloys, but their properties.

Experimental work. The studies made possible to establish the chemical composition of synthesized cast thermite speed steels (table 1) based on the interaction of aluminothermic composition metalothermic charge and to investigate the mechanical properties of these steels (table 2) – hardness, strength and toughness.

Different types of carbides were found in high-speed steels synthesized termite X-ray analysis showed that it is mainly carbides WC, W_2C, W_6C. This heterogeneity observed as a carbide distribution (see table 2). This phenomenon is partially removed by heat treatment – hardening of 1260 ^oC and triple tempering at 560 ^oC. When the vanadium content is large, especially in steel R10K5F5l, the structure appear in large number of carbides VC appear in the structure, and by heat treatment, due to the dissolution of other types of carbide, vanadium carbide impact is even more significant [1].

Table 1

The chemical composition of thermite-speed steel

Number of order	Mark of steel – analogue of industrials	The chemical composition of thermite high-speed cutting steels (% by mass)						
		C	*Cr*	*W*	*V*	*Co*	*Mo*	*Al*
1	Р18л	0,81	3,2	17,4	1,0	–	0,2	0,1
2	Р12л	0,83	3,1	12,8	1,3	–	0,2	0,1
3	Р9л	0,85	3,9	8,7	2,0	–	0,2	0,1
4	Р6М3л	0,85	3,1	5,7	2,0	–	3,2	0,1
5	Р9К5л	0,85	4,0	9,3	2,1	5,7	0,2	0,1
6	Р10К5Ф5л	1,35	4,1	10,1	4,5	5,0	0,2	0,1

Table 2

Physical and mechanical properties of thermite-speed steel

Number of order	Mark of steel – analogue of industrials	γ, kg/m^3 (x10^3)	*HRC*	σ_b, MP a	$a_н$[1], MJ/m^2	Mass of carbide phase, %
1	Р18л	8,6	64	2430	147,0	25
2	Р12л	8,5	51	1530	143,0	23
3	Р9л	8,4	59	1510	130,0	20
4	Р6М3л	8,4	61	–	70,0	20
5	Р9К5л	8,3	60	–	–	21
6	Р10К5Ф5л	8,2	59	–	–	24

[1]Abrader a bunch of sample with snick.

To assess the service properties of high-speed steels thermite research work on establishing their relative grinding has been done. The unit of relative grinding is taken grinding of speed steel Р18л. Data table 3 show that with increasing content of alloying elements in steel thermite the number of retained austenite in the surface layer, especially under the influence of Mo, Co and V grow the relative grinding decreases and heat resistance is 640–650°C.

The main parameters that establish high-speed steel cutting properties, in addition to hardness is heat resistance and period of stability of material at given cutting speed. To assess the stability of period of termite speed standard have been steel plates used for through-cutter type 01 code ОКП 0045 “ГОСТ” 25395-82 in terms of sharpening of steel 50 depending on the brand and cutting speed of cutting alloy under different processing modes for turning and capstan lathe T1 – cutting depth 1 mm, feed on the rotation of 0,08 mm (table 4).

Cast thermite-speed and Р18л and Р12л, showed the best tool material properties demonstrated.

Table 3

Relative grinding of synthesized thermite-speed steel

Number of order	Mark of steel – analogue of industrials	Residual austenite in the surface layer, %	Relative grinding	Heat resistance, °C
1	Р18л	57	1,0	650
2	Р12л	55	0,9	640
3	Р9л	64	0,6	630
4	Р6М3л	58	0,5	640
5	Р9К5л	67	0,5	640
6	Р10К5Ф5л	77	0,4	640

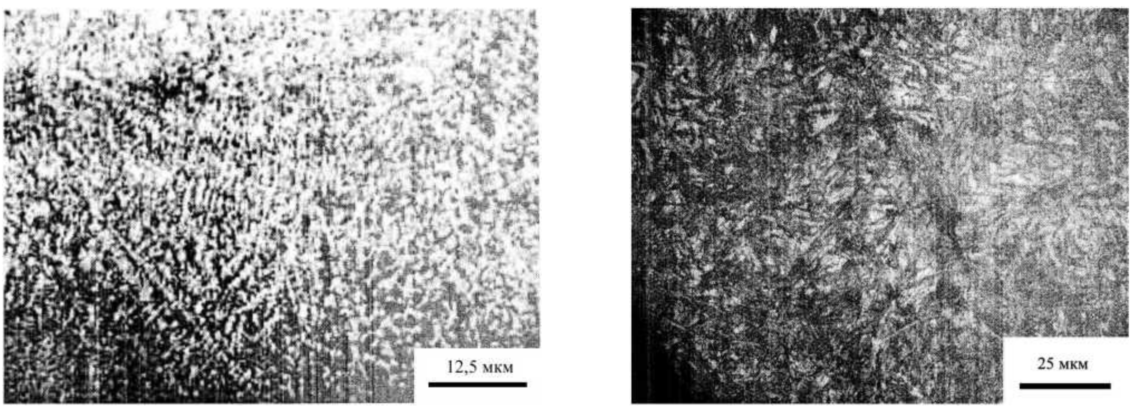
Table 4

Period of relative stability[1] (in min.) with turning depending on the cutting speed and steel grade

Number of order	Mark of steel – analogue of industrials	The speed of cutting, m/min		
		30	50	100
1	Р18л	115 110	150 130	95 90
2	Р12л	100 90	125 120	95 90
3	Р9л	92 80	107 100	61 56

[1]Numerator is period of stability, referring to the experimental high-speed steel, and the denominator – to similar industrial steels [7].

Experiments using thermite speed steels were continued successfully for direct welding tool material at the base of the tool using heat reaction. The base of the tool has been grinded and scoured and then heated to 300–350^{o}C. After igniting of the metalothermic charge liquid melt burnt through plate-fuse reaction chamber and found himself through the hole on the surface of the bottom of the reactor base, where welded metallurgically by heat educed by reaction between components. Then tools were machined by standard technology. But, the most expedient and easiest way is to get a plate of thermite speed steel for mechanical attachment to the base of the tool. The microstructure obtained thermite steel P12 with the introduction of titanium carbide powder in the composition of the mixture is shown in fig. 1. The structure of the alloy after SHS is a eutectic with dendritic component and granular inclusions crystallized in a circular formation. Dendrites grow radially in some regions of these entities. This indicates that the original powder particles are centers of crystallization of the melt.



a *b*

Fig. 1. Microstructure of alloy steel:
a – dendritic; b – martensite with hardness HRC 63

Dendrites rose from the center of crystallization (fig. 1). Integral cooling rate of the melt during its crystallization is defined as dendritic parameter *a*. The values of *a* = 0,03–0,12 mm correspond cooling rate V_c = 105 °C/sec required for martensitic transformation [1]. The result of self-chilling alloy liquid state so martensitic structure of type is formed as fig. 1 b. The hardness of obtained alloy, resulting in additional alloying Mo and his temper increases slightly – to HRC 50...51. Alloys have a high heat resistance, compressive strength limit of σ_b = 2300 MPa, liquid limit σ_t = 2800 MPa, impact strength on samples without notch cop within 3,4 J/cm^2, density 8,3 g/cm^3, porosity – 0,06. X-ray structure analysis alloy shows that the crystal lattice of the alloy Fe_2O_3-Al-TiC has a cubic structure with a main parameter 2,875326 nm.

Substance is heated to the melting point in SHS processes in fusion, but there is not enough chemical energy to melt the product (fig. 1 b). Besides the extra heat generate by the auxiliary metalothermic reaction. Termination of phase-separation to occurs in the moment of complete "output" of drops into molten ingot, or at the time of crystallization of the oxide phase of incomplete phase-separation. The latter forms a porous material.

The results of experimental studies indicate that the method of producing alloy solidification, conditions and peculiarities of synthesis positively influence the properties of synthesized alloys, and suggest that the cast thermite speed steels can be used for cutting process, showing better properties than the alloy obtained by traditional industrial technologies. Thus, despite the increased cost of the synthesized instrumental alloy, autonomy synthesis process and independence of complicated equipment for synthesis, the major sources of energy, high speed and productivity of process (the combustion mixture 20–30 sec) open opportunities for using molten thermite-speed steels.

Conclusions. 1. As a result of studies we found that high-speed steel cast synthesized by combined methods can successfully replace tool materials obtained by industrial methods. 2. Mechanical and technological properties of synthesized brands of thermite-speed steel, industrial analogues of brands Р18л, Р12л, Р9л, Р6М3л, Р9К5л, Р10К5Ф5л have been identified. 3. Microstructure of the synthesized alloys has been installed. 4. The technological features of the synthesis process of mentioned alloys, have been investigated.

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