punch working surfaces corresponded to the structure of the transition zone of the diffusion layer with a hardness exceeding that of the core by more than HV 200. The existence of this developed transition zone leads to an increase in fatigue limit due to an increase in the action of useful compressive stresses [1, 7], and it provides high punch durability.

**CONCLUSIONS**

1. Short-duration carbonitriding of a punching tool for closed die forming made of steel R6M5 makes it possible to increase durability by a factor of 1.7 to 2.5.

2. The composition used for the working bath is more economic and less toxic compared with that used currently.

3. Additional tempering after carbonitriding makes it possible to increase toughness of the diffusion layer without reducing its hardness. An oxide layer is formed which facilitates wearing in and improves the appearance of the tool.

4. The optimum schedule for final heat treatment for punches is carbonitriding at $550 \pm 10^\circ C$ for 10-20 min and tempering at $430-450^\circ C$ for 30 min.

**LITERATURE CITED**


**INFLUENCE OF CARBONITRIDING ON THE LIFE OF CUTTING TOOLS**

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Carbonitriding or soft nitriding is widely used for treatment of cutting tools since it provides high wear resistance in cutting both soft and tough materials, fatigue strength, resistance to galling and corrosion, an improvement in antifriction properties, etc.

In nitriding, two zones are formed on the surface of the steel, the zone of compounds consisting of carbides and nitrides (E-phase) and the diffusion zone consisting of $\alpha$-solid solution and carbides [1]. The thickness of the zone of compounds depends upon the impregnating activity of the bath, temperature, and the length of the process.

With an increase in treatment time there is an increase in hardness, a simultaneous reduction in impact strength of the steel, and embrittlement of its surface. In addition the distribution of hardness across the thickness of the diffusion layer is nonuniform.

The maximum hardness is found in the area of transition from the zone of the compounds to the diffusion zone and gradually decreases toward the core.
The purpose of this work was selection of the optimum carbonitriding time for various high speed steels and an investigation of the hardness distribution across the thickness of the carbonitrided case. The carbonitriding of various forms of tools and the life tests were done under production conditions.

The investigation of carbonitriding was made on R6M5, R6M5K5, R18V, R12F3, R12F2K8M3, and R9M4K8 high speed steels, which are those most widely used for the production of cutting tools. All of the investigated steels passed incoming heat inspection and from each of them were prepared cylindrical samples with a surface finish on the face planes of Rz = 10-20 μm.

Before carbonitriding, all of the samples were hardened and tempered using the optimum cycle for each steel. The samples were preheated in an electric furnace at 400-500°C and then in NT-660 molten salt (TU 6-18-71-70) at 860-880°C. The austenitizing was in BMF salt (TU 6-18-96-71) at 1220-1280°C depending upon the type of steel. The austenitizing was done so as to obtain an austenitic grain size of No. 10-11. The samples were quenched in NT-495 salt (TU 6-18-70-70) at 560°C and then in air. After hardening the samples were triple tempered at 540-560°C for 1 h each in NT-495 salt to a hardness of HRC 64-65.

The carbonitriding of the samples, first heated to 380°C, was done in an NOE-60/200 bath with a titanium crucible in molten mixtures of sodium cyanate (32-40%), sodium cyanide (up to 4%), anhydrous sodium carbonate (15-20%), and potassium chloride (40-49%) at 560°C with subsequent air cooling. The hold time of the samples in the carbonitriding bath was from 5 to 40 min. The hardness of the samples after carbonitriding was HV 1246-1288.

The investigation of the carbonitrided case thickness was made by measuring the microhardness on oblique samples. A high alloy element content and a large quantity of dispersed carbides significantly decreases the apparent thickness of the carbonitrided case.

To artificially increase the case thickness an angle of slope of the samples of 5°44' was selected. This angle provides a ten-times increase in the case thickness and makes it possible to eliminate the error in conversion [1].

The microhardness was measured on a "Durimet" microhardness tester with loads of 2.5 and 5 N. The measurements were made each 0.01 μm starting from the edge of the sample in the direction of the core. The distance from the edge of the sample to the area having the hardness of the base metal was taken as the case thickness. The results of the investigation showed that the hardness of high speed steel samples increases an average of HV 200-300 after carbonitriding.

With an increase in hold time in the bath in carbonitriding the carbonitrided case thickness increases, reaching 0.020-0.035 mm after 10-15 min. With an increase in the hold to more than 30 min there is practically no change (Fig. 1).

Of all of the investigated high speed steels R6M5 and R18F steels, in which a 0.020 mm case depth is formed after 10 min, carbonitride is best (Fig. 1).

In the steels containing cobalt a case depth of 0.02 mm is reached only after a hold of more than 20 min and with an increase in cobalt content in the steel the carbonitrided case is thinner. This is caused by the retarding influence of cobalt on the diffusion of nitrogen and carbon [2].

An increase in tungsten and vanadium content in the steel does not have a significant influence on the carbonitriding process. For R12F3, R12F2K8M3, and R18F steels the optimum carbonitrided case depth of