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Effect of Heat Treatment on Microstructure of Commercial and Vacuum Sintered High Speed Steels AISI M2 and T15

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Abstract: The effect of quenching heat treatments on the microstructure of cast and worked commercial steel AISI M2 and hot isostatically pressed as well as IPEN vacuum sintered AISI T15 have been studied. The quenching treatments were carried out from 1160, 1185, 1210 and 1235°C. The average grain size, volume fraction and average size of the primary carbides M_6C and MC were determined by scanning electron microscopy and by using the digital image analysis method "Quantikov". An increase in average austenite grain size with increase in quenching temperature was observed for the AISI M2 commercial steel and vacuum sintered specimens. In the case of the AISI T15 steel specimens, increase in quenching temperature did not result in an increase in average grain size, both for the commercial and the vacuum sintered steels. The average size and volume fraction of M_6C and MC carbides remained unaltered with increase in quenching temperature.

INTRODUCTION

High speed steels used for cutting tools are iron based alloys and contain tungsten, molybdenum, vanadium, chromium and carbides. During solidification of these steels, different types of carbides form and the important ones are the M_6C and MC type carbides, where M is the metal. The presence and/or amount of these carbides depend on the cooling rate and the concentration of the different elements in these steels [1-4].

The final heat treatment given to high speed steel tools consists of austenitizing, quenching and tempering. This hardening treatment influences austenite grain size and consequently the microstructure and properties of these steels [5,6]. Neumeyer and Kasak [5] reported that austenite grain refinement improved, to a large extent, the performance of the high speed steel tools under conditions of intermittent machining. Under conditions of continuous machining, the grain refinement did not have any effect. Gill [7] stated that grain refinement contributed to a sharp increase in fracture toughness of the high speed steel T1, when it was tested in torsion. Burgardt and Mulders [8] also showed that progressive austenite grain refinement led to a continuous and substantial increase in bending resistance of a M2 high speed steel.

The volume fraction, shape, size and distribution of M_6C and MC primary carbides formed after quenching heat treatments depend on the temperature from which the steel is quenched, the composition and the method used for obtaining the steel [5,9,10,11]. Generally, increase in volume fraction of the primary carbides results in increase of hardness and wear resistance and decrease in fracture toughness.

The objective of this investigation was to evaluate the influence of quenching heat treatment on the microstructure of commercial and IPEN vacuum sintered high speed tool steels AISI M2 and AISI T15.

MATERIALS AND METHODS

In this investigation, commercial AISI M2 (cast and mechanically worked) and AISI T15 (hot isostatically pressed and sintered) high speed steel specimens were used. The commercial steel specimens were supplied by the manufacturer in the annealed state, that is, slowly heated to 870°C, held for 2 hours, cooled to 760°C and held for 4 hours before cooling in air. The AISI M2 specimens that were sintered in IPEN were prepared from water atomized powders of the steel. These powders were pressed uniaxially at a pressure of 800MPa and vacuum sintered at 1249 ± 3°C [13]. In the case of the AISI T15 specimens that were prepared in IPEN, pressing was done under similar conditions but sintering was carried out at 1270 ± 5°C [14]. Subsequently, specimens in the form of square compacts (12.7mm on side) were cut and quenching heat treatments from 1160, 1185, 1210 and 1235°C were given. The specimens were held at the different high temperatures for three minutes prior to cooling in air. Table I shows the chemical composition (wt %) of the two high speed steels.

To study the microstructure of the quenched steels, the specimens were polished to 1µm with diamond paste and etched with 3% Nital solution prior to examination in a scanning electron microscope at magnifications of 1000X and 1500X.

The average grain size, volume fraction and average size of the M_6C and MC carbides were determined by examining SE micrographs using the "Quantikov" digital analysis method of [12]. This method was developed to integrate the resources of the “Windows” platform in image analysis. The objective was to make the micro-particle quantification process from images digitized with a scanner, automatic. Approximately 250 grains were measured, corresponding to four different regions of the specimen. This was carried out to increase statistical reliability. The same procedure was used for studying the carbides.

Table I. Chemical composition of the high speed steels (in wt %).

	C	W	Mo	Cr	V	Co	S
T15	1,60	11,95	0,72	4,06	4,66	4,87	0,06
M2	0,85	6,38	5,25	4,20	1,90	---	0,27

RESULTS AND DISCUSSION

Figure 1 shows typical scanning electron micrographs of high speed steel specimens, AISI M2 and AISI T15, quenched from 1160 and 1210°C. These micrographs reveal austenite grain boundaries that existed prior to quenching, the M_6C (white) and MC (gray) primary carbides.

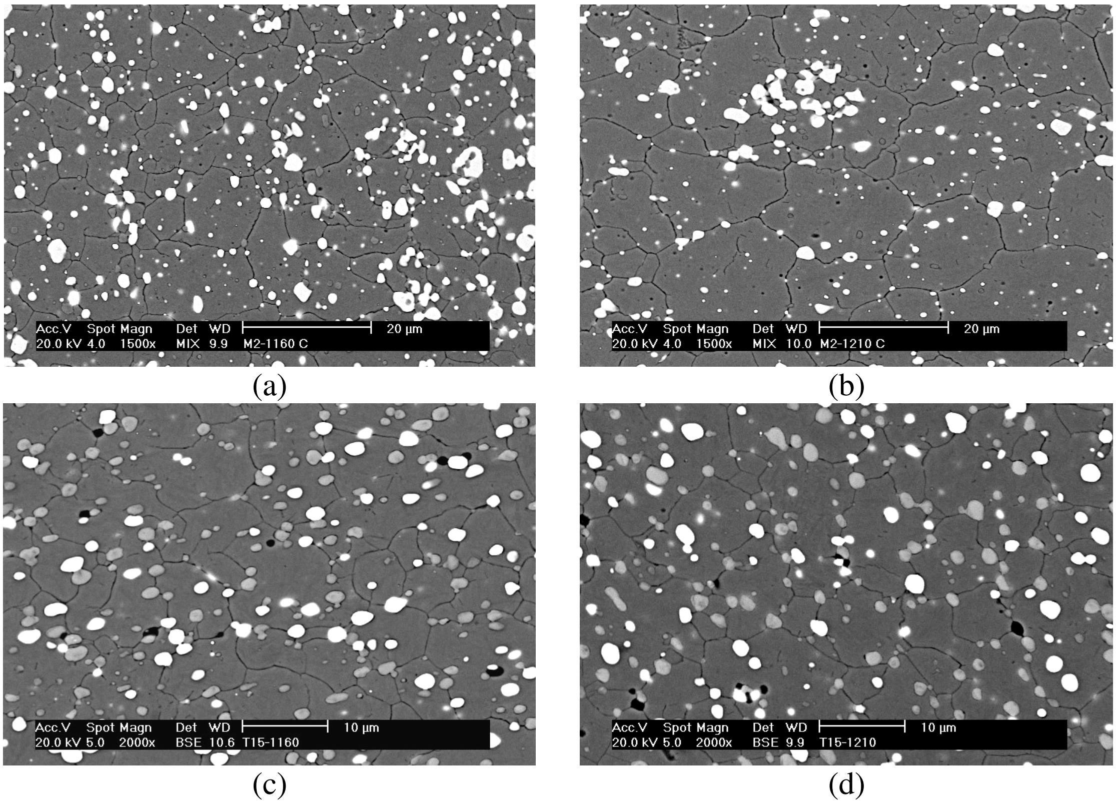


Figure 1: Scanning electron micrographs of steels AISI M2, (a) and (b) and AISI T15, (c) and (d) etched with 3% nital. These specimens were quenched from 1160 and 1210°C respectively.

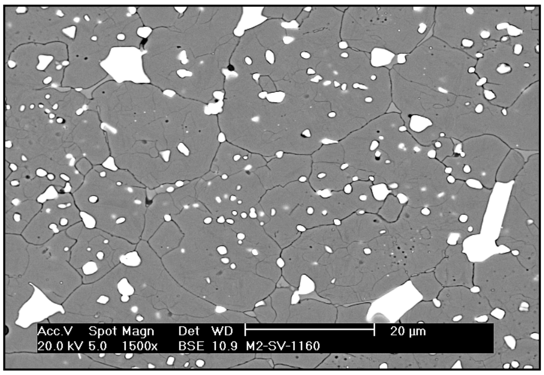
Identification of the MC carbide is very difficult as its density is very close to that of the matrix. The use of back scattered electron images (composition images) facilitates identification. The carbides in the two steels are rounded in shape. Aligned and agglomerated M_6C carbides can be seen in the micrographs of AISI M2 steel specimens. This is considered to be normal as it depends on the manufacturing method. These carbides are more numerous than the MC carbides. In the micrographs of steel AISI T15, the carbides are uniformly distributed and the quantities of the two carbides M_6C and MC, are almost the same.

Table II presents the average size (µm) and volume percent of the primary carbides in specimens quenched from the different temperatures.

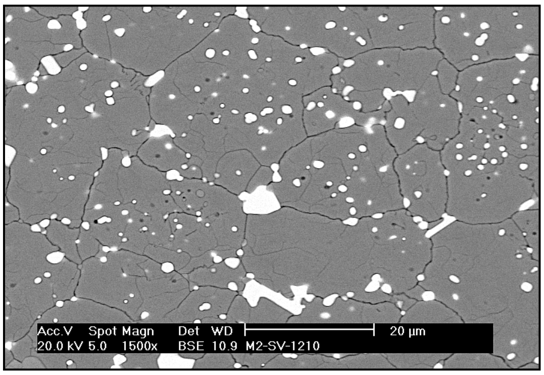
Table II: Average size (µm) and volume percent of M_6C and MC carbides in commercial AISI M2 and T15 steels after quenching heat treatment.

Q.T. (°C)	AISI M2					AISI T15				
	M_6C (µm)	M_6C (%)	MC (µm)	MC (%)	Total (%)	M_6C (µm)	M_6C (%)	MC (µm)	MC (%)	Total (%)
1160	1,1	7,8	0,8	0,8	8,6	1,2	4,7	0,9	3,9	8,6
1185	1,3	7,7	*	*	7,7	1,2	4,6	1,1	3,9	8,5
1210	1,3	4,2	0,7	0,3	4,5	1,2	3,8	1,0	4,5	8,3
1235	1,2	4,8	0,7	0,1	4,9	1,1	3,2	1,0	3,6	6,8

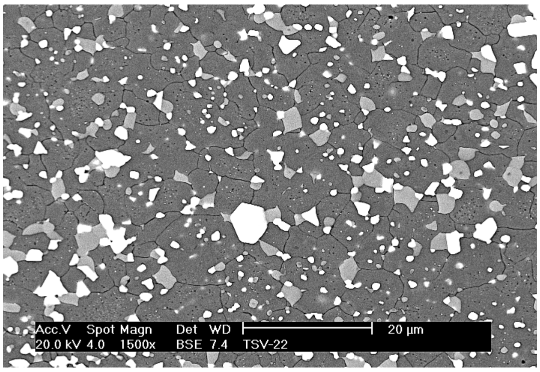
* not detected



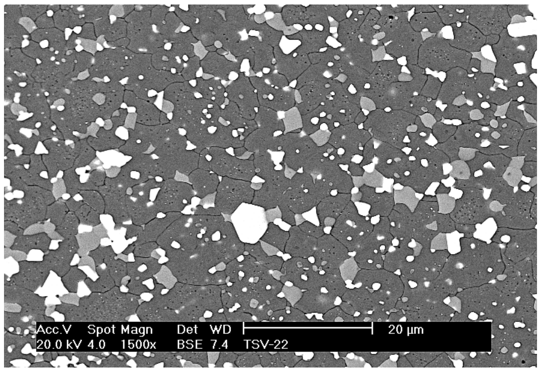
(a)



(b)



(c)



(d)

Figure 2: Scanning electron micrographs of vacuum sintered and 3% nital etched AISI M2 steel, (a) and (b), and AISI T15 steel, (c) and (d), quenched from 1160 and 1210°C respectively.

The M_6C type primary carbides predominate in the high speed steels. In the vacuum sintered steels, these carbides are more angular or in the form of polyhedrons, as shown in figure 2. The quantity of carbides in AISI M2 steels decreased drastically, and in AISI T15, just slightly, with increase in quenching temperature. These carbides dissolve in the matrix and re-precipitate in the form of secondary carbides during tempering. These results are in agreement with data reported elsewhere, even though the amounts are not the same [10]. The micrographs and the data in table III reveal that the volume fraction of the MC carbide in AISI M2 steel is slightly less than that in AISI T15 steel. No appreciable difference in average size of the carbides was observed, as a function of temperature increase.

Table III: Average size (µm) and volume percent of M_6C and MC carbides in vacuum sintered AISI M2 and T15 steels after quenching treatment (Q.T.)

Q.T (°C)	Vacuum sintered AISI M2					Vacuum sintered AISI T15				
	M_6C (µm)	M_6C (%)	MC (µm)	MC (%)	Total (%)	M_6C (µm)	M_6C (%)	MC (µm)	MC (%)	Total (%)
1160	1,6	8,3	1,7	0,7	9,0	1.0	4.7	1.3	6.8	11.5
1185	*	*	*	*	*	0.8	3.8	1.6	6.0	9.8
1210	1,2	4,6	1,8	0,4	5,0	0.8	4.1	1.1	4.8	8.9
1235	*	*	*	*	*	1.0	6.9	2.0	5.2	12.1

* Not determined

Austenite grain size

The austenite grain size of both the commercial steels and those vacuum treated in IPEN were determined. For clarity, the results are discussed separately, according to the type of steel.

AISI M2 steel: The grain size of steels manufactured by the two methods increase with increase in austenitizing temperature. This is a common fact and is in agreement with data from literature for various alloys, including high speed steels. The tendency for grain growth increases with increase in heat treatment temperature, as seen in figure 3. Various authors have reported that the type of annealing given to high speed steels prior to ageing, affects the austenite grain size, indicating that during transformation annealing, the austenite grain growth is more than it is during subcritical temper annealing. The commercial high speed steel used in this investigation was given transformation annealing, similar to that described by Neumeyer and Kasak [5]. Comparison of microstructures of specimens given the same quenching heat treatment, 1160 and 1210°C, reveals that the average grain size of the sintered specimens is higher (figure 2). The expected higher average austenite grain size with higher average primary carbide size, considering the same volume fraction, was not observed in specimens quenched from the two above mentioned temperatures. Comparison of the micrographs in figure 2, reveals large angular carbides in the sintered specimens. This fact could have contributed towards the higher average grain size in sintered specimens, besides the thermal history prior to hardening.

Figure 3 shows the average austenite grain size for the four different quenching temperatures.

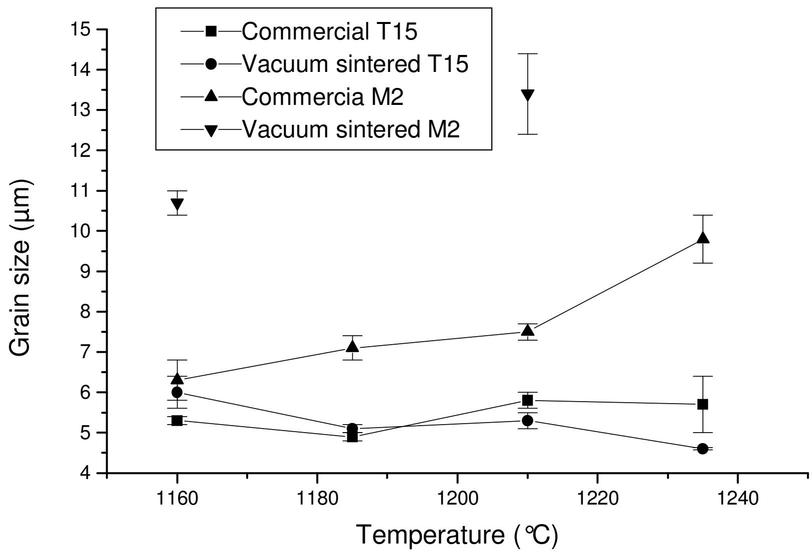


Figure 3: Average austenite grain size as a function of quenching temperature.

AISI T15 steel: The results reveal that the average austenite grain size of both the commercial steel and the vacuum sintered steel did not change with increase in quenching temperature. Even though the average austenite grain size of the sintered specimens was lower, considering the standard deviation also, the values are too close to conclude that they are different. The fact that the carbide volume fractions are almost the same for the different quenching temperatures contributes towards the same grain size being obtained.

CONCLUSIONS

1. Increase in quenching temperature increased average austenite grain size in commercial and vacuum sintered AISI M2 steel specimens.
2. In the case of commercial and vacuum sintered AISI T15 steel, increase in quenching temperature did not alter the average austenite grain size.
3. No marked variations in average M_6C and MC carbide grain sizes, as a function of increase in quenching temperature for the two kinds of steels, were observed.
4. In commercial and vacuum sintered AISI M2 steel, the volume fraction of the MC type carbide is lower, compared to that in AISI T15 steel. Higher amounts of M_6C carbides are present and this decreased with increase in quenching temperature.
5. In vacuum sintered AISI T15 steel, the average size and volume fraction of MC are higher (1.5-3 µm).

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