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Innovative Technologies For Manufacturing Foam Models And Cast Steel Parts Of Harrow Tooth With Wear-Resistant Carbide Coating By Casting On Gasifyable Models And Their Optimal Thermal Treatment

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ABSTRACT

This article describes innovative step-by-step technologies for the manufacture of foam models and cast steel parts of the harrow teeth with a wear-resistant hard-alloy coating by casting on gasified models. Methods of gluing gasified models, the processes of forming, rammers, pouring liquid metal and the formation of cast parts of the harrow teeth are shown. Compositions, microstructures and properties of hard-alloy coatings made of 35GL steel are given. The surface thickness of the coating on the finished harrow tine parts is shown. The hardness and microhardness of the surface and subsurface layers of the samples were determined. Optimal modes of heat treatment with double phase recrystallization for these parts have been developed. It has been proved that heat treatment with double phase recrystallization increases the wear-resistance and durability of finished steel parts by 2-3 times.

KEYWORDS

Gasified Model, Hard-Alloy Coatings, Gluing Foam Models, Molding In A Flask, Pouring Liquid Metal, Carbon Steel 35GL, Macrostructure And Microstructure, Hardness And Microhardness, Heat Treatment With Double Phase Recrystallization, Abrasive Wear-Resistance And Durability Of Harrow Teeth.

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INTRODUCTION

Currently, increasing the wear resistance and durability of the surface layers of cast steel parts in the automotive and tractor-agricultural machine building industry is a very urgent problem [1,2].

Many parts of agricultural and tillage machines and mechanisms fail as a result of surface destruction under the influence of solid abrasive particles falling into the friction zone [3-5]. Expenses for repair or restoration in the republic currently amount to tens of billions of sums. In these conditions, any lengthening of the service life of cast parts by increasing their wear-resistance and durability is economically advantageous, because repair and restoration of parts do not always provide the required quality of products [6]. Therefore, most of the parts of the abovemetioned machines are made of uncoated casting from steel or cast iron, and the shelf life of these parts does not exceed one season, since they wear out quickly during operation. These parts include cast harrow teeth, which are manufactured at the enterprises of the republic and tested in different field conditions during soil cultivation. The results obtained show that the resource of the harrow teeth is 35-40 hectares of cultivated land. The disadvantages of the first option are insufficient hardness and wear-resistance, the second is a high consumption of scarce and expensive hard alloys, and the third is the use of non-standard steel grades.

The purpose of this work is to develop innovative technologies for the manufacture of foam models and the production of cast parts of tillage machines with a wear-resistant hard-alloy sormite coating and subsequent high abrasive wear-resistance. The object of research was the parts of the harrow teeth, experiencing intense abrasive and corrosive wear during soil harrowing.

RESEARCH METHODOLOGY

According to the proposed technologies, using a mold, a foam model is first obtained (fig.1a) and covered with a wear-resistant hard-alloy coating (fig.1b, d), then the foam models are placed horizontally, and their working surface upwards and molded into a casting flask-container, and then poured liquid metal at a temperature of 1600-16500C through the gating system with a siphon supply of metal. The molten metal was fed directly to the foam model. Under the influence of this melt, the polystyrene is gasified and the forming cavity is filled with a metal composition corresponding to steel grade 35GL. In this way, foam models and cast steel parts of the harrow teeth (fig.1e) with a wear-resistant hard-alloy coating are manufactured at the JSC «Uzmetkombinat» [7,8].

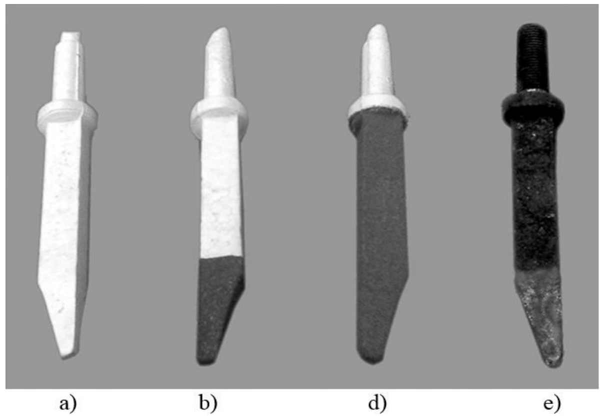

Fig.1. Foam models and castings of harrow teeth parts 3BZS-1,0 with hard-alloy coating: **a**-foam model; **b**-foam model coated on the main wear surfaces; **d**-foam model over the entire wear surface coating; **e**-cast steel harrow tine part with wear resistant carbide coating and heat hardening.

Filling a mold with liquid metal is one of the main stages in the formation of a casting, which determines many indicators of its quality. It should be noted that the casting of forms must be done especially carefully, accurately and evenly with a constant hydrostatic head.

Bonding the gating system. Before forming, well-dried foam models are glued on a round or nut-shaped model ring using a gating system. All foam models should be glued with special adhesives and dried at normal room temperature, for example, expanded polystyrene models of harrow teeth (fig.2a, b, d) [9].

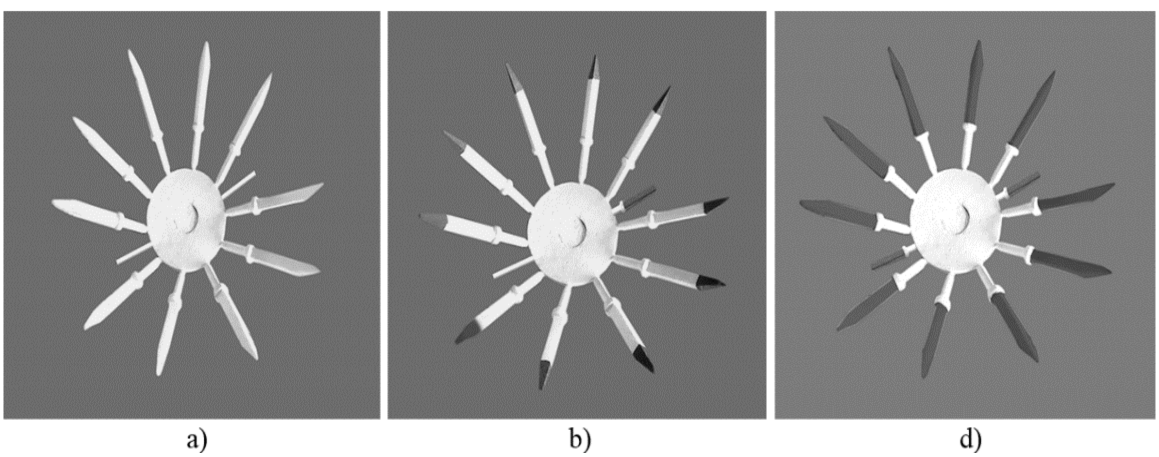

Fig.2. Glued foam models of harrow teeth with three types of hard-alloy coatings: **a**-foam models; **b**-foam model with a coating on the main wearing surfaces; **d**-foam model over the entire wearing surface.

The glued foam models are placed in a metal flask-container, a bed of dry quartz sand is filled up, compacted with manual or automatic vibration, and then a model with a gating system is installed in a given position using ceramic tubes for pouring the melt. The gating system allows for an almost constant rate of lifting of the metal in the mold.

The final molding was carried out as follows. A bed of dry sand was poured onto the bottom of the lower part of the flask-container, compacted with vibration, and then a foam model with a gating system was installed in the desired position using ceramic tubes (fig.3a). The ceramic tube is mainly used for casting steel. After that, the flask was filled with sand manually (fig.3b) or by automatic vibration (fig.3d) to the top (fig.3e). The mold thus compacted was covered with a perforated metal sheet with holes for the passage of gases, and the gating block and weight were installed (fig.3f). Then the flasks-containers from the molding section were sent through a conveyor to the casting section and liquid metal was poured in sequence (see fig.3,f). After pouring the liquid melt, the flask-containers were cooled in the shop air for a certain time, opened and received a high-quality finished casting of the harrow teeth part with a wear-resistant hard-alloy coating of the "sormite" PG-S27 type with a coating layer thickness of 2-3 mm [7] (fig.3g).

The paper investigates the composition of the hard-alloy type sormite PG-S27. The choice of the composition of the applied coating was made according to two criteria: 1-coating must meet the requirement of a 3-5-fold increase in wear-resistance in comparison with the wear-resistance of the steel base; 2-coating should include available and inexpensive components and be distinguished by the simplicity of its application technology. Based on this, a hard-alloy of the sormite PG-S27 type was chosen as a coating on the working surface of the harrow teeth, and a solution of 4% polyvinyl butyral in alcohol was used as a binder.

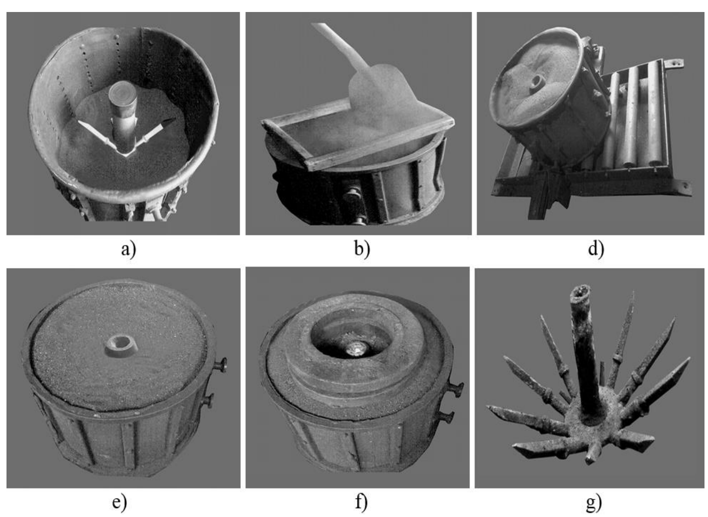

Fig.3. The process of forming and filling the metal container-flask: **a**-forming of the foamed models of the harrow teeth; **b**-hand molding with quartz sand using shovels and a sieve; **d**-automatic vibration; **e**-filling to the top; **f**-pouring melt; **g**-castings of harrow tine parts with wear-resistant carbide sormite coating.

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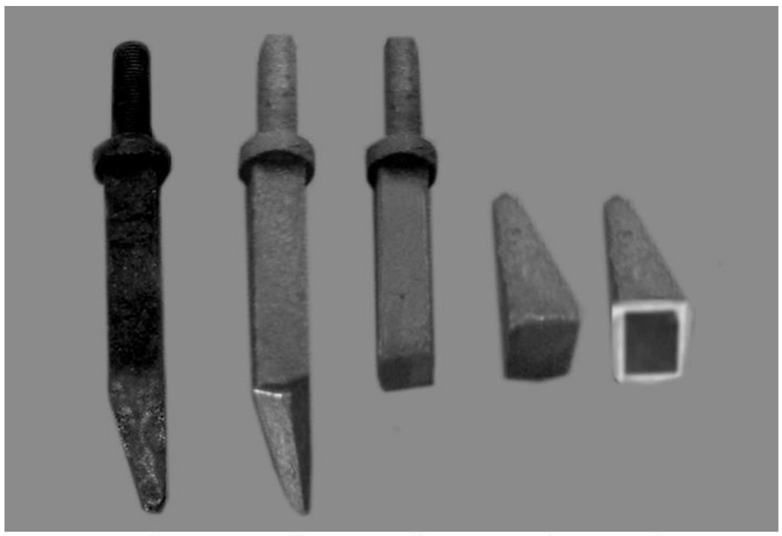
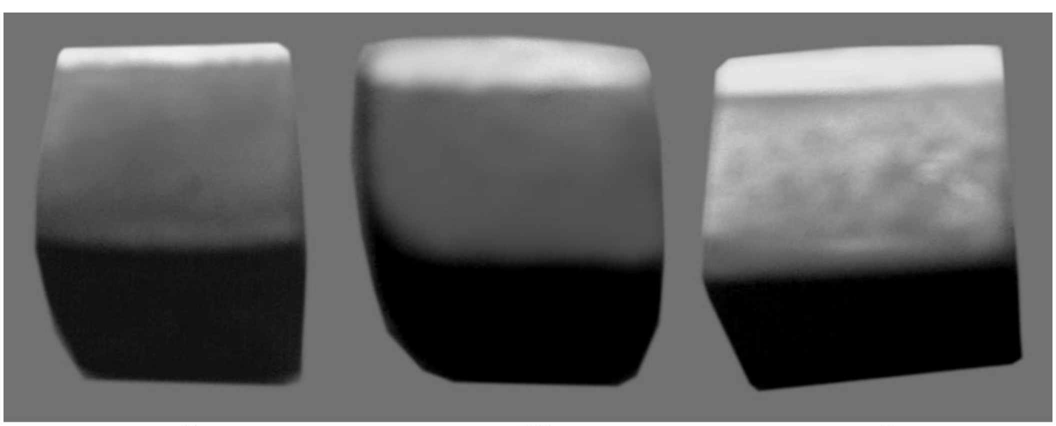
RESEARCH RESULTS AND THEIR DISCUSSION

To check the thickness of the casting layer, we took a finished part of the harrow teeth with a wear-resistant hard-alloy coating (fig.4a), cut out a piece of section for macro - and micro-examination (fig.4b, d), then grinded and polished it (fig.4e), and then washed it. and etched with a special etchant to reveal the surface coating with a coating layer thickness of 2-3 mm (fig.4f). More clearly and visually, the macro image of surface hard-alloy sormite coatings [7] is shown in (fig.5a, b, d).



a) b) d) e) f)

Fig.4. Finished steel castings of harrow teeth parts and cut samples with carbide sormite coating with layer thickness from 2x to 4x mm: **a**-steel part of harrow teeth; **b, d**-cut pieces samples of the detail; **e**-ground and polished sample; **f**-etched sample with a coating thickness of 2,5-3,0 mm.



a) b) d)

Fig.5. Specially prepared steel samples with a wear-resistant hard-alloy coating of the sormite PG-S27 type with a layer thickness: **a**-2,0 mm; **b**-2,5 mm; **d**-3,0 mm.

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Optimal modes of heat treatment. These samples were subjected to various modes of thermal treatment. Thermal treatment of cast samples with wear-resistant hard-alloy coating was carried out in laboratory furnaces, and full-scale products - in a thermal chamber furnace at different heating temperatures:

1) Softening annealing at a temperature of 700-7200C for two hours, and cooling together with the furnace;
2) Heat treatment, quenching of samples with heating to a temperature of 900 to 11500C, and cooling in oil or in air;
3) Vacation at various heating temperatures 3000C, 4500C, 5000C, 5500C, 6000C. The holding time of the samples during tempering is 1,5 hours, and cooling in air;
4) Double hardening. After the first quenching from different heating temperatures and intermediate tempering 4500C-6000C, the samples were reheated to 925-9400C, quenched, cooled in oil and tempered at a temperature of 3000C. Double hardening [6,8] is used for the first time to increase the wear resistance of carbide castings. After double hardening, the hardness, microhardness and, especially, the wear resistance of hard-alloy steel samples and parts increase by a factor of 2-3 or more in comparison with serial products.

Microscopic studies were performed in accordance with the recommendations [6]. An etchant of the following composition was used for etching steel sections from a hard-alloy coating: 1. Nitric acid; 2. Ethyl alcohol - 45 m; 3. Water - 100 ml. Microscopic studies were carried out using MIM-8M and Neophot-21 microscopes at various magnifications. Special eyepieces and objectives of optical microscopes were chosen to enlarge the photograph of objects. The dimensions of the cast steel samples were 15x15, 15x20, 20x20 and 20x22 mm.

Investigations of the microstructure of sample No. 20, obtained by casting according to a gasified model with a hard-alloy coating of a powder of the sormite PG-S27 type with a layer thickness of 3 mm, showed that the structure is eutectic on the surface of the layer. Upon further cooling, the austenite regions transform into its decomposition products, but most likely undergo martensitic transformation. The eutectic part of the structure is generally absent from the erectable "crust". Moreover, the depth of the eutectic zone is 1,5-2,0 mm, and the depth of the hypoeutectic zone to the border of the transition to the base metal is 2,0-2,5 mm. On the working surface of the coating to a depth of 1,5-2,5 mm, a eutectic structure with columnar crystals of Cr_7C_3 and $Cr_{23}C_6$ carbides is formed. The structure of the metal base of the eutectic is not destroyed, but judging by the total hardness HRC = 48 ÷ 51, it is martensitic with a large amount of retained austenite.

This alloy improves wear resistance and is especially effective in abrasive wear conditions. When pouring metal, the foam model burns out, and the surface of the casting is saturated with carbon up to 0.7%. When the mixture of sormite powders comes into contact with the liquid metal, a hard crust of the casting is formed. Then the coating was melted and, after crystallization, a wear-resistant hard-alloy coating with a layer thickness of 2.0-2.5-3.0 mm and a structure [7.9] of a highly alloyed alloy of eutectic and hypereutectic composition was formed on the casting surface (fig.6a, b, d). As a result of thermal treatment, the surface layer has the structure of fine-acicular martensite with fine carbide or isolated areas (the least amount) of retained austenite.

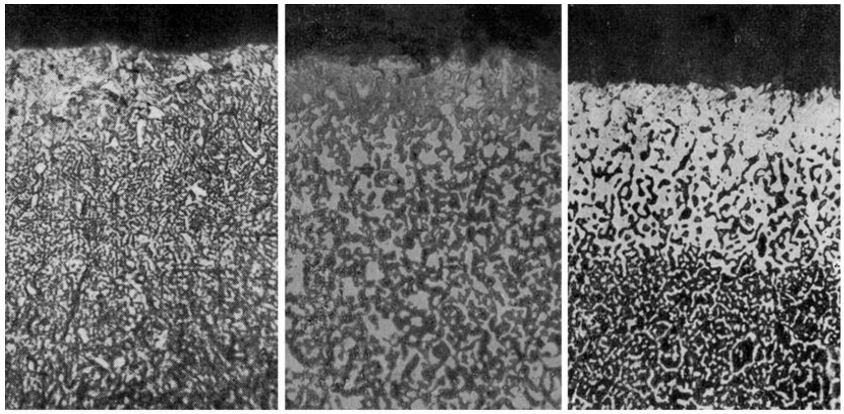

Fig.6. Microstructure of cast steel samples obtained with wear-resistant hard-alloy coating with layer thickness: **a**-2,0 mm; **b**-2,5 mm; **d**-3,0 mm. X500

X-ray diffraction phase analysis was carried out to determine the phase composition of the alloy, the percentage ratio of phases, the level of defectiveness of the crystal lattice of the metal base of this alloy, and the state of the solid solution in iron [7]. The studies were carried out on an X-ray diffractometer DRON-2.0 when taking an X-ray diffraction pattern in the automatic recording mode in the range of angles 30-1600 on the radiation of the iron anode. As a result, carbides M7C3, M23C6, etc. were determined.

For testing for abrasive wear, samples were taken from a hard-alloy coating with dimensions of 70x35x15 mm. Specially-prepared samples before and after tests were weighed on a VLA-200g-M analytical balance with an accuracy of 0.1 mg, and abrasive wear tests were carried out on a PV-7 friction machine. Samples were before and after single and double thermal treatment. Good results on the wear-resistance of the samples were obtained after optimal thermal treatment with double phase recrystallization [9-15] with a hardness of HRC = 58–62.

CONCLUSIONS

Thermal-treated cast samples and parts with wear-resistant hard-alloy coating were tested in field conditions in various regions and districts of the republic. The test results showed that the experimental cast parts of the harrow teeth without a hard-alloy coating by 1,3 times, with a hard-alloy coating by 2,5-2,9 times, with a wear-resistant hard-alloy coating after optimal heat treatment with double phase recrystallization by 2-3 times increases their wear resistance and durability in comparison with serial parts. This promising and innovative technology has been introduced in the metallurgical production of JSC «Uzmetkombinat» with a good economic effect.

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