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Transverse Rupture Strenght of M3:2 High Speed Steel Produced Through Conventional Casting and Powder Metallurgy Techniques

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Abstract. The main aim of this work is to study the influence of the heat treatment on the transverse rupture strength of three M3:2 high speed steel obtained by differents techniques. PM Sinter 23 obtained by hot isostatic pressing (HIP) of gas atomized powders, a vacuum sintered high speed steel obtained by uniaxial cold compaction and liquid phase sintering of M3:2 water atomized powders and a conventional (cast to ingot and hot work) VWM3C were submitted to hardening in order to determine the influence of this treatment on the transverse rupture strength. The two PM high speed steels and the conventional one were submitted to heat treatment of hardening with austenitizing temperatures of 1140, 1160, 1180 and 1200 °C and tempering at 540 and 560 °C. The effectiveness of the heat treatment was determined by hardness tests (Rockwell C hardness). The microstructure was evaluated by scanning eletronic microscopy (SEM). At least five samples of these three high speed steels were manufactured, austenitized, quenched and tempered as described above and fractured in three point bending tests in order to evaluate the influence of this treatment on the transverse rupture strength (TRS).

Introduction

The development of a fine, uniform carbide distribution in wrought high speed steel tools with good mechanical properties requires large sections reductions (hot work) which contributes to elevated costs of manufacturing. On the other side, powder metallurgy techniques can be seen as a suitable alternative processing route which allows the production of near full density high speed steel components with a fine-scale microstructure, reduced segregation and the attainement of a homogeneous dispersion of carbides [1]. This improved structure can lead to a marked reduction in distortion and cracking during heat treatment providing better properties like superior strength and toughness, improved grindability and increased tool life. An alternative processing route could be the vacuum sintering technique which seems to be able to produce components with fine better properties when compared with products obtained by the conventional process with more suitable and optimized microstructure and lower costs relatively with the PM similar steel produced by hot isostatic pressing (HIP) [2]. In this paper the same AISI molybdenum M3:2 high speed steel produced through conventional process and PM techniques (vacuum sintering and hot isostatic pressing) were submitted to the same heat treatment procedures of austenitizing, quenching and tempering and the properties were evaluated by hardness and three point bending tests. The microstructure was evaluated by means of scanning eletronic microscopy (SEM).

Materials and methods

Two PM molybdenum M3:2 high speed steels and a conventional one were object of this work. A molybdenum AISI M3:2 tool steel, known as Sinter 23, manufactured from spherical gas atomized powders by hot isostatic pressing plus subsequent hot working was supplied by Villares Metals in a hot rolled finished round bar 57 mm in diameter. The conventional molybdenum AISI M3:2 tool steel, known as VWM3C, was also supplied by Villares Metals in a hot rolled finished square bar 64 mm in side. Both high speed tool steels were supplied in the annealed condition. The powder of AISI M3:2 high speed steel used to manufacture the vaccum sintered tool steel was supplied by Coldstream Inc. Transverse rupture strength samples were cut and submitted to hardening treatment which consists of austenitizing for 3 min at four different temperatures (1140, 1160, 1180 and 1200 °C) followed by air quenching. The tempering treatments consisted in a triple 2h at 540 and 560 °C (secondary hardening peak). The heat treatments were performed in salt bath. After heat treating the samples were ground to their final dimensions of 6.35 × 12.7 × 31.7 mm as described in ASTM B 528-99 standard, fractured in three point bending test with a span of 25.4 mm in order to determine the transverse rupture strength (TRS). The transverse rupture strength was evaluated only in transverse direction. The samples of the vacuum sintered M3:2 high speed steel were die compacted in a tooling with a pressure of 700 MPa to densities between 6.01 and 6.18 g/cm^3. The vacuum sintering of the samples were performed under production conditions at 1263 °C for one hour leading to densities of almost 8.16 g/cm^3 (theoretical density of M3:2 high speed steel) and then submitted to heat treatments of annealing and hardening and finally ground to their final dimensions [3]. The cross section after grinding was 5.5 × 11 mm^2. The heat treatment procedure was the same used for Sinter 23 and VWM3C [4]. The bars were loaded in three point bending in a rig with a span of 25.4 mm. At least five samples were fractured to each condition of hardening. The chemical composition of Sinter 23, VWM3C and M3:2 powder supplied by Coldstream Inc. is presented in Table 1.

Table 1 - Chemical composition of the three high speed steels object of this work. Weight percent and iron balance.

	C	Si	Mn	Cr	Mo	W	V	S	P
Sinter 23	1.31	0.64	0.36	4.04	4.98	6.16	3.02	0.01	0.021
VWM3C	1.21	0.38	1.52	4.88	4.65	5.77	2.42	-	0.05
M3:2 Powder	0.98	0.2	0.3	3.97	6.2	5.68	2.92	-	-

Results and discussion

The Scanning Electronic Microscopy micrographs of the Sinter 23 submitted to hardening showed that there’s no significant difference in size and distribution of carbides for all conditions of hardening studied in this work. Figures 1 and 2 presents SEM micrographs of the microstructures of Sinter 23 austenitized at 1140 and 1200 °C and tempered at the secondary hardness peak of 560 °C [5].

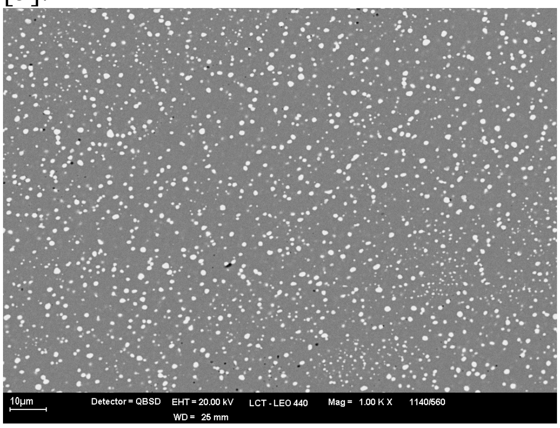


Fig. 1 – SEM micrograph of Sinter 23 austenitized at 1140 °C and tempered at 560 °C.

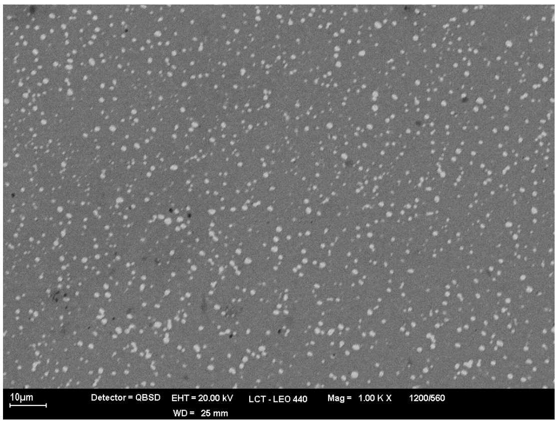


Fig. 2 – SEM micrograph of Sinter 23 austenitized at 1200 °C and tempered at 560 °C.

At these hardening conditions of heat treatment the hardness after tempering increases with the increasing in austenitizing temperature. The highest results for hardness were observed for tempering temperature of 560 °C which corresponds to the secondary hardness peak. The attainment of this highest hardness levels of the order of about 66-67 HRC for this hardening conditions may be a consequence of the increase in the precipitation of finer and harder carbides as MC (VC) [6]. Transverse rupture strength of Sinter 23 decreases in a general manner with the increasing in austenitizing temperatures for both tempering temperatures. It was quite true for tempering temperatures of 540 and 560 °C (secondary hardness peak). The TRS results measured for the tempering temperatures of 540 and 560 °C indicates that the highest results were observed for the austenitizing temperature of 1140 °C. The best result of TRS corresponds to the hardening condition of austenitizing at a temperature of 1140 °C and tempering at 560 °C which gave a value of 3546 MPa. Figures 3 and 4 presents the results of TRS.

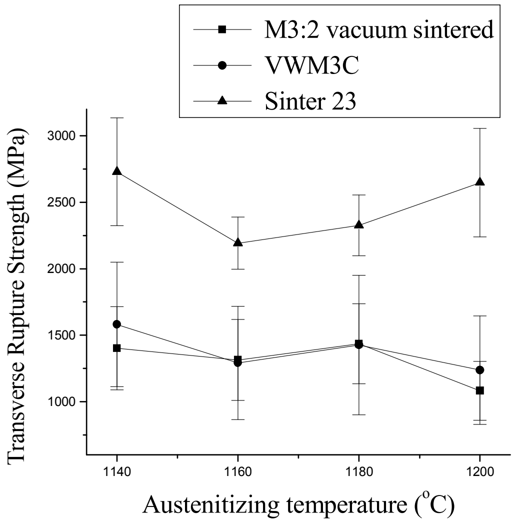


Fig. 3 – TRS results as a function of austenitizing temperature for the tempering temperature of 540 °C.

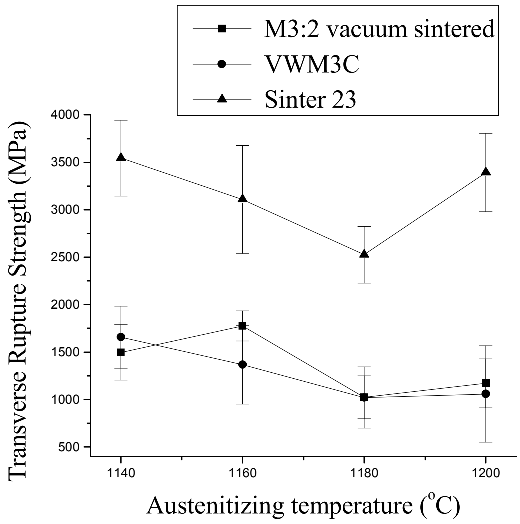
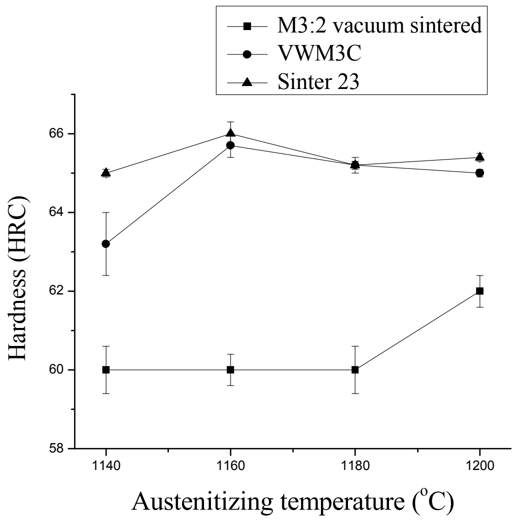


Fig. 4 – TRS results as a function of austenitizing temperature for the tempering temperature of 560 °C.

TRS results for the conventional VWM3C high speed steel showed almost the same behavior observed for PM Sinter 23. The best result was observed for the austenitizing temperature of 1140 °C and tempered at 560 °C (1658 MPa). The same dropping tendency for TRS results with the increase in austenitizing temperature was observed for both Sinter 23 and VWM3C. Sinter 23 SEM micrographs showed a finer, more uniform distribution and smaller carbides when compared with the vacuum sintered M3:2 high speed steel and VWM3C. The results of hardness for the vacuum sintered high speed steel after heat treatment of hardening presented the attainement of low levels in this property. The measurements of TRS showed low levels in this property for the vacuum sintered high speed steel also [7]. The TRS results of VWM3C was almost the same as the results observed for vaccum sintered M3:2. Figures 5 and 6 presents the results of hardness (HRC) for the three M3:2 high speed steels obtained by different processing routes and submitted to the same heat treatment procedure.



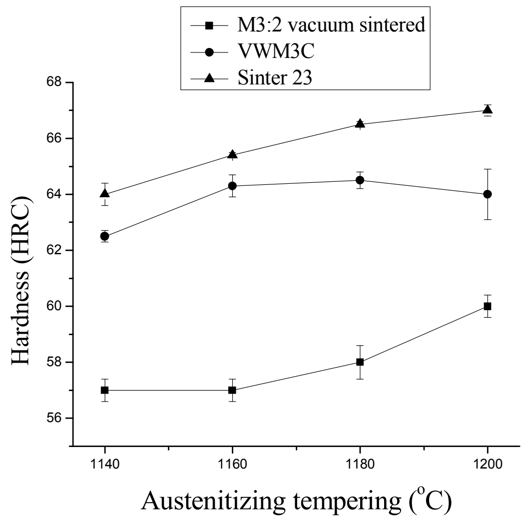


Fig. 5 – Hardness results as a function of austenitizing temperature for the tempering temperature of 540 °C.

Fig. 6 – Hardness results as a function of austenitizing temperature for the tempering temperature of 560 °C.

Figures 7 and 8 presents SEM micrographs of VWM3C and vacuum sintered M3:2.

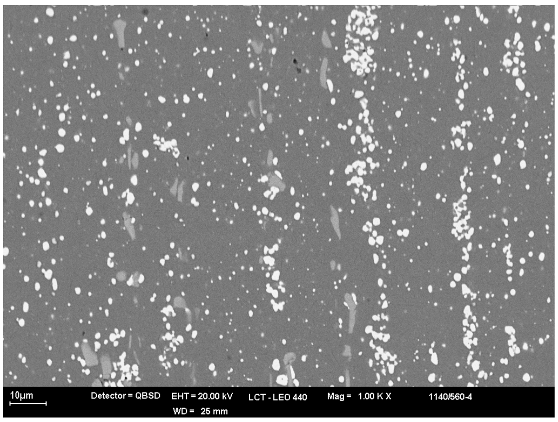


Fig. 7 – SEM micrograph of VWM3C high speed steel austenitized at 1140 °C and tempered at 560 °C.

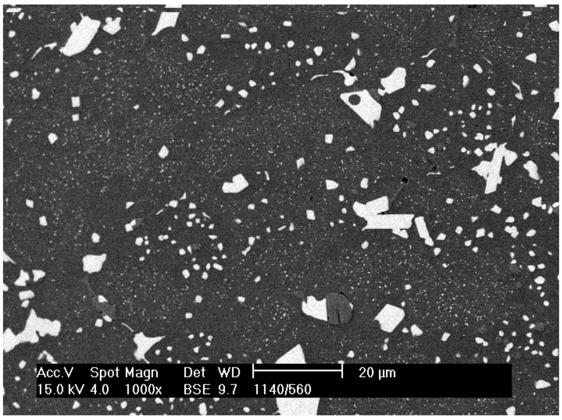


Fig. 8 – SEM micrograph of vacuum sintered M3:2 high speed steel austenitized at 1140 °C and tempered at 560 °C.

PM Sinter 23 produced by hot isostatic pressing (HIP) presented a better response to heat treatment and better results of transverse rupture strength (TRS) when compared with PM M3:2 vaccum sintered high speed steel and the conventional VWM3C due to its optimized and more adequated microstructure [8].

Conclusions

1. Sinter 23 presented in its microstructure a finer, more uniform distribution and smaller carbides when compared with the others which explain the best response of the PM Sinter 23 to heat treatment and the best results of TRS;

2. The highest results for hardness in the case of Sinter 23 were observed for tempering temperature of 560 °C which corresponds to the secondary hardness peak (66 - 67 HRC);

3. Transverse rupture strength of Sinter 23 decreases in a general manner with the increasing in austenitizing temperatures for both tempering temperatures. The best result of TRS corresponds to the hardening condition of austenitizing at a temperature of 1140 °C and tempering at 560 °C which gave a value of 3546 MPa. VWM3C presents the same behavior for TRS results;

4. The results of hardness for the vacuum sintered high speed steel after heat treatment of hardening presented the attainement of low levels in this property. The measurements of TRS showed low levels in this property for this tool steel also;

5. The best result of TRS for the vacuum sintered M3:2 was observed for the hardening condition of austenitizing at 1160 °C and tempering of 560 °C (1777 MPa).

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