Microstructure Characterization of 12Cr Martensitic Steel Weld Metal

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***Abstract*— In this study, microstructure of 12Cr martensitic steel weld metals with different Mo content was investigated. The weld metals with different Mo contents were fabricated by shielded metal arc welding (SMAW). Both of the weld metals with 0.4 Mo and 0.9 Mo have tempered martensite microstructure. While transformation temperatures of the weld metals changed with Mo amount, the hardness' of the samples did not change significantly.**

***Keywords*— 12Cr martensitic steel, all weld metal.**

I. INTRODUCTION

40% of the world electricity is produced by power plants with coal fired. The most important source of CO2 emission is coal fired power plants. A few increasing on efficiency coal fired power plants causes a recognizable effect on decreasing CO2 emission. The efficiency of the power plants can be controlled by temperature and pressure. However the temperature and pressure depend on construction materials [1-6]. 9-12% ferritic-martensitic steels are widely used in fossil fuel and nuclear power plant construction materials such as main steam pipes. They are also used in petrochemistry industry. The steels are attractive material for the energy industry due to the high oxidation resistance, high creep strength, and low thermal expansion when compared with austenitic stainless steel [7-9]. The steel is also known creep resistant steel. Superior creep property is a reason of stable microstructure at elevated temperature for a long time due to carbides and carbonitrides in the microstructure. 12 Cr steel is supplied in normalized and tempered condition. Fusion welding technics such as shielded metal arc welding (SMAW) and gas tungsten arc welding (GTAW) are used to join of the steels. 12 Cr steel has high hardenability properties, austenite to martensite transformation occur by cooling in air. Therefore, post welding heat treatment (PWHT) temperature must be under Ac_1 transformation temperature in which ferrite transform to austenite according to Cr content, to prevent the low toughness and high hardness due to fresh martensite.

II. EXPERIMENTAL

In this work, effect of Mo on microstructure and mechanical properties of 12 Cr steel weld metal was investigated. All weld metals with different Mo contents were produced by shielded metal arc welding (SMAW) technique. Stick electrodes were fabricated by Gedik Welding Co. in Turkey. Table 1 shows the chemical compositions of 12 Cr steel weld metals. Table 2 summarizes the welding conditions used in this study. Preheat and interpass temperatures were held at 150-190 oC. The weld metals were subjected to post weld heat treatment process (PWHT) at 760 oC for 6h. Fig. 1 illustrates the PWHT cycle applied to all weld metals.

TABLE I

CHEMICAL COMPOSITION OF 12 CR STEEL WELD METALS (WT%).

	C	Si	Mn	Ni	Cr	Mo	W	P	S	V
OPUS CWS1	0.1	0.3	0.7	0.5	10.9	0.4	2.0	0.008	0.003	0.2
OPUS CWS2	0.1	0.2	0.7	0.5	11.0	0.9	2.0	0.008	0.004	0.2

TABLE II

THE WELDING PARAMETERS USED TO PRODUCE WELD METAL.

Weld Pass Number	Preheat and Inter Pass Heating [oC]	Current [A]	Voltage [V]	Weld speed [mm/min]	Heat Input [kJ/mm]
23	150/190	130	34	125	2.05

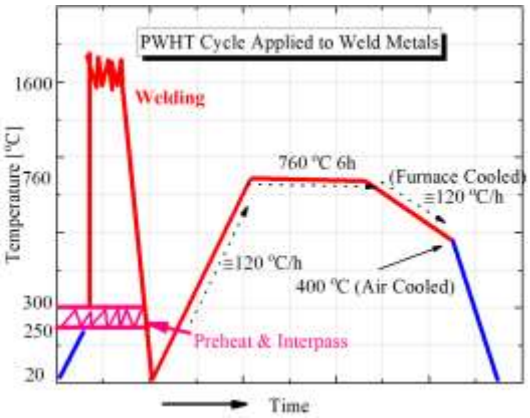

Figure 1. Schematic view of post weld heat treatment (PWHT) cycle

For microstructure characterization, Nikon Eclipse MA100 inverted optical microscope and Zeiss EVO® LS 10 model scanning electron microscopy (SEM) instrument with Energy Dispersive X-Ray Spectroscopy (EDS) were employed. Metallographic specimens were prepared via traditional process such as grinding and polishing. Modified vilella's reagent (2.5 gr picric acid + 2.5ml HCI + 95ml Ethanol) was used as etching solution. Transformation temperatures of the weld metals were determined by Mettler Toledo TGA/DSC 2 with Argon atmosphere up to 1000 oC temperature. Hardness of the weld metals was measured by using Q10 A+ QNESS model micro-hardness device under a load of 2000 g.

III. RESULTS AND DISCUSSION

Generally, the microstructures of the weld metals can be seen in Fig. 2 having tempered martensite. Prior austenite grain boundary was observed with SEM images. The steels are supplied in normalized and tempered condition. The steels and their weld metal have martensitic microstructure cooling condition in air. Therefore the steels and their weld metal have to be subjected to tempering. δ-ferrite phase was also detected in all weld metal microstructure (Fig. 2). However the weld metal with higher Mo has higher volume fraction of δ-ferrite. In literature [10] Schaeffler diagram indicates the possible presence of amounts of δ-ferrite. With SEM images (in Fig. 3) the carbides were also observed in the weld metals. The carbides were identified by EDS mapping and line analysis. The carbides may be M23C6, M2C and MC types in which M denotes a sum of carbide forming elements such as Fe, Cr, Mo and V. M23C6, M2C and MC are Cr, Mo/W and V rich respectively.

To determine the transformation temperatures of the all-weld metals with different Mo contents, DSC analyses were carried out. Heat flow curves of the samples with lower and higher Mo content were given in Fig. 4 a and b respectively.

Curie temperatures, Tc, at which ferromagnetic materials lose their permanent magnetic field, were also determined by DSC heating. It can be seen that Curie temperatures decreased with increasing Mo addition (Fig.4).

Martensit start (Ms) temperatures were also determined with DSC cooling curves. The all weld metals with 0.4% Mo have higher Ms temperature than that of 0.9% Mo. Martensite finish (Mf) temperature of the weld metal with 0.4% Mo is higher than that of the weld metal with 0.9% Mo as well. However, it can be seen that in Fig. 4 Ac1 and Ac3 temperatures, which are transformation temperatures from ferrite to austenite and from austenite to ferrite respectively, of the weld metals with 0.4% Mo is lower than that of 0.9% Mo. In the heat flow curves of the samples with lower and higher Mo content, Ac2 curie temperature could not be observed. Hardness' the weld metals with 0.4Mo and 0.9 Mo are 221HV and 211 HV respectively. Therefore, it can be said that such a difference in Mo content has not effect on hardness.

IV. SUMMARY

In this study, it was aimed to investigate of the influence of Mo addition to 12Cr steel weld metal. From the results of this study the following conclusions can be drawn:

1. All of the weld metals showed same tempered martensitic microstructure.
2. The weld metals microstructures have carbides along the grain boundaries.
3. Curie and Ms temperatures decreased by increasing Mo amounts.
4. Hardness did not change increasing Mo content.

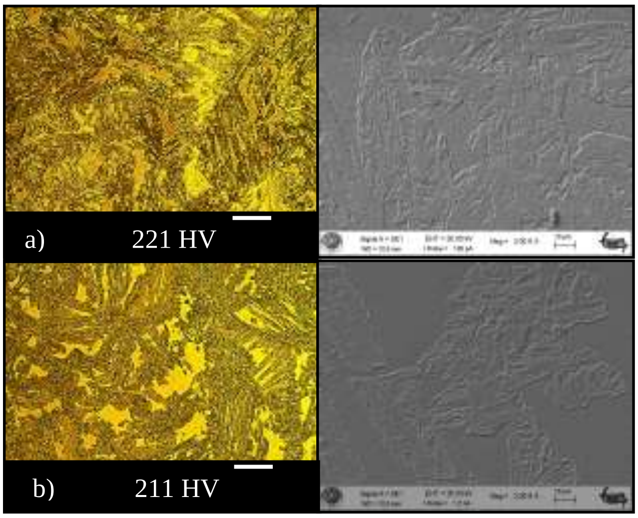

Figure 2. Optical and SEM images of the weld metals a) lower Mo b) higher Mo

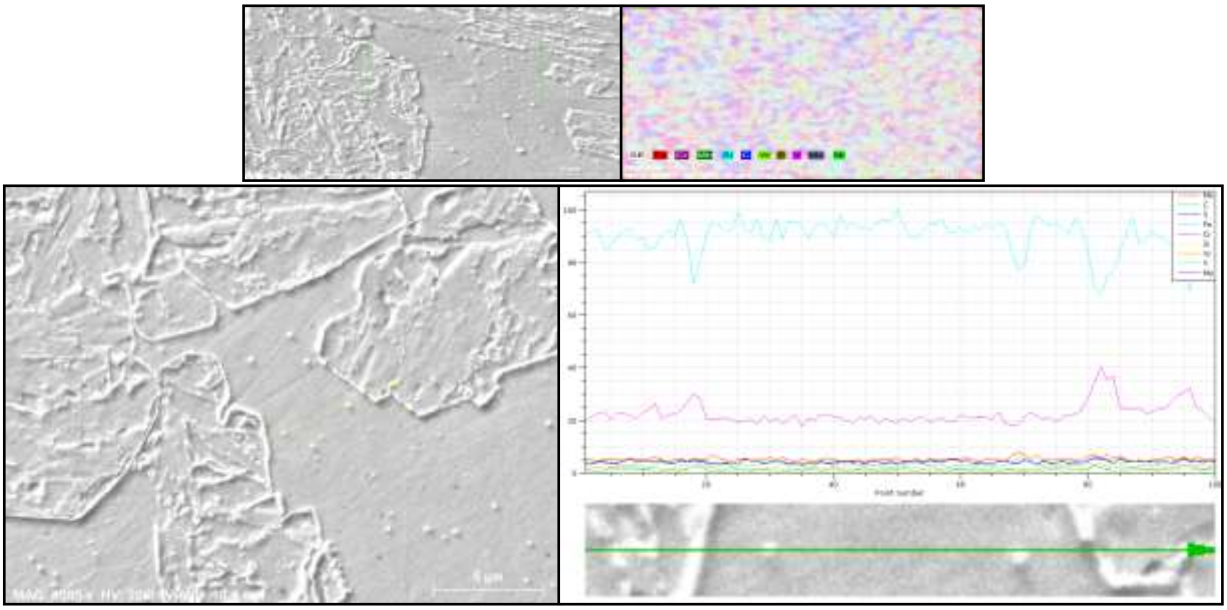

Figure 3. SEM images and EDS analyses

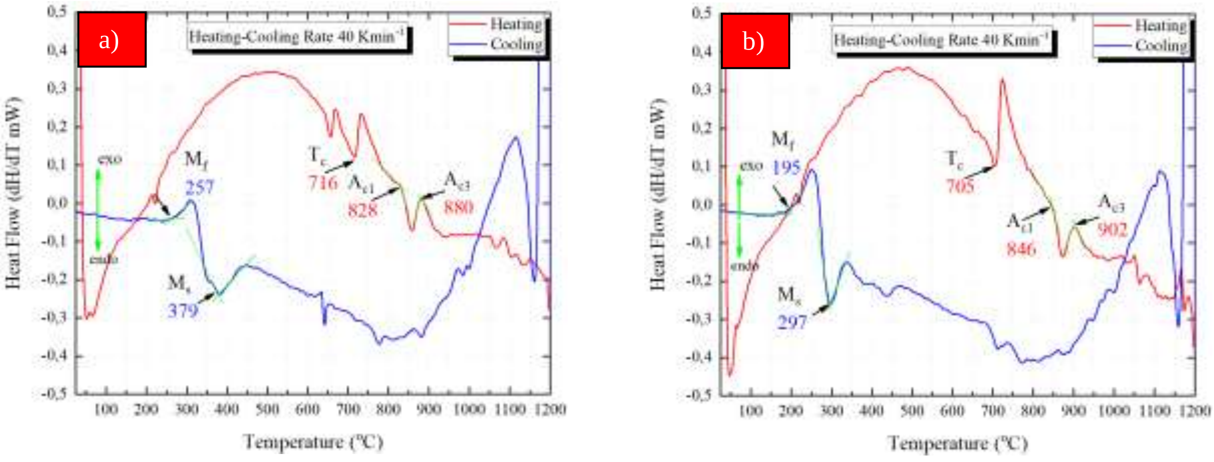

Figure 4. DSC plots of the weld metals with a) 0.4 Mo b) 0.9 Mo

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