Grain Size of Commercial High Speed Steel

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Abstract: The heat treatment of high speed steel tools consists of austenitizing, quenching and tempering. The size of austenite grains formed during the hardening treatment is an important factor in the final microstructure of the steel, and it also affects properties such as wear resistance and toughness. This paper presents the austenite grain size, matrix composition and hardness of commercial AISI M2, AISI T15, VWM3C and Sinter 23 high speed steels that were austenitized and quenched from five distinct temperatures. This study shows that increase in quenching temperature results in grain growth of steels such as AISI M2 and VWM3C, obtained by the conventional method (cast to ingot and worked). The P/M Sinter 23 high speed steel showed a slight grain growth (about 10%). This effect was not observed in AISI T15 obtained by the powder metallurgy process.

Introduction

High speed steels are used as cutting material and in many other applications, such as structural, anti-wear and bearing materials. Fracture toughness and thermal stability are essential properties in a special class of highly alloyed steels and their microstructure consists of a matrix and carbides [1-5]. The ability to retain high hardness even at high speeds resulted in this particular group of tool steels, also known as high speed steels (HSS). Initially, the high speed steels were supplied in the annealed condition and they had to be given a hardening heat treatment prior to use. The hardening heat treatment consists of austenitization, quenching and tempering [6]. Double or triple tempering is always necessary to prevent the formation of undesirable and deleterious γ phase or retained austenite in these steels with high carbon content. During heat treatment, carbide precipitation takes place and influences properties such as hardness, bending strength and grain size. The carbides which remain undissolved are known as primary carbides, generally M_6C and MC types. Wear resistance and hardness are strongly dependent on these carbides. Since the alloying elements dissolve in the matrix during the austenitizing heat treatment, the material must be cooled rapidly for hardening to reach completion. This is achieved through quenching, and in the as-quenched state the austenite phase changes to martensite. After quenching, the material consists of a martensite phase, with some retained asutenite and carbides. In this investigation, the mean austenitic grain size, the chemical composition of the matrix and hardness of the commercial high speed steels produced by the conventional processing route (cast to ingot and hot-worked) and other steels produced by powder metallurgy techniques (P/M) have been evaluated, after heat-treatment (austenitizing and quenching) at 1135, 1160, 1185, 1210 and 1235°C.

Materials and Methods

In this investigation commercial high speed steels AISI M2 and VWM3C (M3 class 2 hss) that were produced by the conventional processing route and P/M commercial high speed steels AISI T15 and Sinter 23 (P/M M3 class 2) were studied. The chemical composition of these steels are presented in Table 1.

Table 1: Chemical composition of commercial high speed steels AISI T15, Sinter 23, AISI M2 and VWM3C (wt%).

	C	Cr	Mo	W	V	Co	Fe
AISI T15	1.60	4.00	0.70	11.90	4.70	4.90	Bal.
Sinter 23	1.32	4.02	4.95	6.00	2.97	-	Bal
AISI M2	0.85	4.20	5.20	6.40	1.90	-	Bal
VWM3C	1.17	4.11	4.94	5.87	2.75	-	Bal

The austenite grain size determinations were made with the aid of an image analysing computer method “Quantikov” from micrographs of polished and etched specimens in the quenched condition.[7-8] At least five micrographs of specimens in each of the austenitized and quenched conditions were evaluated.

The matrix composition was determined semi-quatitatively with the aid of a scanning electron microscope (SEM) equipped with an energy dispersive analyser (five different areas at 2500X were measured). Polished specimens were etched with 5% nital to reveal prior austenite grain boundaries. At least five regions were examined in each specimen, to obtain a standard error as low as possible.

Hardness tests were carried out and several indentations were made using a 100 gf load.

Results and Discussion

Figure 1 presents typical scanning electron micrographs of high speed steel specimens, VWM3C (a and b), AISI M2 (c and d), AISI T15 (e and f) and Sinter 23 (g and h) that were austenitized and quenched from 1135 and 1235 °C. These micrographs reveal the presence of M_6C (white) and MC (grey) primary carbides at austenite grain boundaries that existed prior to quenching. Stringers of aggregated M_6C carbides aligned in the deformation (hot work) direction can be seen in the micrographs of AISI M2 and VWM3C high speed steels. M_6C carbides are more frequently observed in these steels than MC carbides. It can be seen from these micrographs that there is a general tendency for the quantity of M_6C carbide to decrease with increase in quenching temperature. P/M AISI T15 and Sinter 23 HSS specimens presented a fine-grained and more uniform carbide distribution.

The austenite grain size of both the conventionally processed AISI M2, VWM3C and P/M AISI T15 steels, as well as Sinter 23 produced using powder metallurgy techniques were determined. Figure 2 shows the average austenite grain sizes in specimens quenched from the five temperatures.

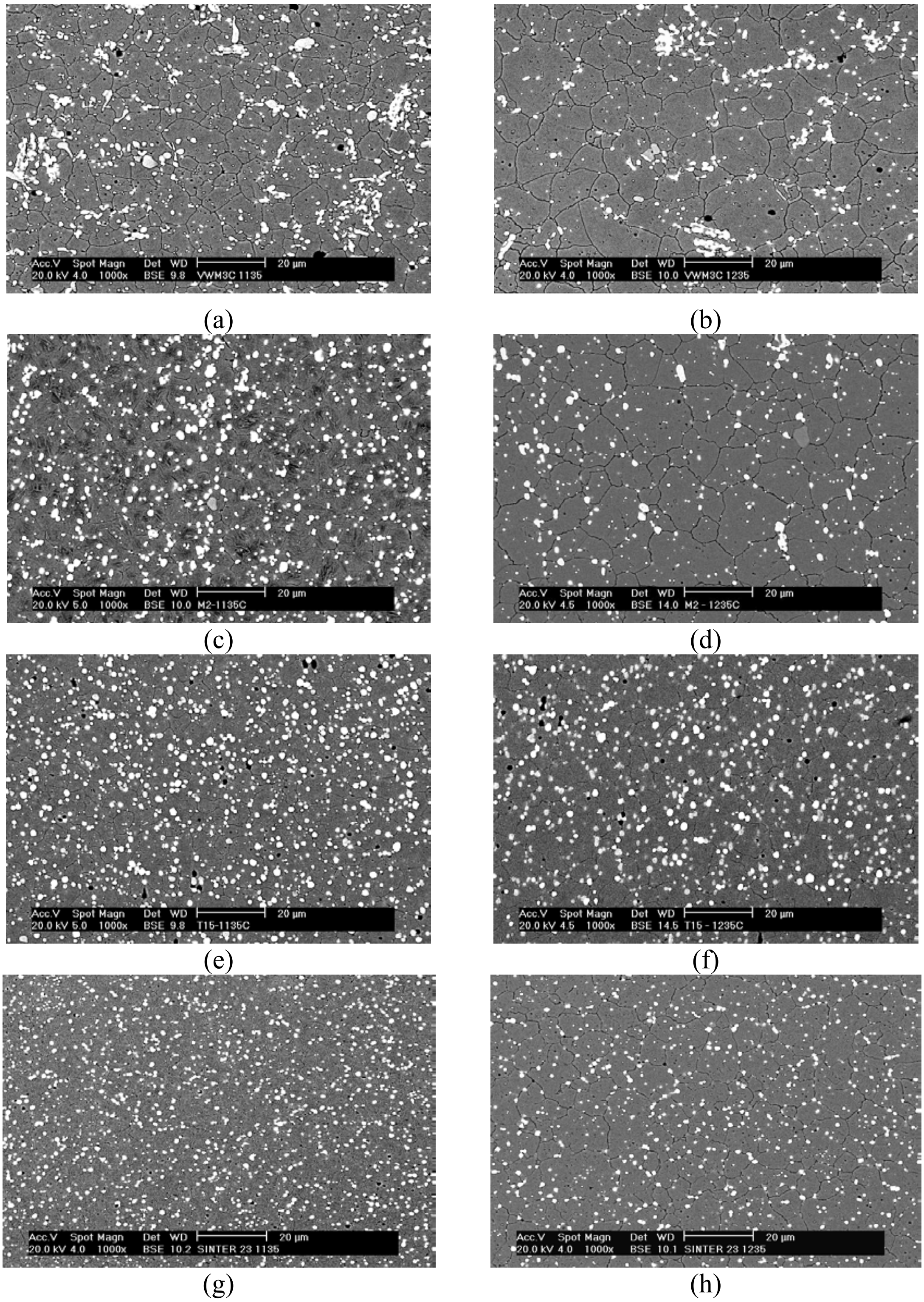

Figure 1: Scanning electron micrographs of high speed steel specimens austenitized and quenched from 1135°C and 1235°C; (a and b) VWM3C, (c and d) AISI M2, (e and f) AISI T15 and (g and h) Sinter 23.

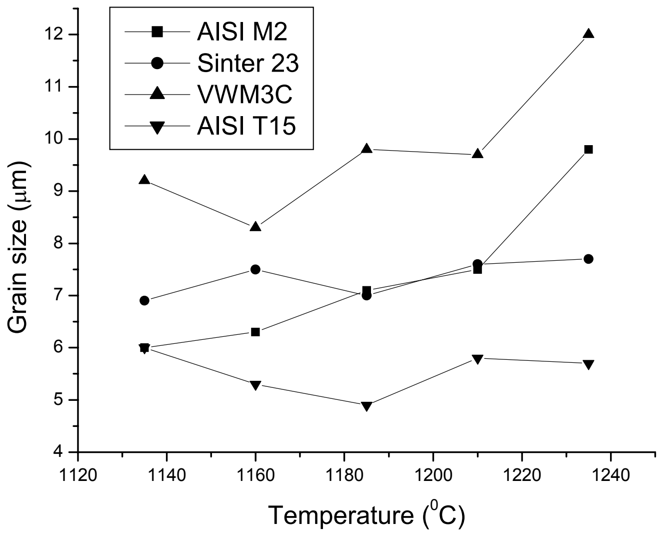

Figure 2: Average austenite grain size as a function of quenching temperature

AISI M2 and VWM3C conventional high speed steels presented a sharp increase in austenite grain size with increase in quenching temperature. P/M Sinter 23 showed a slight grain growth, about 10%. However, AISI T15 did not present grain growth but a slight decrease in the austenite grain size with increase in quenching temperature. The average austenite grain size of T15 changed from 6.0 μm to 5.7 μm.

The results of hardness as a function of quenching temperature are shown in figure 3.

In an attempt to establish a relationship between primary carbide dissolution and increase in quenching temperature, the specimens were semi-quantitatively examined in a scanning electron microscope (SEM) equipped with an energy dispersive analyser (EDS). The semi-quantitative results in terms of chemical composition of the matrix phases of the four high speed steels heat-treated at the five quenching temperatures are presented in figure 4.

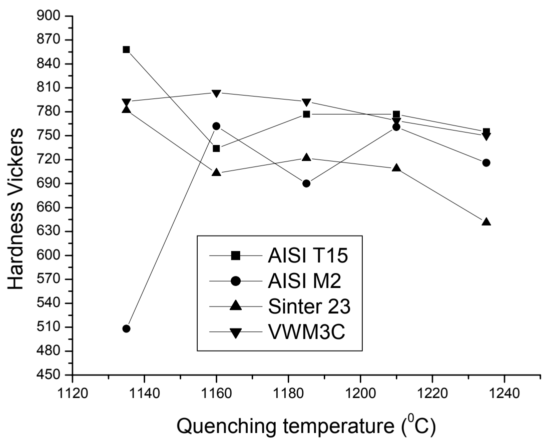

Figure 3: Hardness as a function of quenching temperature.

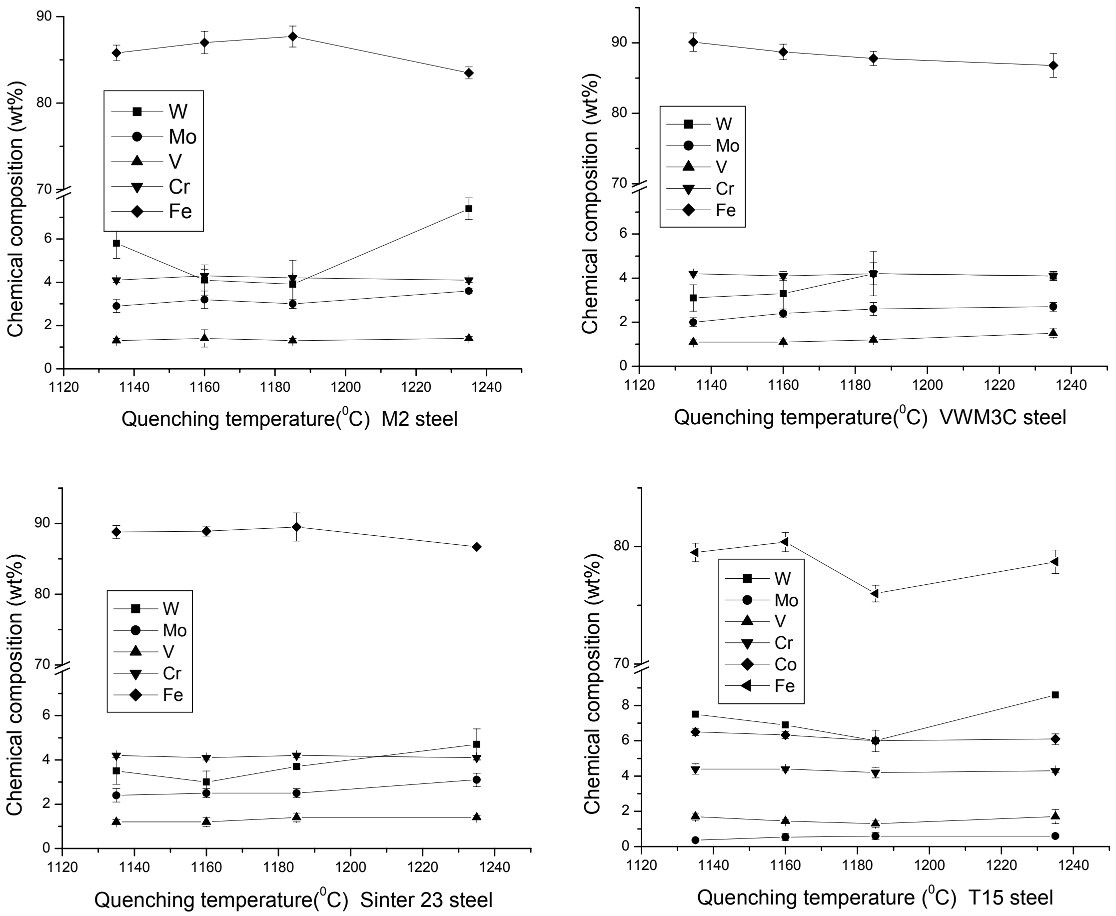

Figure 4: Matrix composition (wt%) as a function of quenching temperature of the different high speed steels.

It can be seen from these data that the iron, tungsten and molybdenum contents vary in the conventionally processed (AISI M2 and VWM3C) and P/M (AISI T15 and Sinter 23) high speed steels.

A marked increase in tungsten content in the matrix with increase in quenching temperature was observed for AISI M2, VWM3C and Sinter 23. In the case of AISI T15 this effect was slight. The iron content in the matrix decreased in all high speed steels with quenching temperature. The molybdenum content showed almost the same increment in all the high speed tool steels.

The hardness values showed a sharp drop in steels quenched from 1160°C and a slight increase in specimens quenched from 1185°C. In the case of P/M high speed steels T15 and Sinter 23, the hardness values showed a tendency to decrease when quenched from higher temperatures. The VWM3C high speed steel presented similar microhardness values and a slight drop in this property with increase in quenching temperature. The microhardness of M2 was relatively lower than that of the other high speed steels at 1135°C. Upon quenching from higher temperatures, the microhardness of this steel (M2) increased sharply and remained at this high value. The general tendency for decrese in microhardness can be attributed to the increase in the fraction of retained austenite (γ) with increase in quenching temperature.

Since the vanadium content remained almost the same in specimens quenched from the different temperatures in all high speed steels, this study focussed on the volumetric fraction of the primary M_6C carbide as shown in figure 5.

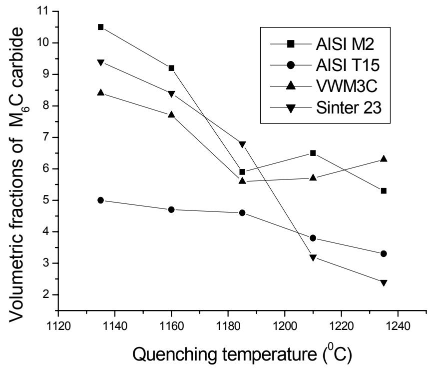

Figure 5: Volumetric fractions of M_6C carbide as a function of quenching temperature.

The volumetric fraction of the primary M_6C carbide in all the high speed steels decreases with increase in quenching temperature. In the case of M2 and Sinter 23 this reduction is nearly 50%. In the case of T15 and VWM3C the reductions were 36% and 25%, respectively.

Conclusions

1. The conventionally produced high speed steels AISI M2 and VWM3C presented a sharp increase in austenite grain size with increase in quenching temperature. The P/M Sinter 23 showed a slight grain growth, about 10%. However AISI T15 did not present grain growth, but a slight drop in the austenite grain size with increase in the quenching temperature.
2. The tungsten content in the matrix increased with increase in quenching temperature, especially in the steels AISI M2, VWM3C and Sinter 23. In the case of AISI T15, this effect was slight. The iron content decreased in all the high speed steels, whereas the molybdenum content showed the same level of increase.
3. The increase in tungsten content of the matrix and the decrease in volume fraction of the primary M_6C carbide with increase in quenching temperature, in all high speed steels, indicates dissolution of this carbide.
4. The general tendency for hardness to decrease can be attributed to increase in fraction of retained austenite (γ) with increase of quenching temperature.

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