INDUCTION HARDENING FOR STRENGTHENING FORMING TOOLS OF STEEL 45

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It is of considerable interest to plants of the electric engineering industry that it is possible, in principle, to ensure good durability of heavy-duty forming tools (in the form of grooved flattening drums for rolling a series of filled electrode strips with powdered filler) made of medium carbon structural steels when there is a shortage of blanks made of high alloy tool steels [1]. There are not data in the literature on the wear resistance of such tools under conditions of high contact loads and the constant presence of a powdered abrasive mixture on the interface between the tool and the formed material.

The present article contains the results of work at the Dzhizak accumulator plant connected with the introduction of the technology, tooling, and equipment for the surface hardening by high-frequency currents of forming tools of steel 45 (GOST 1050–74) to the machine model FO 12 for making filled electrode strips by continuous stepped rolling.

The heat-treated forming tools are grooved flattening drums with 203-207-mm outer diameter, 400 mm length, and 120-mm inner diameter with a keyway over the entire length of the generatrix; the height of the grooves is 0.8-1.5 mm, the weight of the drums is 60-100 kg (Fig. 1).

The technological process of the heat treatment of the tools includes cyclic (2-5 cycles) preliminary heating with forced limitation in intensity and area of the cooled working surface after each cycle and subsequent final heating for quenching at 920 ± 20°C with cooling of the working surface of the tool with water to 200 ± 20°C, ensuring with the previously accumulated heat in the inner layers that conditions of self-tempering are provided. Preliminary heating was carried out in the process of accelerated (v = 150-180 mm/sec) reciprocating motion of the tool past the inductor-sprayer with the use of 55-70% of the nominal power of the high-frequency generator (I_a = 9.5 A, I_C = 1.4 A, W = 7.5 kW) until the inner surface of the drum attains 250-300°C while the temperature of the outer surface does not rise to more than 70°C.

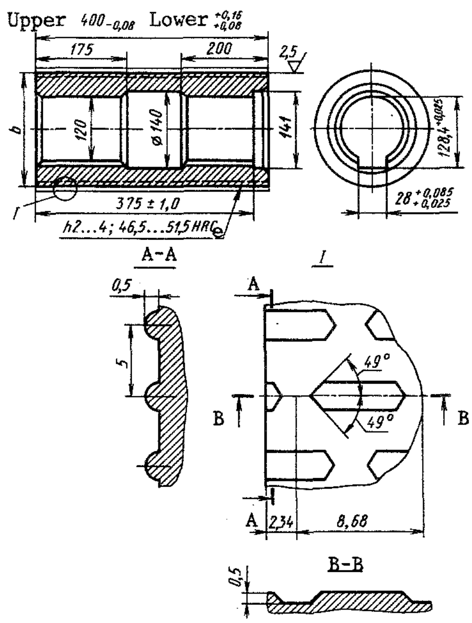

Fig. 1. Grooved drum.

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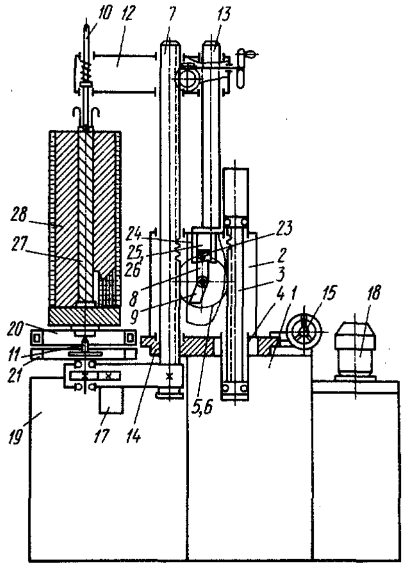

Fig. 2. Diagram of the hydraulic hoist belonging to the HRC installation for hardening forming tools.

The intensity of cooling in the process of preliminary heating is $(0.7\text{-}0.9)\cdot 10^{-5}$ m^3/cm^2. Surface hardening is effected by the continuous successive method in the process of slowed-down (v = 0.8-1.5 mm/sec) moving of the tool past the inductor-sprayer, the power of the generator being up to 90-95% of the norminal power (I_a = 15 A, I_C = 2.1 A, W = 10.5 kW); the intensity of cooling is $(2.0\text{-}2.5)\cdot 10^{-5}$ m^3/cm^2.

The use of preliminary multiple heating with cooling of the surface in the process of each cycle instead of the commonly used single induction heating was decided on because of our previously obtained experimental dependence of the items of the heat balance of supply and removal of heat from the profile of the forming tool (Fig. 1). Reducing the time of final heating under the described conditions in accordance with the experimental data previously obtained by us prescribes that the time of heat removal (the action of the cooling liquid) be shorter than with a single induction heating; in the final analysis this not only ensures that the requirement of the technical conditions of the blueprint concerning hardness and thickness of the hardened layer are fulfilled, it also provides for a state of reduced stress, lower probability of cracking, etc., i.e., the characteristics of the operational durability of the treated tool are improved. All the heat-treatment operations with the tool were carried out on a hydraulic hoist model 0312-02 (Fig. 2) provided with a load-lifting arbor for transporting and mounting the tool between the centers of the hydraulic hoist.

The hydraulic hoist contains the frame 1 carrying the hydrochemical reduction gear 2 whose driving shaft 3 is made in the form of a rack-like piston rod of the hydraulic cylinder 4 and is connected with pinion 5; on the same shaft pinion 6 is mounted, too, and this connected with the rack of the driven shaft 7 of the reduction gear 2. Jointly with pinions 5 and 6 the shaft also carried regulators 8 and 9 of the travel of shaft 7 acting as guide of the upper center 10, which can slide on it, and the fixedly mounted lower center 11. Mounted on shaft 7 is the moving rest 12 ensuring shifting of the upper center 10 or setting of the distance between the centers in dependence on the length of the treated object and connected with the additional guide 13 which is firmly mounted on the housing of the reduction gear 2. The housing of reduction gear 2 is connected with frame 1 through faceplate 14 which is driven by drive 15 and runs in guides 16 (not shown in Fig. 2). The rotating mechanism of the lower center is provided with the hydraulic motor 17 which is connected with the hydraulic drive 18. Attached to the frame of the hydraulic hoist is the collection tank 19 for the quenching liquid arranged on the axis of the centers in the plane of the base. The hydraulic hoist is provided with the inductor-sprayer 20 made of profiled pipe with small section (8 × 8 mm) and equipped with additional inlets for quenching liquid for wide-ranging control of intensity of quench cooling, a cut-off 21 of quenching liquid for regulating the cooled zone, both in cyclic preliminary heating and, as far as necessary, in the process of final heating prior to quenching, and with a desk for automatic control 22 (not shown in Fig. 2). The cut-off of liquid 21 is made in the form of a closed housing with an annular cavity in which there is a baffle forming a slit and dividing the housing into two sections; in one of them is the heating element, and in the other a pressure equalizer; both sections contain channels for the escape of compressed air which is supplied to the cut-off, and the housing is able to move axially. The compressed air supplied to the cut-off is distributed over the sections of the annular cavity and is fed to the treated surface at a certain angle, thus removing the quenching liquid over a specified length from the inductor-sprayer 20. The design and operating principle of the cut-off of quenching liquid are presented in greater detail in [2]. The moving stops 8 and 9 are made in the form of serrated half-couplings connected with the throttles 23 and 24 of the hydraulic cylinder and the fixed stops 25 and 26. The length of the circle formed by the rotation of stops 8 and 9 through 360° is equal to the travel of the centers 10 and 11. When the travel for the centers (the length of the quenched zone) is changed, the movable part of the half-coupling rotates through a certain angle corresponding to teh change of the travel. When the centers are moved "up" or "down," stops 8 and 9 rotate about the axis, and when the shift ends, they interact with the throttles 23 and 24, shutting off the hydraulic cylinder. Since the throttles shut off the hydraulic cylinder gradually, braking of the shaft proceeds smoothly, and in an emergency situation (when throttles 23 and 24 do not function), braking of shaft 7 is effected by the fixed stops 25 and 26. The tool 28 is placed on the centering arbor 27, and with the aid of a hoisting mechanism (single-rail overhead traveling crame, telpher, etc.) it is mounted between centers 10 and 11 of the hydraulic hoist.

The hydraulic hoist operates in automatic regime with stepless control of the speed of axial rotation of the drum and shifting.

The technical characteristic of the hydraulic hoist model 0312-02 is presented below:

Distance between centers, mm	0-1200
Travel of carriage, mm	0-900
Speed of motion of carriage ("up," "down"), mm/sec	0-200
Rotational speed of centers, rpm	60-1000
Total rated power of independent drives, kW	4.5
Distance between inductor-sprayer and cut-off of liquid, mm	12
Overall dimensions, mm:	
length	2000
width	1110
height	2750
Weight, kg	1700
Maximally permissible noise level, dB	80

The hardness of the hardened layer of the drums is 54-56 HRC_e, the layer with this hardness is 2.5-3.2 mm thick, the structure is finely acicular temper martensite with separate sections of troostomartensite. Warping after hardening does not exceed 0.005 on a length of 100 mm of the generatrix of the tool.

The life of the heat-treated drums is $(1.1\text{-}1.5)\cdot 10^6$ load cycles, only after that there appeared and developed macrocracks 0.02-0.04 mm deep on the working surface; however, the tool was operated successfully up to $0.9\cdot 10^7$ cycles.

The savings attained by the introduction of the technology, tooling, and equipment at the Dzhizak accumulator plant amounted to 19,100 rubles.

CONCLUSIONS

1. Forming tools operating under conditions of the constant presence of an abrasive-powder mixture, contact pressures in the range 1.3-1.8 kN/mm^2, and low angular velocity (0.5-0.8 rps) can be made of structural steel 45 instead of high alloy tool steels.

2. The service properties of forming tools made of structural steel 45 are determined by the carbon content and by the parameters of cyclic heat treatment with the use of induction heating.

3. The maximal life of forming tools made of structural steel 45, subjected to cyclic surface hardening, is $0.9\cdot 10^7$ cycles under conditions of continuous stepped rolling of filled electrode strips.

LITERATURE CITED

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NATURE OF THE DEFECT "BRIGHT RING" FORMING IN FRICTION WELDING OF TOOL STEEL

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When end milling cutters break in the region of the welding seam, a defect is found which in the literature is called "bright ring" [1, 2]. The cause of this defect is ascribed to incomplete fusion, and the defect is also called incomplete fusion [1, 2]. To eliminate the defect "bright ring," the All-Union Tool Research Institute recommends raising the temperature and pressure in welding.

At the Pavlodar plant making special tools and technological equipment, friction welding of end milling cutters is used, and the defect "bright ring" is fairly widespread. Acting on the recommendations of the Tool Research Institute did not yield any positive results.

The object of the present work is to study the nature of the defect "bright ring" and to find ways of eliminating it.

We investigated welding seams on tool blanks of steel R6M5 welded to steel 45 on a machine MST-35. Fractures in the region of the welding seam were investigated on a scanning electron microscope RÉM-200 with magnification up to ×4000, the microstructure in the region of the welding seam was investigated on a transmission microscope and on a scanning electron microscope. We investigated tools both in the annealed state and after final heat treatment. From the blank in the region of welding we cut out a cylindrical specimen. Part of the cylinder was cut off in such a way that a plane perpendicular to the welding seam formed. On it we made a microsection on which we investigated the microstructure both without etching and after etching in 2% solution of HNO_3. By scratching or making indents on a PMT-3 instrument we marked the parts where the appearance of "bright rings" was expected in case of fracture. Fracture of the specimens was carried out by bending without damage to the microsection. The kind of fracture and the microstructure were compared.

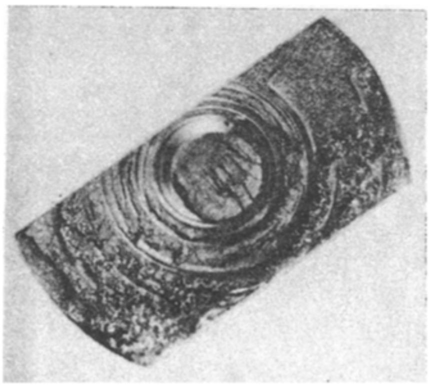

Fig. 1. "Bright rings" in the fracture of a tool blank.

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