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# Liquid Boriding for Small Cutting Tools

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**Abstract.** In steel surface hardening methods, Boriding produces a layer of uniform hardness from the surface to a depth of the diffusion layer, with high resistance to wear and corrosion. This method can be applied to carbon steels, low alloy steels, tool steels, stainless steels, etc. Specifically for parts subject to high levels of wear, such as valve parts (gates, body/stem, etc.), pump components (housings, cylinders, etc.), agriculture equipment (harvesting cut tools, separators, etc.), and automotive parts (engine oil pumps, gears, etc.). This study focuses on studying the formation mechanism of permeable layer Boriding, the nature of absorbent layer B forming on the steel surface, and exploring the influence of factors such as infiltration temperature, infiltration time, and mixture ratio on the microstructure, properties of the permeability layer Boriding. The salt bath consists of 70% borax + 30% silicon carbide, and the permeability temperature is from 850 ºC to 1050 ºC for about 2-10 hours. The results show that the penetration rate is relatively fast, about 0.04 mm/h, and the quality of the layer is relatively uniform. After Boriding, quenching, and tempering, the hardness obtained about 1000 – 1100 HV.

**Keywords:** Permeability layer thickness, microstructure, quenching, boriding.

## 1. Introduction

Small cutters, such as nail trimmers (figure 1), are usually made of JIS SUS420J2, TCVN CD90 steels. Forming process of small cutting tool products is billet cutting → heating - hot stamping → burr cutting, scraping, and heat treatment → inspection → mechanical processing (milling, drilling, grinding, etc.) → heat treatment → plating → test-packing. The heat treatment of small cutting tools includes two parts heat treatment. Preliminary heat treatment includes annealing or normalizing to soften the steel after stamping and cutting the billet, stabilizing the microstructure after stamping, performing after the hot stamping operation, and the product must be cut burr and rusted after when hot stamping. Next is the end heat treatment: Boriding and chromizing, etc. Then use the method: quenching and tempering.

Some new chemical and thermal treatment technologies, such as boriding and carburizing, have been produced in many factories [1-3]. These technologies improve product quality, save precious materials, and create excellent economic efficiency [4-8]. However, there has not been much research in Vietnam on chemical heat-treatment technology methods, especially new chemical heat treatment methods. Therefore,

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studying liquid Boriding for small cutting tools is urgent and has scientific novelty and high practical significance.

This study focuses on the basic rules of surface layer formation in the Boriding process. The study focuses on the formation mechanism of the permeable layer and the nature of the permeable layer B formed on the steel surface and the study of the influence of factors such as infiltration temperature, infiltration time, and permeation mixture ratio on the properties of permeable layer B includes microstructure, permeability layer thickness, surface hardness, abrasion strength on the steel sample studied. This research tries to generate a Boriding layer that could increase the part's surface hardness, wear resistance, and corrosion resistance. The permeability layer does not crack, the average depth of the permeability layer is about 85 μm and the hardness is about 1000-1100 HV. This research could be applied to steel grades serving the field of aesthetics and applied to manufacturing cosmetology services.

## 2. Materials and Methods

This study uses steel sample SUS420J2, 6 samples, size Ø16 mm, parallel grinding on both sides, as shown in figure 2.

**Figure 1.** A nail trimmer [9]

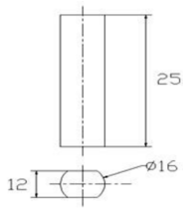



**Figure 2.** Experiment sample size (mm)

**Figure 3.** The resistance furnace Model 1P20 in the Material Testing Laboratory at HCMUTE

The heat treatment process uses a resistance furnace: Model 1P20, voltage 220V-50 Hz, capacity 3 kW, maximum temperature 1100 $^{o}$C, as shown in figure. 3.

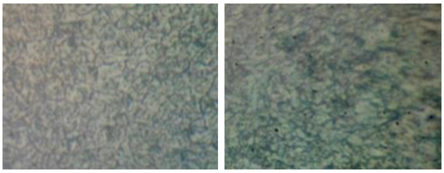
The sample after penetration is measured on the HRD – 150 Rockwell hardness tester, the HV-1000 Vicker hardness tester.

Samples were etched with 4% $HNO_3$ acid in alcohol, then observed the microstructure on the XJZ-6A microscope.

## 3. Results and Discussion

### *3.1. Microstructure before Processing*

The microstructures of the sample at horizontal cross-section and vertical cross-section are shown in figure 4.



a) Horizontal cross-section; b) Vertical cross-section

**Figure 4.** Microstructure of sample at the horizontal cross-section and vertical cross-section.

+ Hardness before processing is presented in table 1:

**Table 1.** Hardness number of samples before processing.

| Sample | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|
| HRB | 97 | 97.5 | 96.5 | 97 | 96 | 97 |

### *3.2. Heat treatment*

#### *3.2.1. Isothermal Annealing*

For 6 samples numbered from B1 to B6, the annealing temperature is 880 $^{o}$C, holding time for 15 minutes, then transferring to an oven at 700 $^{o}$C, holding time for 1 hour and 30 minutes, and cooling in air (shown in figure 5).

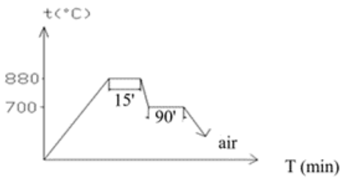



**Figure 5.** Isothermal annealing diagram.

+ Purpose: uniform in mechanical properties and soften steel before machining and cutting and to remove internal stresses.

+ Requirements: the sample has been ground to the correct size, and the two grinding faces must be parallel: bevel and clean the sample.

- Hardness of sample after annealing is presented in table 2:

**Table 2.** Hardness number of samples after annealing.

| Sample | B1 | B2 | B3 | B4 | B5 | B6 |
|---|---|---|---|---|---|---|
| HRB | 92 | 93 | 93 | 92 | 91 | 92 |

- Microstructure after annealing is shown in figure 6:

**Figure 6.** Microstructure of sample after annealing.

### *3.2.2. Liquid Boriding*

The Boriding box (figure 7) holds all 6 samples and is made of steel. The chemical agents are mixed with the composition as:

- Chemical agents: 70% $Na_2B_4O_7$ +30 % SiC (specifically, in this paper is 350g $Na_2B_4O_7$ + 150g SiC)
- Put the samples in the box:
  • Melt the mixture in the box for a specific time.
  • After the mixture has melted, place 2 unannealed samples B5, B6, and 2 isothermally annealed samples B1 and B2, cleaned into the absorbent box.
  • Permeation temperature 1000 °C, heating time is 2 hours (shown in figure 8).

**Figure 7.** Boriding box with graphite.

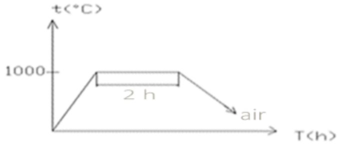



**Figure 8.** Boriding process diagram.

- After the Boriding process:
  + Observing the microstructure of the permeable layer.
  + Measuring permeation depth
  + Measuring HV hardness
- Compare the two sample groups incubated and not yet incubated after permeation.

### *3.2.3. Quenching*

Heat to 880°C, holding time for about 15 minutes, and cooling in oil (shown in figure 9).

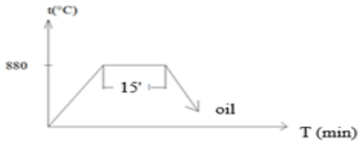



**Figure 9.** Quenching process diagram.

+ Purpose: achieving the martensite microstructure and increasing the hardness and wear resistance of the cutting edge.
+ Requirements: samples are cleaned and made after annealing.

### *3.2.4. Tempering*

Tempering at 250 °C, holding time for 3 ÷ 4 hours, and then cooling in the air (shown in figure 10).

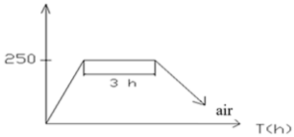



**Figure 10.** Tempering process diagram.

+ Purpose: check the tempered martensitic structure achieved after quenching. Tempering in this mode reduces internal stress, increases ductility and toughness, and makes breaking brittle harder.

+ Requirements: samples are cleaned and made after tempered.

### *3.3. Depth of Boriding Layer*

The average depth of the Boriding layer is 85 μm, as shown in figure 11.

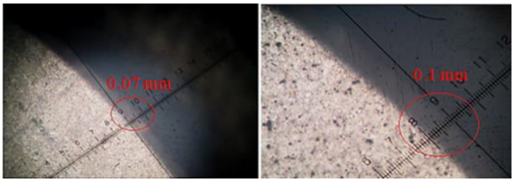



**Figure 11.** Depth of Boriding layer.

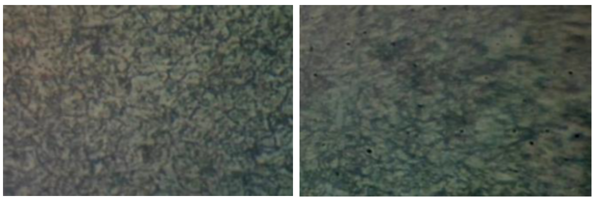
### *3.4. Hardness after BORIDING, Quenching, and Tempering*

Figure 12 shows the hardness trace after Boriding, quenching, and tempering. The measured value is approx 1000 – 1100 HV.

**Figure 12.** The hardness measurement of the Boriding layer.

### *3.5. Microstructure after Boriding, Quenching, and Tempering*

Figure 13 shows the microstructure after Boriding, quenching, and tempering. The results show that the boriding layer shape is uniform.



a) Horizontal cross-section b) Vertical cross-section

**Figure 13.** The microstructure of the Boriding layer (magnification 312.5X)

## 4. Conclusions

The study proved the theoretical basis of thermo-chemical treatment, absorbent materials of Boriding, methods of Boriding, and characteristics and properties of permeable layers of Boriding. For the liquid boriding process, controlling the atomic boron concentration at the part's surface to be impregnated is relatively difficult. The boron absorbent technology is relatively simple, the equipment investment is small, and the absorbents used, such as borax and silicon carbide, are available on the Vietnamese market and are relatively inexpensive, suitable for details with simple and small shapes.

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