BORIDING OF DIE STEELS

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Boriding conditions were investigated for forging dies working at 600-850°C under pressures of 40-50 kg/mm^2.

Boriding was conducted in molten borax ($Na_2B_4O_7$) by the technique developed at Giproneftemash [1].

The case depth increases with the time, temperature, and up to a certain limit current density in electrolytic boriding [2]. The wear of forging dies occurs in thousandths, hundredths, and rarely tenths of a millimeter, and therefore the wear resistance of the die hardened by boriding depends not only on the depth of the boride case but also its quality, the working conditions of the die, etc.

A study of the effect of boriding time on the wear resistance of dies subject to substantial thermomechanical effects showed that the durability first increases with the boriding time and then decreases (see Fig. 1). This is due to the formation of Fe_2B during formation of the boride case. With further boriding time FeB is formed, which has a microhardness of 17,000-19,600 [3]. The hardness of both borides is high, and therefore, to increase the wear resistance it is necessary to reduce the brittleness of the case, which can be achieved by reducing the depth of the harder and more brittle FeB by shortening the boriding time (see Fig. 1).

The boriding temperature has a considerable effect on the wear resistance. At temperatures above 1000°C a complex eutectic is formed, leading to reduction of the wear resistance. The presence of a fused layer in the case and the formation of pores (of diffusion origin) at elevated temperatures also impair the properties of the boride case [3].

At elevated boriding temperatures and times the boron diffuses into the base metal on a massive front, acicular borides are smoothed out, and as a result the area of contact with the base metal is reduced, thus lowering the adherence of the boride layer to the base metal.

The current density during boriding has no effect on the wear resistance. In electrolytic boriding the boron diffuses into the steel in the form of positively charged ions [4], and therefore the applied electric field has an accelerating effect on the diffusion rate of the boron ions [3]. The number of boron ions discharged on the cathode increases with the current density only up to a certain point. Beginning with the saturation voltage, the number of boron atoms discharging on the cathode remains constant; further increase of the current density leads to the discharge of sodium ions on the cathode. With increasing current density the depth of FeB increases, increasing the brittleness and lowering the durability. Comparative data on the durability of borided and unborided dies are given in Table 1.

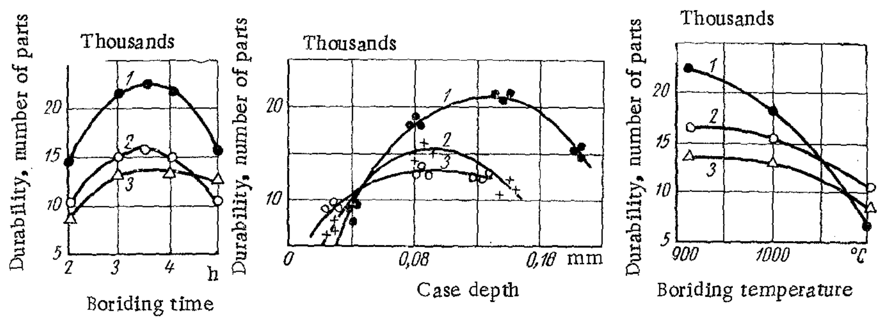

Fig. 1. Variation of the durability of dies with the boriding time and temperature and depth of the boride case. 1) Steel U8; 2) 8Kh3; 3) 5KhNV.

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TABLE 1

Steel	Hardness, HB, after quenching and tempering of unborided dies	Boride case depth, mm	Microhardness of case	Maximum wear resistance (thousands of parts)	
				borided	hardened (not borided)
5KhNV	390—430	0,06—0,09	20 600—21 100	13 000	5000
8Kh3	390—430	0,07—0,1	19 100—19 600	16 000	4200
U8	62—64*	0,11—0,17	16 700—18 200	22 500	3500

* *HRC*.

The wear resistance of borided dies of steel U8 is approximately 150% that of borided dies prepared from alloyed steels 5KhNV and 8Kh3.

It has been found [3, 5, 6] that such elements as manganese, nickel, chromium, molybdenum, and tungsten increase the amount of FeB in the boride case, while an increase of the carbon content of the steel reduces the proportion of this boride, thus increasing the wear resistance in use.

The wear resistance is also affected to a great extent by the design of the die, the surface finish, the working conditions, the heat treatment after boriding, etc.

The main type of wear in borided dies of alloy steels is fatigue damage. To create a hard sublayer and retain the strength and ductility after boriding, the dies are subjected to isothermal quenching and high-temperature tempering, as the result of which the fatigue strength is restored to a value equal to that of the unborided steel in the original condition.

Alloyed steels are more sensitive to the influence of alternating loads in the presence of small scratches, notches, and cracks. They require careful finishing and heat treatment, slight departures from which can cause cracking and then fracture in the first stages of operation.

CONCLUSIONS

1. Boriding of dies effectively increases the resistance to periodically changing thermomechanical influences.

2. The optimal conditions for electrolytic boriding are 3.5 h at 920-950°C at a current density of 0.15 A/cm^2.

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