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APPLICATION OF CHIPS OF STEEL 5KhNM IN ELECTROSLAG SURFACING OF DIES IN CURRENT-CONDUCTING MOLD

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Different methods for melting chips during electroslag process are considered. For electroslag surfacing of dies, chips of a tool steel were used as a discrete surfacing material in combination with a special device for melting of filler and formation of deposited layer, which is the current-conducting mold. The results of surfacing the press dies with chips of steel 5KhNM are presented. The prospects of the proposed technology for renovation of dies from the point of view of producing high-quality die with a relatively low power consumption during surfacing are shown. 9 Ref., 5 Figures.

Keywords: *chips of a tool steel, electroslag surfacing, dies, current-conducting mold*

Extensive development of die stamping and pressing as economy methods of production of parts and necessity of hot deforming of increased strength materials required development of steels of different composition and differentiation of the areas of their application (groups) [1]. These are steels of increased toughness, namely semi-heat-resistant (5KhNM, 5KhNV, 5Kh2NMF, 4KhMFS etc.), moderate heat resistance (4Kh3MVF, 4Kh3VMS etc.), increased heat resistance (4Kh5MFS, 4Kh4VMFS, 5Kh3V3MFS, 4Kh-2V5MF, 3Kh2V8F, etc.), high heat resistance (2Kh-6V8M2K7, 2Kh5V5M2K5, 2Kh12V8K10, etc.).

Today steel 5KhNM is most widely used (mainly for forging dies) from all the variety of steels. Simplicity of its composition and relatively low price assisted this. Moreover, it started to be used as universal material for different groups of tools.

In this case it is possible to see the analogy with high-speed steels. Among the large range of these steels R6M5 steel got the widest distribution. Such «narrowing» of number of used grades of tool steels, on the one hand, reduces resistance of tool of separate designation groups and, on the other hand, simplifies collection of chips appearing at this treatment.

According to data of work [2] in 2017 in Ukraine 60107.9 t of chips of steels of different designation and composition were formed at lathe turning and other types of machining. If to assume that at least 10 % of this amount of formed chips is the tool steel chips, than it is sufficiently large stock for the case of appearance of possibility for usageing such wastes as surfacing material. Particularly, it is necessary to note in comparison with production of surfacing materials by Ukrainian enterprises in 2016. For example, there were manufactured around 2 thou t of alloyed welding wire and around 0.5 thou t of flux-cored [3] one.

The most widespread method of recycling of chips is its partial remelting in arc, induction and other types of furnaces in form of additional filler in metal melting. The rest of chips are stored in dumps deteriorating ecological situation at enterprises producing them as well as in whole in corresponding regions. At that it is necessary to take into account that at long-term storage they significantly oxidize; during transporting part of chips is lost and there is mixing of different their types; during remelting in metallurgical units content of alloying elements significantly drops.

Taking into account such evaluation of situation with chips processing existing today, it should be recognized that the most reasonable method of chips conversion is their transformation into liquid metal with the help of electroslag process. At that, they, on the one side, are purified passing in melting through refining slag and, on the other side, when providing their regulated addition into a slag pool it is possible to reach high quality of metal being crystallized. This in particular takes place using the chips in form of discrete filler in electroslag surfacing (ESS).

Of course, not all available chips of tool steel can be used in the initial state as surfacing material in ESS. Curling chips are not good for surfacing as well as chips containing cooling mixture (CM). In this case, such chips should be subjected to additional technological operations for making them in correspondence with necessary technical conditions (crushing, cleaning with chemical agents, heat treatment) [4].

Three schemes of performance of electroslag process in water-cooled mold using filler material in form of chips have found practical application.

First of them assumes application of nonconsumable electrodes, usually graphitized, in ESS of dies. They are used in heating of surface being deposited, billet or worn die [5, 6]. After melting of base metal

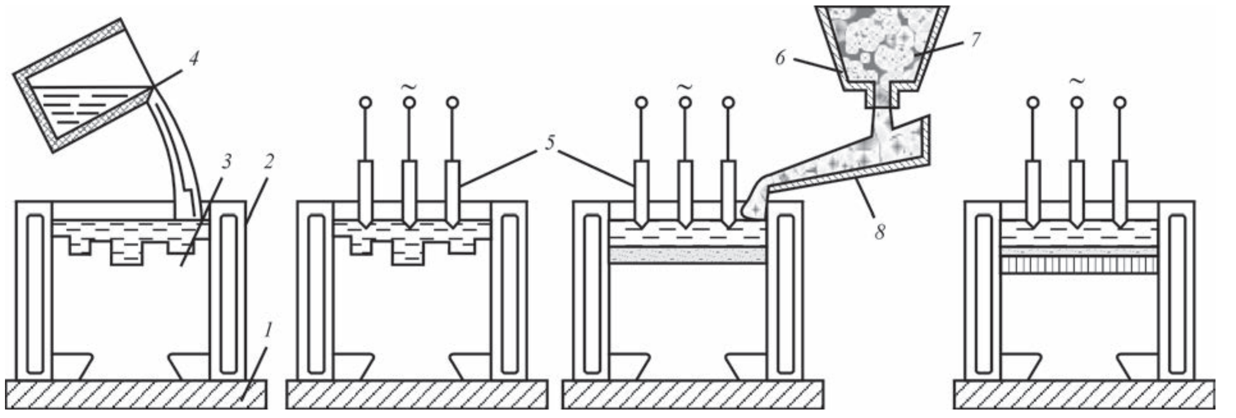

Figure 1. Scheme of electroslag surfacing of worn dies using chips of die steel as filler: *1* — bottom plate; *2* — fixed mold; *3* — worn die; *4* — ladle with liquid slag; *5* — nonconsumable electrodes; *6* — tank for filler material; *7* — filler material; *8* — channel

surface the slag pool is filled with chips of die steel, which in melting form deposited layer (Figure 1).

The next was determined under commercial conditions at supply of chips of 5KhNM steel, application of flux AN-15M and three-phase scheme of current connection to slag pool. Surfacing of press dies of 400×260 mm size shall be performed at specific power of heating $2.2–2.5\cdot10^4$ kW/m^3. At that mass velocity of supply of chip particles should make 0.3–0.7 kg/h per 1 kW of input power [5]. In work [6] surfacing of press dies with oxidized chips of steel 4Kh5MF1S under AN-292 flux in 150 mm diameter mold and single-phase scheme of current supply was carried out at specific power $12.6–14.1\cdot10^4$ kW/m^3.

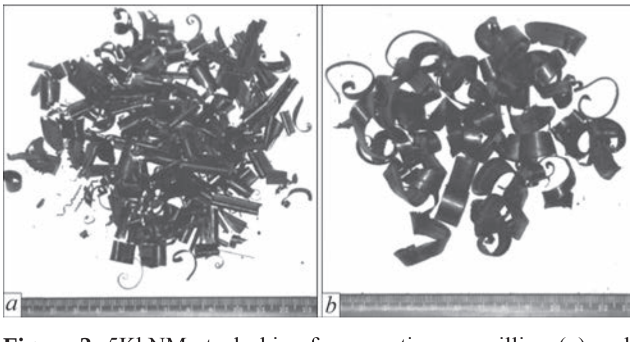

Figure 2. 5KhNM steel chips from continuous milling (*a*) and planing (*b*) machines

The second scheme is also realized with the help of nonconsumable hollow electrode both graphitized and metallic water-cooled, but not solid one. The chips being remelted are supplied through inner cavity of it. The chips coming into underelectrode heat center of the slag pool promote decrease of slag temperature in whole volume of the pool, namely in the center due to effect of coming cold chips and on the edges due to cooling effect of mold walls. Therefore, using such scheme of surfacing it is difficult to provide good fusion of base and deposited metal, in particular, on the part edges. Obviously this is the reason of the fact that the scheme is usually proposed in form of a method for production of ingots from different composition steels, when formation of outer surface is not related with quality of joining [7, 8] of metals.

This paper outlines the results of surfacing of dies made on the third technological scheme of electroslag process using nonconsumable electrode and sectional type mold, named by designers as a current-conducting mold (CCM) [9]. Its peculiarity is supply of electric energy to a slag pool not on its center, but on periphery (through walls of current-conducting section). Therefore, the main heating-through of the pool takes place near the mold walls that affects a shape of metallic pool and, respectively, nature of base metal penetration.

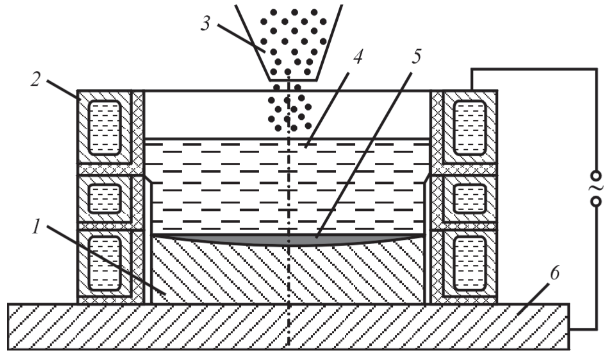

Figure 3. Scheme of surfacing of dies in CCM using discrete filler in form of chips: *1* — die being deposited; *2* — current-conducting mold; *3* — filler (chips); *4* — slag pool; *5* — metal pool (metal being deposited); *6* — bottom plate

Figure 4. Stage of start of CCM work at removed from slag pool water-cooled electrode with graphite tip

Figure 5. Press die of 170 mm diameter and 80 mm height of steel 5KhNM: *a* — before surfacing; *b* — in mold before surfacing; *c* — after surfacing

There is one more feature of mold design. During electroslag process it promotes rotation of a slag pool in a horizontal plane, providing uniform distribution of chips over the pool surface and acceleration of their melting. Press tools of 170 mm diameter and 80 mm height made of steel 5KhNM were chosen for surfacing. The die bed contours before surfacing were not machined due to this the height difference of working surfaces in the center of dies reached up to 16 mm and on the edges up to 14 mm.

5KhNM chips from continuous milling and planning machines (Figure 2) were used as filler material.

Regardless the fact that the chips have no obvious traces of CM, they still were backed in electric furnace at 400 °C temperature, 2 h.

Surfacing was carried out in CCM of 180 mm diameter at its stationary position (Figure 3).

The chips were supplied in the mold working zone using vibrobatcher of PWI design. Flux AN-15M was used as a working flux. Start of the process was with «solid start» using water-cooled electrode having graphite tip. Transfer from arc to electroslag process took place in electric mode providing minimum penetration of die surface.

After generating a necessary slag pool volume in the mold using water-cooled electrode the process was performed only due to work of current-conducting section of CCM. At that, the electrode was removed from the slag pool (Figure 4).

After reaching the optimum mode of surfacing the filler (chips) was supplied on the slag pool surface by vibrobatcher. Surfacing process was stable. Thickness of deposited layer made approximately 25–30 mm. Deposition rate made approximately 0.4 kg/min. Figure 5 shows the dies before surfacing, position of die in working space of CCM and appearance of deposited die.

Specific heat power, introduced into the slag pool, made approximately 2 kW/m^3, i.e. 6–7 times less than in surfacing of press tools at single-phase scheme of current supply to the slag pool (first technological scheme) in work [6].

For performance of commercial tests at PJSC «Tokmak Forging and Stamping Plant» two sets of M-112 press dies were repaired by ESS in CCM with chips of steel 5KhNM and billets of 170 mm diameter and 100 mm height were obtained. It should be noted that after surfacing the tool was machined without difficulties, no defects were found in the deposited layer. Deposited tool was tested in forge-and-press shop of PJSC «TFSP». The tests showed that in comparison with the serial forged dies the resistance of deposited ones increased 1.5 times.

Thus, resource-saving technology of surfacing of small size die tooling with 5KhNM chips using current-conducting mold allows obtaining quality deposited die tool at relatively low consumption of electric energy.

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