EFFECT OF COOLING RATE ON THE QUALITY OF HARD ALLOYS

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In principle, heat treatment can be effectively applied to tungsten-cobalt alloys, because in the pseudobinary system WC-Co there is a line of limited solid-state solubility of tungsten carbide in cobalt. According to M. M. Babich, E. N. Kislyakova, and other authors [1], the solubility of tungsten carbide in cobalt is 2% at 700°C, about 3% at 800°C, approximately 4% at 1000°C, and just under 10% at 1350°C. Under industrial conditions, sintering is usually performed so that the resulting alloys have a two-phase WC + Co composition.

In a typical industrial process, the composition of the cobalt phase cannot be expected to undergo appreciable changes, because the speed of boat travel in the furnace ranges from 3.6 to 13.9 m/min, resulting in cooling rates ranging from 5 to 20 deg C/min. The heat treatment of hard alloys has been the subject of a number of investigations [2-6], but the results reported are largely contradictory and call for additional study and verification. Apart from this, the heat-treatment experiments described were invariably carried out on fully processed (sintered) alloys. It must therefore be of interest to study the effect of the rate of cooling from the sintering temperature on the quality of hard alloys. The results of such a study are presented below.

The two most widely used tool-grade hard alloys, VK15 and VK6, were chosen for investigation. To ensure constancy of the chemical composition of the mixture and, consequently, of the physicomechanical properties, the use of WC with 15 and 6% Co, respectively—Translator's note.

![Fig. 1. Quenching device: 1) graphite tube; 2) lock; 3) quenching bath; 4) cooling liquid; 5) discharge opening; 6) trough; 7) brass screen; 8) band; 9) guide launder; 10) support; 11) table. (All dimensions in millimeters.)](image-url)
Fig. 2. Effect of cooling rate on Brinell hardness HB.

Fig. 3. Effect of cooling rate on transverse rupture and impact strengths.
Alloys: ○ VK6; × VK15.

properties of the resulting alloys, specimens of each alloy were pressed from the same batch of mixed powders. Powder mixtures were prepared by the usual technique. The plasticizer, SKB-60 synthetic rubber, was added to the mixtures in the form of a 5% solution in benzene. The compaction pressure was 1-1.2 tons/cm². In the as-sintered condition, the specimens were 5 × 5 × 35 mm size. After pressing, the specimens were at once subjected to final sintering in a batch-type resistance furnace with a graphite tube in a hydrogen atmosphere. The following sintering schedule was employed: heating from 20 to 900°C at a rate of 5 deg C/min and from 900 to 1420°C at a rate of 2 deg C/min, with soaking for 1 h at the sintering temperature.

Blanks were placed in a specially made graphite boat on graphite plates which had been sprinkled with aluminum oxide. Corrax* with 0.5% of graphite granules was used as the packing material. VK15 and VK6 alloy specimens were sintered together.

The following methods of cooling from the sintering temperature were used:
1. Quenching in oil (cooling rate 80-100 deg C/min).
2. Quenching in water (130-150 deg C/min).
3. Cooling in the air (28-30 deg C/min).
4. Cooling with the furnace (1-3 deg C/min).
5. Standard sintering. Here the specimens were furnace-cooled to 1200°C at a rate of 3.1 deg C/min, while from 1200 to 40°C cooling was performed in the furnace cooler at a rate of 26-29 deg C/min.

Quenching in oil and in water was carried out, using a special device (Fig. 1), as follows. The device was mounted next to the discharge end of the final sintering furnace so that the axis of its tube 1 coincided with the axis of the furnace tube, and the end of the trough 6 was located at a distance of 12-20 mm from the discharge door of the furnace. At the instant when the boat reached the furnace cooler, the discharge door was quickly opened and the boat was transferred by means of a special rod into the tube of the quenching device. As soon as the boat engaged the lock 2, it was turned over. Its contents were released through the discharge opening and fell, guided by the launder 9, into the quenching bath, where the specimens were caught on the brass screen 7, while the Corrax settled down on the bottom of the tank. The specimens were removed from the bath when the temperature of the quenching medium reached 80-100°C.

Heat-treated alloys were tested together with alloys sintered by the usual technique. The alloys were subjected to metallographic, x-ray diffraction, and magnetic analyses, and their mechanical properties (transverse rupture strength, hardness, and impact strength) were determined. It will be seen from Fig. 2 that the hardness of both VK6 and VK15 alloys is unaffected by cooling rate and invariably remains constant.

Examination of data on transverse rupture strength (Fig. 3) reveals that the curves exhibit maxima (the strength increases by about 15% compared with that attained in orthodox sintering); the curve for VK6 alloy has two such maxima, at cooling rates of 50-100 and 2-3 deg C/min. For both alloys, the strength rises slightly at a cooling rate of 130-150 deg C/min and fall at 28-30 deg C/min. The impact strength curves have a similar character. The experimental data are in good agreement with literature data [3, 4] obtained in experiments on the heat treatment of sintered alloys.

* A pure grade of electrocorundum — Translator's note.