Materials Science Forum
ISSN: 1662-9752, Vol. 899, pp 361-365
doi:10.4028/www.scientific.net/MSF.899.361

Submitted: 2016-12-20
Accepted: 2016-12-29
Online: 2017-07-03

Secondary Hardening of an AISI M3:2 High Speed Steel Sinter 23 Hot Isostatic Pressed

O.O. Araújo Filho[1], C. H. Gonzalez[1], S. L. Urtiga Filho[1], C. A. N. Oliveira[1], N. D'E. G. Silva[1], F. Ambrozio Filho[2]

[1] Universidade Federal de Pernambuco – UFPE
Av. Arquitetura, s/n, Cidade Universitária, CEP 50740-550, Recife, PE, Brazil

[2] Instituto de Pesquisas Energéticas e Nucleares, IPEN - CNEN/SP
Av. Prof. Lineu Prestes, n. 2242 - Cidade Universitária - CEP 05508-000 - São Paulo - Brazil

oscaroaf98@hotmail.com

Keywords: high speed steels, Sinter 23 HSS, hardening, secondary hardening.

Abstract. The main aim of this work was to study the behavior of the secondary hardening of AISI M3:2 high speed steel named Sinter 23® produced by powder metallurgy process of hot isostatic pressing (HIP). The M3:2 high speed steel Sinter 23® was submitted to heat treatment of hardening with austenitizing temperatures of 1140 ºC, 1160 ºC, 1180 ºC and 1200 ºC and tempering at 540 ºC, 560 ºC and finally 580 ºC. The effectiveness and response of the heat treatment was determined using hardness tests (Vickers and Rockwell C hardness) and had its property of secondary hardness evaluated. The results showed that the secondary hardening peak of Sinter 23® high speed steel (tempering temperature at which maximum hardness is attained) is at 540 °C for the lower austenitization temperatures of 1140 °C and 1160 °C, and it is at 560 °C for the higher austenitizing/quenching temperatures of 1180 °C and 1200°C.

Introduction

The high speed steels are used for making tools and were largely developed for applications in machining operations. Initially, the high speed steels were intended for making cutting tools such as bits, drills, wideners, milling cutters, fellow blades (knives, cutters, taps and helicoidally milling cutters [1,5]. Later on, these steels found applications like matrixes, punches and structural components in which resistance to high stress/high temperature were the requisites as in the case of airplane bearings and pump components. There are two classifications or groups as per AISI that linked 25 high speed steels and these were molybdenum containing high speed steels (group M) and tungsten containing high speed steels (group T). Molybdenum has gradually substituted tungsten due to scarcity of the latter and currently most of the high speed steels that are produced belong to group M (over 95% in the USA) [3,4].

The main aim of this work was to study the behavior of the secondary hardening of AISI M3:2 high speed steel named Sinter 23® (trade mark of Villares Metals) obtained by powder metallurgy technique. The M3:2 high speed steel Sinter 23® was submitted to heat treatment of hardening with austenitizing temperatures of 1140 ºC, 1160 ºC, 1180 ºC and 1200 ºC and tempering at 540 ºC, 560 ºC and finally 580 ºC. The effectiveness and response of the heat treatment was determined by hardness tests (Vickers and Rockwell C hardness) and had its property of secondary hardness evaluated. This class of steel is used to manufacture bits, Fellows knives, cutters, drills and etc. Tab. 1 presents the observed developments since the introduction of high speed steels.

Table 1 – Significant dates in the development of high speed steels for tools [1].

Date	Development
1903	Prototype of high speed steel 0.70 % C, 14 % W, 4 % Cr for cutting tools.
1904	Addition of 0.30 %V to the prototype.
1906	Introduction of melting in an electric furnace.
1910	Introduction of high speed steel with the composition 18% W-4% Cr-1%V (T1).
1912	Addition of 3-5 % Co to increase hot hardness.
1923	Addition of 12 % Co to increase cutting speed.
1939	Introduction of high speed steels with high C and V content (M4 and T15).
1940-52	Increasing substitution of tungsten with molybdenum.
1961	Introduction of extremely hard high speed steels with high C and Co content.
1970	Introduction of high speed steels produced by powder metallurgy (P/M).
1980	Development of cobalt free super high speed steels for cutting tools.

Experimental

A commercial molybdenum containing M3:2 high speed steel, Sinter 23® was studied in this investigation. The commercial high speed steel Sinter 23®, made with gas atomized powder and sintered during hot isostatic pressing followed by hot deformation was supplied by Villares Metals as a 57 mm diameter rod. This steel was supplied in the annealed condition. The microstructures of the 'as received' Sinter 23® high speed steel consisted of a ferrite matrix with tungsten, molybdenum and vanadium rich carbides. The nominal chemical composition of Sinter 23®, high speed steels are shown in Table 2. the specimens for the hardness tests to determine the effect of heat treatment, were machined and then given hardening heat treatments that consisted of austenitization for 3 minutes at four different temperatures (1140 ºC, 1160 ºC, 1180 ºC and 1200 °C) followed by quenching in air. Triple tempering was done for 2 hours at 540 ºC, 560 ºC (presumable secondary hardness peak) and 580 °C.

Table 2 – Nominal chemical composition of the Sinter 23® high speed steel (mass %) [6].

	C	Si	Mn	Cr	Mo	W	V	S	P	Fe
Sinter 23®	1.31	0.64	0.36	4.04	4.98	6.16	3.02	0.01	0.021	bal.

The need for triple tempering was due to increase in the amount of retained austenite caused by the high carbon content in the high speed steel. All the heat treatments were carried out in salt baths. The Vickers and Rockwell C hardness of the specimens was determined with the objective of evaluating the response of the M3:2 high speed steels to the different heat treatments. At least six specimens were tested for each set of heat treatments.

Results and discursion

The results of Vickers Hardness and Rockwell C hardness, present on Tabs. 3 and 4, show a peculiar behavior of the secondary hardness peaks of this class of steel. For the lower austenitizing/quenching temperatures of 1140 °C and 1160 °C the best results of both hardness were observed at the tempering temperature of 540 °C so it is reasonably to say that this temperature is the temperature of secondary hardening for this class of high speed steel at these temperatures of hardening. On the other hand, observing the results of hardness it is reasonably say that the secondary hardness peaks for the higher temperatures of austenitizing/quenching temperatures of 1180 °C and 1200 °C the best response obtained from the heat treatment of hardening were observed at the temperature of tempering of 560°C. Observing the XRD pattern of these steel heat treated at temperatures of austenitizing/quenching of 1140 °C, 1160 °C, 1180 °C and 1200 °C, showed on Fig. 1, Fig. 2, Fig. 3 and Fig. 4, it is reasonably say that the main peak corresponding to the secondary hardness is in agreement with the conclusions listed above in such way that the main peak for the higher temperatures of austenitizing/quenching of 1180 ºC and 1200 ºC correspond to a peak of martensite (α' phase) at the tempering temperature used of 560 °C while the temperature of tempering of 540 °C produced a main peak of austenite (γ phase). Figs. 5 and Fig. 6 show SEM images of the Sinter 23® high speed steel heat treated at the austenitizing/quenching of 1140 °C and 1200 °C showing a microstructure of tempered martensite as matrix phase and carbides distributed in the matrix [2,3].

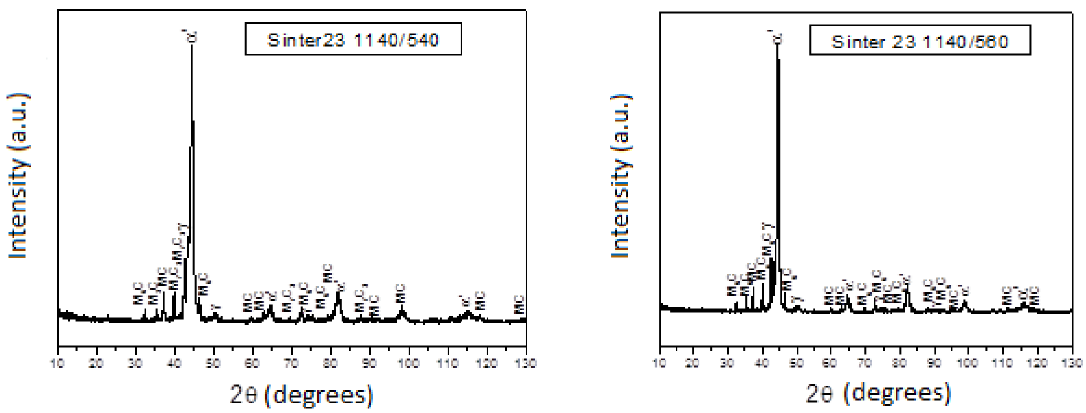
Table 3 – The Vickers hardness results of the heat treated high speed steel Sinter 23®.

Austenitization/ tempering temperature	**1140 °C**	**1160 °C**	**1180 °C**	**1200 °C**
540 °C	926 ± 7	950 ± 22	932 ± 15	939 ± 8
560 °C	879 ± 29	937 ± 8	961 ± 6	976 ± 10
580 °C	849 ± 18	893 ± 10	939 ± 5	926 ± 5

Table 4 – The Rockwell C hardness results of Sinter 23® high speed steel.

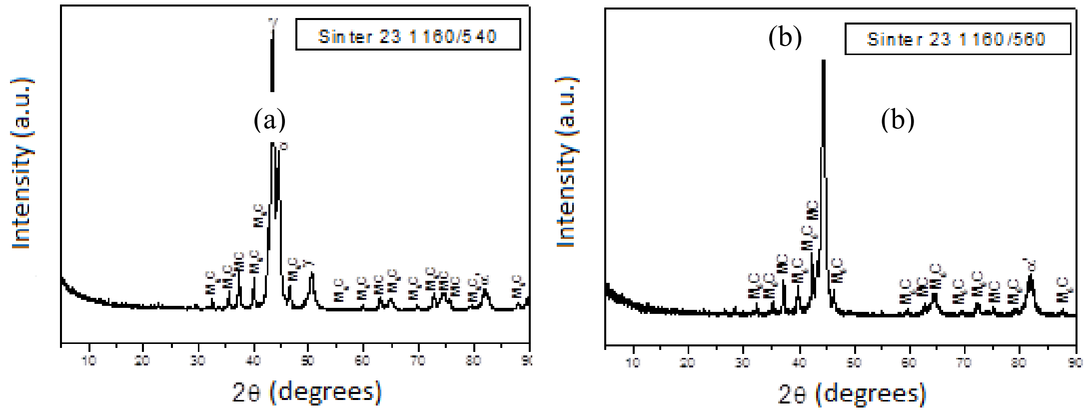
Austenitization / tempering temperature	**1140 °C**	**1160 °C**	**1180 °C**	**1200 °C**
540 °C	65 ± 1	66 ± 1	65 ± 3	65 ± 1
560 °C	64 ± 1	66 ± 1	67 ± 1	67 ± 1
580 °C	63 ± 1	64 ± 1	65 ± 1	67 ± 1

The Fig. 1, Fig. 2, Fig. 3 and Fig. 4 show the XRD diffraction pattern of Sinter 23® austenitized, quenched and triple tempered.



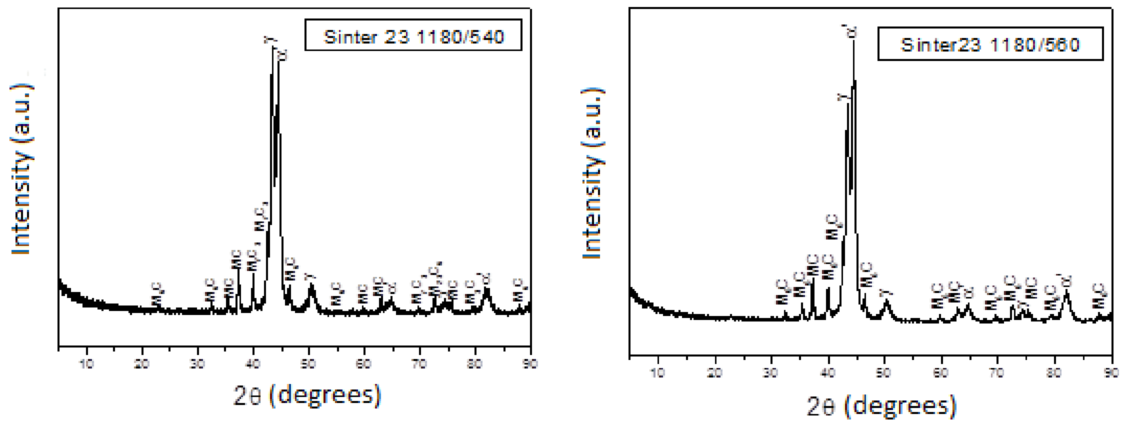
(a) (b)

Fig. 1 – X-ray diffraction pattern of Sinter 23® high speed steel austenitized at 1140 °C (Cu-K_{α} radiation). (a) Tempered at 540 °C. (b) Tempered at 560 °C.



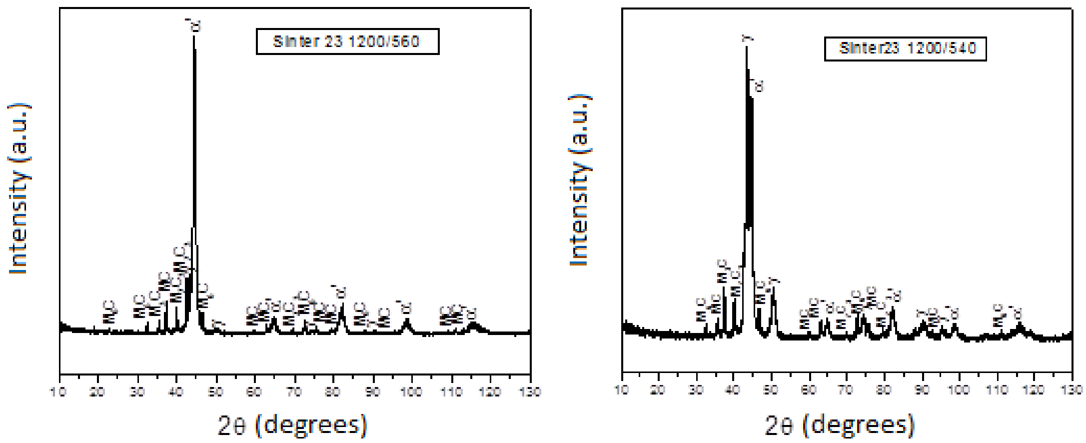
(a) (b)

Fig. 2 – X-ray diffraction pattern of Sinter 23® high speed steel austenitized at 1160 °C (Cu-K_α radiation). (a) Tempered at 540 °C. (b) Tempered at 560 °C.



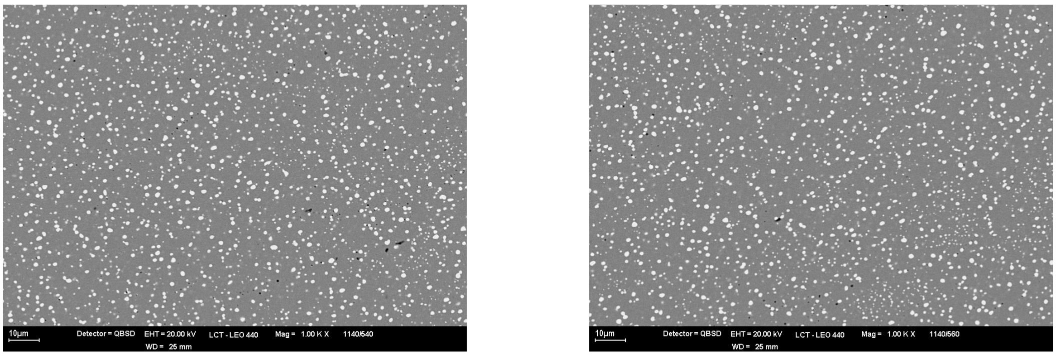
(a) (b)

Fig. 3 – X-ray diffraction pattern of Sinter 23® high speed steel austenitized at 1180 °C Cu-K_α radiation. (a) Tempered at 540 °C. (b) Tempered at 560 °C.



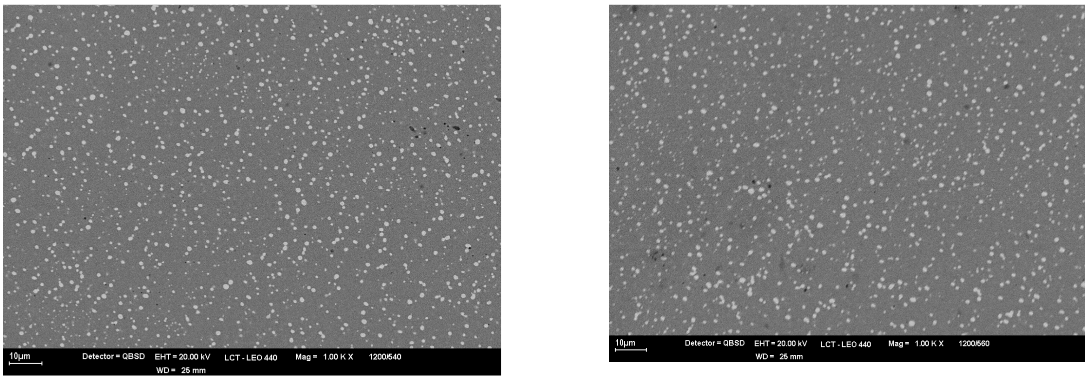
(a) (b)

Fig. 4 – X-ray diffraction pattern of Sinter 23® high speed steel austenitized at 1200 °C (Cu-K_α radiation). (a) Tempered at 540 °C. (b) Tempered at 560 °C.



(a) (b)

Fig. 5 – MEV image of Sinter 23® high speed steel austenitized at 1140 °C. (a) Tempered at 540 °C. (b) Tempered at 560 °C.



(a) (b)

Fig. 6 – MEV image of Sinter 23® high speed steel austenitized at 1200 °C (a) Tempered at 540 °C. (b) Tempered at 560 °C.

Conclusion

The secondary hardening peak of Sinter 23® high speed steel (tempering temperature at which maximum hardness is attained) is at 540 °C for the lower austenitization temperatures of 1140 °C and 1160 °C, and it is at 560 °C for the higher austenitizing/quenching temperatures of 1180 °C and 1200 °C. This is corroborated in the X-ray diffraction pattern. This is not according to the manufacturer's recommendations suggested temperature of 560 °C as tempering temperature. The high speed steel Sinter 23® showed a very good response to the hardening heat treatments, demonstrating high hardness for all the heat treatment conditions that were studied.

References

[1] Ustinovshchikov, I. Yu: Metal Science Vol. 18 (1984), p. 337-343.
[2] R.A. Mesquita, and C.A. Barbosa: High Speed Steel Produced Through Conventional Casting, Spray Forming and Powder Metallurgy. 6TH International Tooling Conference. (2002). 325-337.
[3] W. Khraisat, L. Nyborg and P. Sotkovszki: Powder Metallurgy Vol. 48 (1) (2005), p. 33.
[4] R. Wilson: *Metallurgy and Heat Treatment of Tool Steels*. (McGraw-Hill Book Company Limited UK, 1975).
[5] G. Hoyle: *High Speed Steels*. (Butterworth & Co. Publishers Ltd, 1988).
[6] ASTM standard A600-92a: Standard Specification for Tool Steel High Speed, ASTM; 2004.