Research on the technology of paste boronizing for H13 die steel

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Abstract. In this paper, the boronizing effect of H13 hot work die steel is studied. The experiment is carried out to compare the boronizing effect of H13 steel at 850 °C, 900 °C and 950 °C. The heating time is set to 4 hours. The experimental results indicate that the temperature at 950 °C is suitable for boronizing of H13 steel. At 950 °C the boronized layer is more tightly bonded to the matrix, and the depth of the layer is deeper than at 850 °C and 900 °C. The hardness of the layer at 950 °C is better than at 850 °C and 900 °C in terms of the hardness of the layer. Therefore, 950 °C is a suitable temperature for boronizing the H13 hot work die steel.

1. Preface

Metal component surface treatments or surface modification techniques include such techniques as physical vapor deposition, chemical vapor deposition, induction beam hardening, hot dip coating, nickel plating, chrome plating, tin plating, carburizing, nitriding, carburizing, boronizing, and the like. Some of these treatments involve coatings that are the outer film layer of the metal substrate outer casing, while others process the physical and chemical properties over a distance of the substrate by diffusing another element. In the latter process, the change in substrate thickness is negligible. Boronizing is a surface diffusion treatment that increases some properties of the matrix to a certain depth \cite{1,2,3}. After the boronizing treatment of steel material, the wear resistance, corrosion resistance and high temperature oxidation resistance can be improved, and the parts can be used in a more complicated and multi environment \cite{4}. The performance of boronized steel is always superior to that of nitrided steel and carburized steel \cite{5,6,7}.

H13 hot work die steel is widely used in extrusion die and die casting. It is usually characterized by high strength and toughness. In direct contact with the work piece during operation, the temperature can reach 400-500 °C. In the forging machine, it can reach 650-700 °C. However, such die steels are commonly used in corrosive environments. The use of thermochemical treatment technology can improve the surface wear resistance, thermal fatigue and corrosion resistance. Boronizing technology
is an effective surface treatment method. Due to the nature of the diffusion process, the boride layer has good adhesion to the substrate compared to conventional physical coating processes. Due to the high hardness of boride (1500–2000 HV), it has the advantage of high hardness compared with traditional surface treatment such as carburizing, nitriding and carbonitriding [8,9,10].

In this paper, the effect of temperature on the boronizing layer was determined by comparing the boronizing effect of H13 die steel at the same boronizing time at different temperatures. According to the literature [11,12], it can be concluded that the boronizing temperature is generally between 850 and 1000 degrees, so the temperatures are selected as 850 °C, 900 °C, 950 °C.

2. Experimental materials and experimental methods

2.1. Experimental materials

The experimental material used in this paper is H13 hot work die steel, the chemical composition of which is shown in table 1. The micro hardness of H13 steel is 450HV–550 HV, and the H13 steel is cut into 20 mm × 10 mm × 10 mm size, which is used for the micro hardness test of boronizing experiment. The experimental plasters are C, B₄C, NaF, and the like.

Table 1. Composition of H13 hot work die steel.

| Element | C     | Si   | Mn   | Cr   | Mo   | V     | P      | S      |
|---------|-------|------|------|------|------|-------|--------|--------|
| Content (%) | 0.32-0.45 | 0.80-1.20 | 0.20-0.50 | 4.75-5.50 | 1.10-1.75 | 0.80-1.20 | ≤0.030 | ≤0.030 |

2.2. Experimental methods

The H13 steel sample, having a size of 20 mm × 10 mm × 10 mm, was sanded and polished with a sandpaper, and then the surface grease and the like were washed with alcohol and dried by a blower to be placed in a desiccator for use. After weighing the appropriate amount of the agent, add a proper amount of water to form a paste and apply it evenly on the sample. The thickness is about 3~5 mm. Place it in a dry and ventilated place and dry it during one night. Then put it in a dry box and heat it to 150 °C for 2 hours. Dry thoroughly. The heating temperature of the resistance box was set to three temperatures of 850 °C, 900 °C, and 950 °C, respectively, and three samples were heated, the heating time was set to 4 hours, and the sample was cooled to room temperature with the furnace.

After the sample is completely cooled, it is taken out and knocked out of the outer casing, and the sample is cut from the middle by wire cutting. The cut surface of the sample is polished, polished, etched, etc. with different types of sandpaper. The sample was placed under an optical microscope OLYMPUS DSX-HRUF to observe the layer structure. Hardness was measured by applying a force of 25 g on a (HV-100) hardness tester for 10 s.

3. Experimental results

3.1. Analysis of boronized layer

Three samples which had been subjected to boronizing treatment at 850 °C, 900 °C, and 950 °C were again polished and polished. According to the literature [13, 14], the surface of the treated sample was etched by disposing a 3 % to 5 % nitric acid solution, and then the boronized layer was observed under a microscope. The (a), (b), and (c) of figure 1 are boronized layers of 850 °C, 900 °C, and 950 °C, respectively.

It can be seen from (a), (b), and (c) in figure 1 that the boronized layer is sparse at 850 °C and the boronizing depth is shallow, when the temperature rises to 900 °C, the temperature of the boronizing layer begins to become tight and begins to appear jagged. When the temperature reaches 950 °C, the boronized layer is more compact, and the sawtooth shape is more obvious. The boronizing depth is obviously improved relative to 850 °C and 900 °C. Table 2 shows the depth of the boronized layer at
850 °C, 900 °C, and 950 °C. It can be seen that the effect of temperature on the boronized layer indicates that the boronizing effect at 950 °C is significantly better than at 850 °C and 900 °C.

![Figure 1. The boronized layer at different temperatures.](image)

**Figure 1.** The boronized layer at different temperatures.

| Temperature (°C) | 850 | 900 | 950 |
|------------------|-----|-----|-----|
| Layer thickness (μm) | 30~40 | 35~40 | 55~60 |

3.2. **Analysis of the hardness of the layer**

Table 3 presents the hardness value of each point of the sample, and figure 2 shows the approximate hardness curve at 850 °C, 900 °C, and 950 °C.
Table 3. Hardness values.

|               | 20 μm   | 40 μm   | 100 μm  | 200 μm  | 300 μm  |
|---------------|---------|---------|---------|---------|---------|
| 850 °C        | 1127.82 HV | 620.2 HV | 475.10 HV | 510.32 HV | 463.33 HV |
| 900 °C        | 1298.76 HV | 570.3 HV | 479.33 HV | 530.20 HV | 478.20 HV |
| 950 °C        | 1402.77 HV | 590.2 HV | 454.32 HV | 490.72 HV | 530.21 HV |

Figure 2. Hardness value curve.

Since only 20 μm of points on the thinner layer of the infiltrated layer are on the infiltrated layer, 40μm are on the transition layer, 100 μm, 200 μm, 300 μm are on the base material. It can be seen from table 2 and figure 2 that the hardness of the layer at 950 °C in the 20 μm layer is better than the hardness of the layer at 900 °C and 850 °C.

4. Conclusions
The research results indicate that the temperature at 950 °C is suitable for boronizing of H13 steel. At 950 °C, the boronized layer is more tightly bonded to the matrix, and the depth of the layer is deeper than at 850 °C and 900 °C. The hardness of the layer at 950 °C is better than that at 850 °C and 900 °C in terms of the hardness of the layer. Therefore, 950 °C is a suitable temperature for boronizing the H13 hot work die steel.

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