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Effect of heat treatment on the microstructure and mechanical properties of High Manganese Steel 15Mn2Cr1V

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***Abstract*— In this work, we want to propose the method to increase the abrasion of the High Manganese Steel (HMS) 15Mn2Cr1V, which is heat treated by the different processes, i.e. the HMS is intermediate heated and without intermediate heating treated before austenizing. The obtained experimental result reveals that with intermediate heating, the austenite is uniform, small size grain (level 6 according to ASTM) and no carbides at the grain boundary. The obtained hardness value is equal to 98 HRB and much larger than one for the process without intermediate at 650^{0}C. The obtained average impact toughness is equal to 115 J.cm^{-2}. This value is also larger than one for the process without intermediate (17 J.cm^{-2}).**

***Index Terms*— intermediate heating, carbide precipitated, 15Mn2Cr1V, grain boundary**

I. INTRODUCTION

The HMS with the carbon content from 1.0 to 1.4% and the manganese content from 11.5 to 15% was applied to produce the parts require high abrasion resistance and high impact toughness as hammers, bucket teeth [1-3].To meet requirement of work, the microstructure ofHMS is required to achieve uniform austenite and no carbide exist at grain boundary. Therefore, the microstructure received by austenizing at high temperature, then it is quenched in the water. During the work, under the impact effect, austenite is strongly changed and theHMS is increased surface hardness by themselve. Hence theresistance to abrasion is alsoincreased. The hard surface did not loss due to when the hard surface losses, the next hard layer will be formed. The uniform austenitic is the good impact toughness but un-sufficient abrasion resistance for longevity service. It is better the microstructure include austenite matrix with the carbide uniform distribution in it. On the other hand the mechanical properties of steel will be increased with fine grain size of austenite [4-6].

There have been many studies recently increassing the abrasion resistance for the parts made of high manganese steel. However, the many problems of the microstructure and mechanical properties in HMS have not been fully understood yet. In this work, we want to propose the methods to increase the abrasion of the HMS by steel alloyingviachromium, molybdenum, vanadium, titanium [2,3] carrying out to a HMS 15Mn2Cr1V. These elements react with carbon in steel to create carbide particles with high hardness, increases abrasion resistance, followedbyintermediate heating to get the carbide dispersion before austenizing at high temperature [1,4,6].That is, the microstructure and promoting abrasion resistance without reducing the impact toughness for materials. Microstructure receiving by this process, it not only offer a small particles uniform distributed carbide but also fine grain austenite matrix, both good abrasion resistance, impact, durability working for the parts.

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II. EXPERIMENTS

We construct HMS sample with the steel composition as shown in Table 1. After casting, the samples were removed from the mold at a temperature of 650^{0}C to analyze the microstructure and hardness, this sample is called sample-0. Then the sample-0is heat treated with the two different procedures:

Procedures 1 (PD1): Sample is heated up to 1050^{0}C and soaked at this temperature for 2 hour. Then, sample is quenched in the water. The obtained sample is called the sample-1.

Procedures 2 (PD2): Sample is heated up to 650^{0}C and soaked at this temperature for 2 hour. Next, sample is cooled in the air to the room temperature. Then, sample is reheated to 1100^{0}C and soaked in this temperature for 3 hour. Final, the sample is quenched again in the water. The late sample, we call sample-2.

Table 1. The characteristics of constructed sample-0.

Composition	C	Mn	Cr	V	Si	P	S
Concentration	1.36	14.7	1.82	1.02	0.81	0.08	0.02

After heat treatment, the microstructure and the content of carbide of samples are analyzed and determined by Axiovert-25A. Next, the hardness and impact toughness of samples are tested as following: the hardness is identified according to ASTM E-18; the impact of samples is in accordance with ASTM form Chapy-E23; the samples are also analyzed by SEM and EDS.

III. RESULTS AND DISCUSSIONS

3.1. Microstructure

Figure 1 is the microstructure of sample after casting. It can be shown that the microstructure of sample includes the austenite matrix (casting austenite) and a lot of carbides located in grain boundaries (casting carbide). This can be explained that after casting the slow cooled processing, carbide is precipitated at grain boundaries.

As shown in Figure 2a the microstructure almost unchanged compared to the microstructure of sample after casting (level 5 according to ASTM). Carbide percent is equal to 6.12%, carbide is still distributed in the grain boundaries austenite matrix (see Figure2b). ThePD1 shows that the temperature of austenite is not enough to completely dissolve carbides at the grain boundaries of austenite. Therefore, it can be concluded that the by PD1 processing austenite microstructure has not uniform. The formed carbides in the grain boundaries lead to the stress concentration during deformation and cracks formation. Therefore, the reduced mechanical properties may be the reason for the destruction of steel.

In the case of PD2, in the soaking time at 650^0C, from casting austenite matrix, the carbide was precipitated [1]. The sample is reheated to 1100^0C and soaked in this temperature for 3 hour subsequent. Figure 3a reveals that at this temperature casting-carbides located in grain boundaries was almost dissolved in the austenite matrix. Analysis of the carbide according to PD2 as shown Figure 3b, we can be seen that the number of carbides remains in samples after heat treatment of 0.35%. Compare to the case of PD1, this value is much smaller.

Although the sample-2 is soaked in high temperature, the austenite grain is smaller than one in the case of austenite after casting. The average particle size is equal to 1.950 μm^2 corresponding to level 6 according to ASTM. It is explained that because less active than the carbide at grain boundaries, the carbide precipitated in side grain austenite at 650^0C. When steel is soaked at 1100^0C this carbide is not only dissolved but also inhibits the growth of austenitic grain.

The SEM image and analysis EDS are shown in Figure 4. Figure 4A and B reveal that the carbide did not concentrate in grain boundaries of austenite. From the EDS analytical result (Figure 4C), we can find the elements Cr, V and Mn in HMS.

3.2. Testing of hardness and impact toughness

Table 2 mentions the characteristics of hardness and impact toughness of obtained samples. It can be seen that the hardness of sample-2 is highest values in the obtained samples. It means that in the sample-2 appears dispersed carbide particles lead to increases the hardness value. This result also is agreement with the above microstructure analysis. The small carbide particles dispersed in the matrix with very high hardness will increase resistance to abrasion for steels. Further, the impact toughness of sample-2 is also much higher than that in sample-1. This phenomenon is explained as following: According to PD2 has not carbides at grain boundary, and grain side of austenite matrix is smaller than that according to PD1. The small grain size of austenite has different crystallization orientations, under the effect of force, the large number of grains significantly participates in the deformation process and samples can withstand the big deformation force before failure. Therefore the sample-2 has higher toughness. This result is close that in ref. [6]. This effect enhances the mechanical properties of steel [5].

Table 2. The characteristics of hardness and impact toughness of obtained samples

Samples	Hardness (HRB)	Impact toughness ($J.cm^{-2}$)
Sample-0	90	-
Sample-1	86	17
Sample-2	98	115

IV. CONCLUSIONS

The study of the microstructure and mechanical properties of HMS 15Mn2Cr1V using the different processes has obtained results as following: Heat treatment for the 15Mn2Cr1V steel by PD2 reveals that the obtained sample (sample-2) is uniform austenite, small size grain. No carbides locates in the grain boundary. The hardness value of obtained sample of 98HRB is much larger than that for casting sample and PD1. Further, the average impact toughness of sample-2 is equal to $115 J.cm^{-2}$. This value is also much larger than that for processes without intermediate at 650^0C. Therefore, applying PD2 may be lead to increase server life expectancy for products made of 15Mn2Cr1V steel.

ACKNOWLEDGEMENT

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REFERENCES

[1] D.K. Subramanyam. *Austenitic manganese steel*. Metals Handbook 10. Edition, Volume 1, Properties and selection: stainless steels, tool materials and specialpurpose metals. ASM International, 1995.
[2] S.B. Sant, R.W. Smith. *A study in the work-hardening behaviour of austenitic manganese steel*. Journal of Materials Science 22 (1987) 1808-1814.
[3] Pham Mai Khanh, Nguyen Duong Nam, Le Thi Chieu, Hoang Thi Ngoc Quyen. *Effects of Chromium content and impact load on microstructures and properties of High Manganese Steel*. Materials Science Forum Vol. 804 (2015) 297-300.
[4] I.G. Korshunov, I.I. Kositsina, V.V. Sagaradze, and N.I. Chernenko. *Effect of the Carbide Phase on the Tribological Properties of High-Manganese Antiferromagnetic Austenitic Steels Alloyed with Vanadium and Molybdeum*. The Physics of Metals and Metallography Vol. 112 (2011), pp. 90-100.
[5] D.A. Porter, K.E. Easterling. *Phase Tranformation in Metals and Alloys*. Second Edition ISBN 0 412 45030 5, 1992.
[6] R.E. Smallman, R.J. Bishop. *Modern Physical Metallurgy and Materials Engineering*. Sixth Edition Chapter 7, ISBN 0 7506 456 44, 1999.

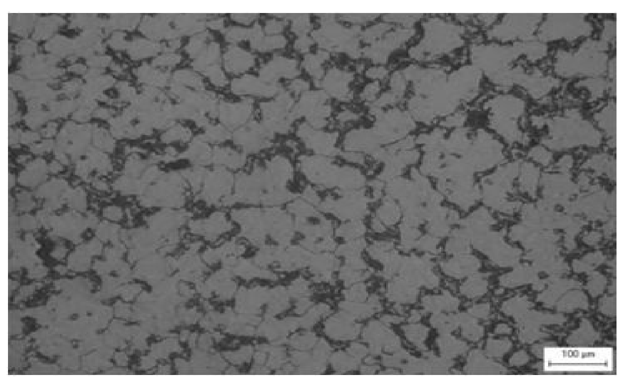
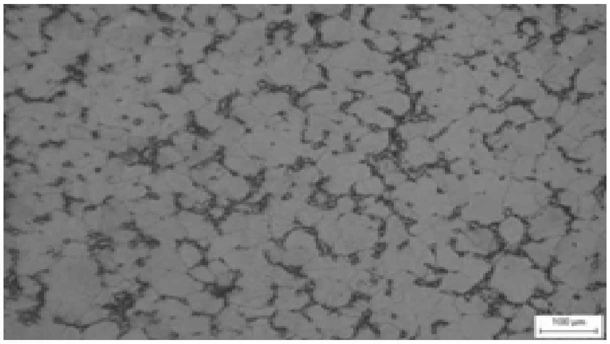
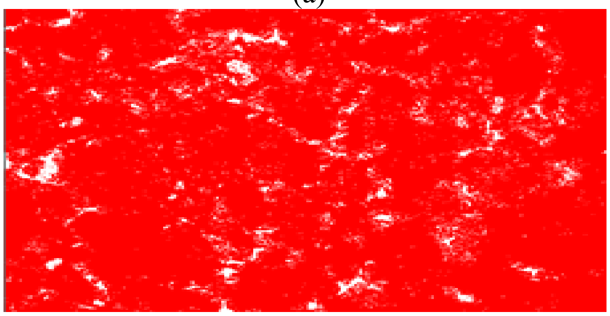


Figure 1. The Axiovert image for sample-0 after casting



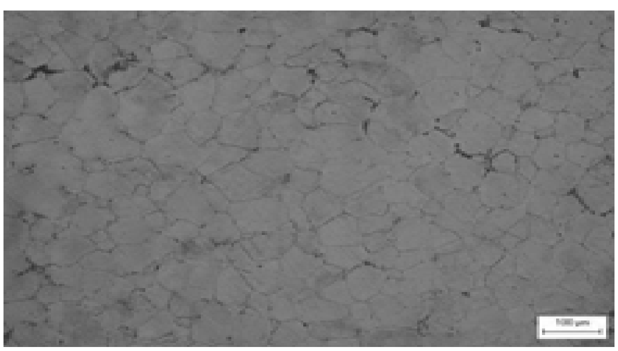
(a)



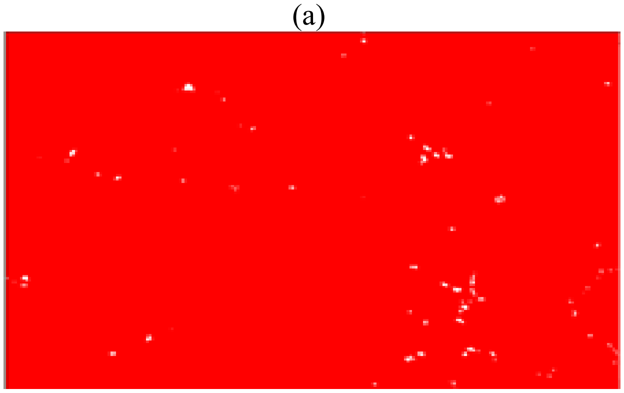
(b)

Phase	Area (μm^2)	Percentage %
Background	218063.52	93.876633
Carbide	14223.818	6.1233726

Figure 2. (a) Microstructure and (b) analysis of the carbide according to PD1 for **s**ample-1.



(a)

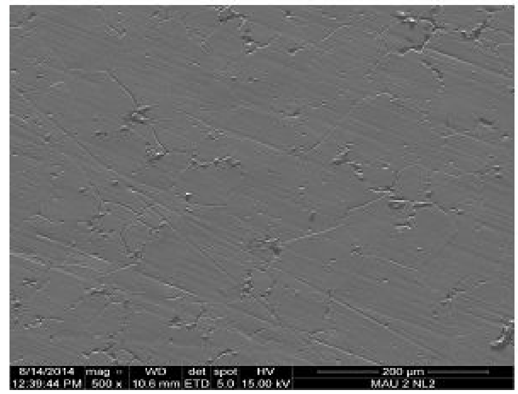


(b)

Phase	Area (μm^2)	Percentage %
Background	231460.88	99.644211
Carbide	826.46503	0.35579428

Figure 3. (a) Microstructure and (b) analysis of the carbide according to PD2 for **s**ample-2.

(A)



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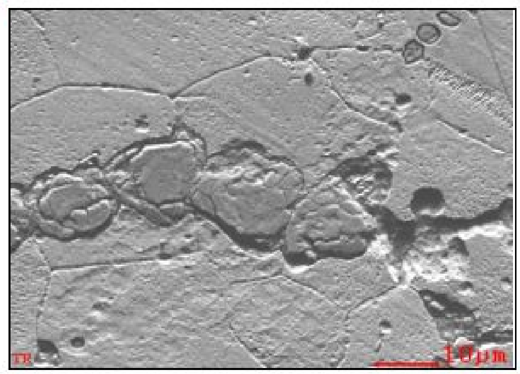

(C)

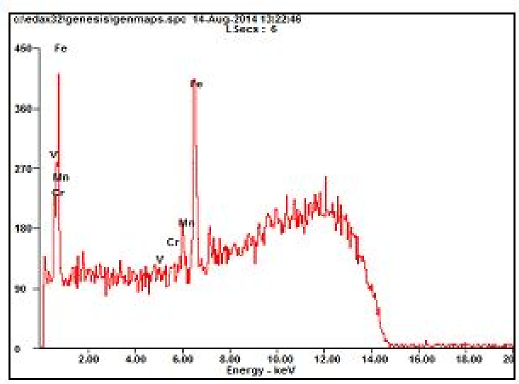

Figure 4. The SEM image (A) and (B); The EDS (C) for sample-2.