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The effect of aluminium on the microstructure and hardness of high austenitic manganese steel

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Abstract. High-strength manganese aluminium and austenitic steels have the reason of their perfect combination of high mechanical properties and good plasticity for the structural elements. They have the microstructure stability, and goodstrength properties because of the addition of aluminium. The effect of aluminium on high austenitic manganese steel were investigated. The samples wereexamined with several tests such as microstructure, chemical content, and hardness. The effect of aluminiumhad been influenced the formation of the Fe-Al-Mn-C phase and the lower hardness of samples.

1. Introduction

In recent new, the structural elements (automotive and railway industries) are used high-strength manganese-aluminium austenitic and austenitic-ferritic steels by reason their perfect combination of high mechanical properties and good plasticity. The application of construction materials is relied on improvement of their casting properties and deformability under conditions of plastic working by their development and commercialization. A proper selection of chemical composition, modification of the initial microstructure, grain refining, and application of proper parameters of the thermo-mechanical treatment may be accepted by its, completing an optimal combination of strength and plastic properties[1-9].

In various industries,the demand for high strength steels with excellent ductility has been increasing and automobile manufacturing in particular, aimed at not only improving the productivity, safety and comfort levels, but also reducing the weight of automobile body to decrease fuel consumption and exhaust emission as well [7-10]. On other hand, the newest high-manganese steels, such as transformation induced plasticity (TRIP) and twinning induced plasticity (TWIP), have the microstructure stability, stacking fault energy value and good strength properties [10-14].Material TWIP (twining induced plasticity) is represented by Fe-Mn-C chemical composition with low aluminium content, finally, even with poor silicon, subsequently. Even though, material TRIPLEX (beside iron three elements) is established on the origin of Fe-Mn-C-Al with aluminium content higher than 8 wt % and without silicon content. Depending on high manganese type and on carbon content manganese reaches higher level than 19 wt. % usually and in this way recognizes the basic austenite microstructure of FCC type, consequently [15-17].

Therefore, the main of this research was to investigate the effect of low weight percent aluminium on the microstructure and hardness of high austenitic manganese steel. Whereas high carbon in high austenitic manganese steel can affect on its microstructure.

2. Experimental

The high carbon austenitic manganese steel with aluminium and non-aluminium was investigated. The chemical composition of the sample is presented in table 1. Steel, aluminium scrap, and ferromanganese was melted at temperature 1600°C and then it was poured in the mould. The effects of aluminium on the hardness and microstructure of austenitic manganese steel were examined. The measurement of hardness and density was conducted by using Rockwell hardness testing machine and Archemedes's teory, while the microstructure was analyzed by an optical microscope (Nikon Eclipse MA 100, Japan).

Tabel 1. Chemical composition

	Mass fraction of element, wt. %				
	C	Mn	Si	Ni	Al
Sample 1	1.15	15	0.73	0.26	0.002
Sample 2	1.06	20	0.7	0.23	2.78

3. Result and Discussion

3.1 The characterization of high carbon austenitic manganese steel

The microstructure of high carbon austenitic manganese steel in as-cast condition comprised austenitic and some of the carbides $(Fe,Mn)_3C$ (black) in austenite (white) and grain boundaries, as shown in figure 1. According [18],The carbides were formed and precipitated along austenite grain boundaries due to the slow cooling in solidification process. This carbide network resulted a negative effect on toughness. From figure 1, the matrix was austenite. The hardness of high carbon austenitic manganese steel was only 19 HRC.

Figure 1. Microstructure of sample 1

3.2 The effect of aluminium on the microstructure and hardness of high carbon austenitic manganese steel

The addition of aluminium was conducted to dissolve the carbides that were found in sample 1. In figure 2 shows the microstructure of austenitic manganese steel after adding aluminium. It was found that Fe-Mn-Al-C phase appeared on its structure. According [4], the characteristic of high aluminium manganese alloys with high content of carbon was the presence in the structure of carbide variable composition $(Fe,Mn)_3AlC_{1-x}$ with FCC lattice in which atoms of iron or manganese are arranged on the faces, and a carbon atom is in the center . Its matrix will be dominated by dendrite of Fe-Al-C structure and austenite matrix. This Fe-Al-C structure resulted the low hardness of this austenitic manganese steel. All carbides were dissolved into the dendrite Fe-Al-C by adding aluminium. Carbon will be decreased in the austenitic matrix in table 1 and figure 2.The hardness of sample 2 was only 11,5 HRC.The hardness of sample 2 was lower than sample 1.

Note : → Fe-Al-C Structure.

→ Austenite.

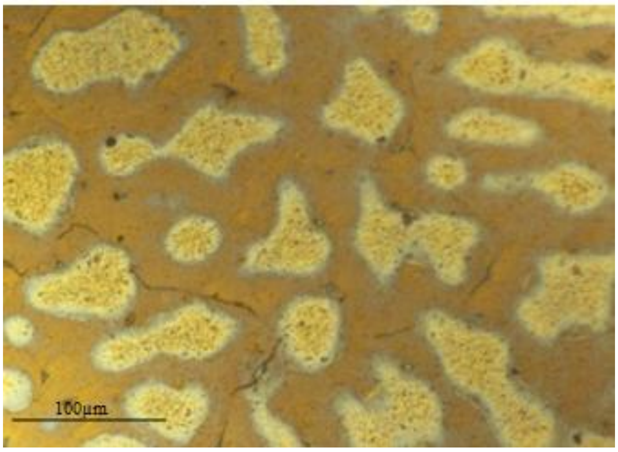

Figure 2. Microstructure of sample 2

4. Conclusion

The microstructure of material 1 consisted the austenitic matrix with carbide along its grain boundaries. However the material 2 founded the Fe-Al-C dendrite in austenite matrix was caused the addition of aluminium. The hardness have the small effect of aluminium. At higher weight percent of aluminium would be affected larger the dispersion of Fe-Al-C dendrite, and lower hardness. Adding aluminium hadn't.

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References

[1] Hamada A S, 2007 *Manufacturing, Mechanical Properties and Corrosion Behaviour of High-MnTWIP Steels* (Czech Republic:Universitatis Ouluensis) 1 - 56.
[2] Kuc D, Hadasik E, Niewielski G, Schindler I, Mazan-cová E, Rusz S and Kawulok P 2012 *Archives of Civil and Mechanical Engineering* **12** 312 - 7
[3] Lasek S and Mazancova E 2013 Metalurgija **52(4)** 441 - 4
[4] Mazancova E, Ruziak I and Schindler I 2012 *Archives of Civil and Mechanical Engineering* **12** 142 - 7
[5] Wiewiórowska S 2013 Archives of Metallurgy and Material **58** 573 - 8
[6] Jabłońska M and Śmiglewicz A 2013 *Defect and Diffusion Forum* **334-335** 177 – 81
[7] Bleck W and Phiuon K 2007 *Freiberg: Säsiche Fachtagung Umformtechnik, Werkstoffe und Komponen-ten für Fahrzeugen* **14** 38 - 55
[8] Jab łońska M, Śmiglewicz A, Niewielski G and Hetmańczyk M 2011 *IOP Conference Series - Materials Science and Engineering* **22** 1 - 5
[9] Farahata A I Z, Hamedb O, El-Sisi A and Hawash M 2011 *Materials Science and Engineering A* **530** 98 – 106
[10] Jabłońska M B 2014 *Arch. of Metal. and Mater.* **59(3)** 1193 - 7
[11] Grajcar A, Różanski M, Kaminska M and Grzegorczyk B 2014 *Arch. of Metal. and Mater*. **59 3** 1164 - 9
[12] Yang W S and Wan C M 1990 *Journal of Materials Science* **25** 1 - 3

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[13] Kuziak R, Kawalla R and Waengler S 2008 *Archives of Civil and Mechanical Engineering* **2** 103 - 18
[14] Chen L, Zhao Y and Qin X 2013 *Acta Metall Sin.* **26** 1 - 15
[15] Scott C, Allain S, Farel M and Guelton N 2006 *Rev. de Met.* **103** 307 – 17
[16] Schumann V H 1972 *Neue ütte* **17** 605 – 9
[17] Grässer O and Frommeyer G 1998 *Material Sci. and Technology* **14** 1213-121
[18] Nurjaman F, Bahfie F, Widi A and Shofi A 2017 *IOP Conf. Series: Journal of Physics: Conf. Series* **817** *012063*