THERMOCHEMICAL TREATMENT OF TOOLS FOR HOT FORGING

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INTRODUCTION

It is known [1, 2] that the best service parameters of forging tools are provided by gas nitriding. Low-temperature nitriding (below the point of eutectoid transformation of the Fe – N diagram, i.e., 591°C) is the most interesting among the possible nitriding processes (in the classification of Yu. M. Lakhtin and Ya. D. Kogan) as an optimum technology for forging tools from alloy steels 4Kh5V2FS, 4Kh5MFS, 3Kh3M3F, etc. The alloying elements (Cr, Mo, W, and especially V) causing the effect of secondary (dispersion) hardening [3] promote preservation of the high hardness of the metal in the core of the tools subjected to a long-term heating.

Experience in the nitriding of the entire range of hot-forging tools (dies, punches, pushers, drawing plates, stamps, etc.) from steels 4Kh5MFS, 3Kh3M3F, 5KhB2S shows that the service stability of parts subjected to nitriding increases by a factor of 2 – 3. In addition, it is 20 – 30% higher than that of tools from steel 3Kh2V8F. The traditional nitriding regime involves [2] saturation in dissociated ammonia at 560 ± 10°C for 24 h and cooling in a muffle to 150 – 200°C (with continuous feeding of ammonia) for 6 – 8 h. The thickness of the nitrided layer is 0.3 – 0.25 mm. The nitrided tools are subjected to light polishing only (virtually without a decrease in the layer thickness). However, nitriding of the whole of the range of hot-forging tools by this regime requires considerable production power, and the practical performance of the process is often restricted (under the recent complicated conditions) by the arrival of compressed ammonia and the availability of high-temperature chromium-nickel cast stock like retorts or furnace buckets.

This has made it expedient to search for alternative power-saving processes of thermochemical treatment that would increase the service stability of the tools and intensify the nitriding process.

RESULTS AND THEIR DISCUSSION

Cyaniding of tools. We have analyzed the range of tools subjected to nitriding from the standpoint of its service at a thickness of the diffusion layer less than 0.1 mm. It is known [4] that cyaniding at 520 – 560°C provides a layer 0.05 – 0.08 mm thick. Therefore, this process cannot be an adequate substitute for nitriding which guarantees a layer over 0.25 mm thick. However, there are quite a number of forging tools, for example, dies of hot-pressing crank presses (HPCP), press molds for pressure casting of silumin parts, and gages for cold stamping, that have a no worse service stability after cyaniding [5]. This can be explained by the comparatively mild service conditions of the mentioned tools.

The duration of the contact with the hot (1200°C) preform in forging in HPCP is much shorter than in low-speed hydraulic presses. For this reason, the tool accumulates less heat and is heated to a lower temperature; the level of the thermal stresses arising in the heat cycles (cooling of the working tool after each forging cycle) is lower the smaller the number of thermal erosion cracks formed on the functional surfaces (the main cause of failure of this tool).

The tools of press molds for pressure casting (dies, punches, dissectors, etc.) experience comparatively low specific loads. The necessity to replace the tool is connected with the wear of the surface caused by adhesion upon contact with liquid metal injected under pressure into the working cavity of the die. The tool not subjected to THT begins to wear after forging several tens of castings, which makes it necessary to clean the working surface of the tool and which often worsens the surface purity. For this reason, the liquid metal (silumin) often welds to the surface, which leads to
new cleaning operations. The cleaned sites, where the purity of the surface has worsened, serve as sources of erosion of the metal and breakage of the tool.

We have established that even the presence of a diffusion layer with a small thickness (up to 0.05 mm) prevents welding of silumin to the surface of the tool and increases its service life by almost a factor of 4, which corresponds to the service stability of nitrided tools (Fig. 1). Thus, it is possible to resort to a rapid process of cyaniding for some kinds of tools instead of nitriding. The duration of the cyaniding is 30–40 min.

We cyanided the tested parts in a melt of the following salts: 90% \( K_4[Fe(CN)_6] \) + 10% KOH [4]. The melting of potassium ferrocyanide is accompanied by its dehydration and decomposition, i.e.,

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K_4[Fe(CN)_6] \cdot 3H_2O \rightarrow K_4[Fe(CN)_6] + 3H_2O; \quad (1)
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\[
K_4[Fe(CN)_6] \rightarrow 4KCN + Fe + 2C + 2N; \quad (2)
\]

\[
2KCN + O_2 \rightarrow 2KNO; \quad (3)
\]

\[
2KNO + O_2 \rightarrow K_2CO_3 + CO + 2N. \quad (4)
\]

The active atoms of carbon and nitrogen emitted in the decomposition of potassium ferrocyanide are adsorbed by the surface of the tool, diffuse into its depth, and create a saturated layer 0.05–0.09 mm thick. In the initial state the potassium ferrocyanide is known to be nontoxic, which makes the cyaniding process safe (however, the rules for deoxidizing the baths and for storing and burying the formed slurry should be observed very strictly).

Under steady process conditions one cyaniding bath performs the work of at least four nitriding furnaces.

**Boronizing of forging tools.** The search for an alternative for nitriding for hardening forging tools was performed by comparing the service stability of specific tools after various kinds of thermochemical treatment. We have determined the range of tools whose endurance increases after boronizing. It is known that a negative property of a boronized layer is its brittleness. For example, even in the determination of the hardness of the layer, cracks or even cleavages can arise in the region of a Vickers indentation (which depends on the hardness of the metal of the matrix; for example, cleavages can be observed on structural steels of the type 38KhS at 35–40 HRC). The brittleness of the obtained layer limits the use of boronizing in machine building and the production of tools. However, there are cases when a boronized layer operates under conditions of impactless loading or abrasive wear; then its effect on the wear resistance can hardly be overestimated. For example, boronizing has become a necessary process for increasing the wear resistance of link pins and crawler belt parts of various machines. The process was first used by the Ural Carriage Plant and is now successfully employed by other plants too.

Our experiments on boronizing highly loaded forging tools and subsequent comparative tests of nitrided and boronized parts allowed us to judge the expediency of using boronizing for hardening press tools. We have established that boronized tools for hydropresses have an endurance no worse than that of nitrided parts. Under the conditions of deep piercing of steel nozzles, the endurance of boronized punches is 25–30% higher than that of nitrided ones (Fig. 1). Thus, we have shown that a considerable group of tools for hydropress forging (piercing and drawing punches, dies, pushers) can be more successfully hardened by boronizing than by nitriding.

We analyzed the known boronizing techniques in order to choose the optimum variant for the Ural Carriage Plant. At first we chose electrolytic boronizing, which is the most intense of the known processes [6]. However, the difficulties encountered by the plant in the conversion and twenty-five-year use of the process have shown that they can be only overcome by a large enterprise only. The first problem was the availability of high-temperature cast stock for the muffles used for boronizing, which were subjected to continuous erosion (the muffles are anodes and the suspension is a cathode). When the muffles failed, the molten borax hardened in the form of monoliths which were very hard to remove. The design of the current-conducting suspension was unfortunate in the sense that the boronizing could not be combined with the subsequent quenching.

Taking into account the mentioned difficulties we tested another known variant of liquid boronizing known as current-free boronizing [7].

The use of boron powder in the melt of technical borax instead of boron carbide \( B_4C \) or iron boride \( FeB \) allowed us to accelerate the process of boronizing at the expense of its higher reactivity and reduce the amount of the solid phase in the bath and the slime content in the bath. In order to elevate...