International Journal of Chemical, Materials and Biomolecular Sciences
ISSN: 2415-6620
Vol:7, No:7, 2013

Optimization of Heat Treatment Due to Austenising Temperature, Time and Quenching Solution in Hadfield Steels

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***Abstract*—**Manganese steel (Hadfield) is one of the important alloys in industry due to its special properties. High work hardening ability with appropriate toughness and ductility are the properties that caused this alloy to be used in wear resistance parts and in high strength condition. Heat treatment is the main process through which the desired mechanical properties and microstructures are obtained in Hadfield steel. In this study various heat treatment cycles, differing in austenising temperature, time and quenching solution are applied. For this purpose, the same samples of manganese steel was heat treated in 9 different cycles, and then the mechanical properties and microstructures were investigated. Based on the results of the study, the optimum heat treatment cycle was obtained.

***Keywords*—**Manganese steel (Hadfield), heat treatment, austenising temperature, austenising time, quenching solution, mechanical properties.

I. INTRODUCTION

HADFIELD Steel compromising of Ferrous, Carbon and Magnesium upon which other alloy elements will be applied in its structure in particular situation based on its application. Its standard alloy is including of 1.2 to 1.4% Carbon and 12 to 14% Magnesium [1]-[6].This alloy has wide range application due to high wear resistance, high work hardening capability and appropriate toughness and ductility. On the other hand there is no application within mentioned alloy steel due to its low yield strength and low resistance against plastic deformation in situation which is subjected to high service tensile. Also, its application within alloy steels which precise dimension of parts is required is limited since machining difficulties situation. Excellent Hadfield steel properties in temperature range of 205˚C make it proper to the application related to ambient temperature [4].

Its structure in form of casting is containing of Carbide phases as $(Fe,Mn)_3C$,upon which through proper Heat treatment, it could be possible to construct complete austenitic structure [2].

Under austenising and quenching heat treatment, austenitic single phased microstructure will be obtained. Within heat treatment, the mentioned alloy will obtain proper toughness, so solution temperature would be high enable to solve carbide within austenite and within quenching austenitic single phase structure will be achieved. To complete solving of carbides it is required to perform austenising in temperature of 30 to 50˚ C upper than A cm. In mentioned situation solution temperature is limited to 1010 to 1120˚C. Heating would be performed slowly to prevent internal cracks. Quenching rate shall be adequate high to minimize carbide amounts. During heat treatment, austenite phase would not been allowed to permutation to achieve full austenitic structure after quench operation. Otherwise, it may be degraded the austenite phase to others as perlite. This situation is dominant within central area of thick parts. For such these reason, it is recommended that the thickness of produced parts of Hadfield steel would not be more that 152mm (6 inches). Austenising temperature control and holding time is of high importance. Most of fractures are faced due to undesired control of austenising temperature related to low cooling rate in water [4].

Hadfield magnesium steel brittleness is corresponding to brittle phases within grain boundaries. In addition to inter granular carbides, which have key role in steel brittleness, other brittle phases such as phosphide non-metallic inclusion is effective [7]. To achieve more proper specification within Hadfield Steel, a wide range heat and thermo mechanical treatment has been performed [8]. The present research aiming mainly to optimizing related heat treatment through austenising temperature and time and quench rate.

II. METHODS & MATERIALS

Casting Samples with chemical composition that is showed in Table I, heat treated in 9 different cycles and quenched in solution with varied amount of salt. Table II and Fig. 1 illustrates applied heat treatments operation. Heat treatment has been performed within electrical furnace (50x50x50cm).

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TABLE I
WEIGHT PERCENT OF CHEMICAL COMPOSITION

C	Si	Mn	P	S	Cr	Mo	Ni	Al	Co	Cu	Nb	V	Sn
1.32	0.49	13.32	0.041	0.00004	1.91	0.009	0.039	0.014	0.016	0.041	0.005	0.02	0.005

Metallographic examination has been done in according to with the ASTM E3-01(metallographic samples preparation), ASTM E407-99 (metal micro etch) and ASTM 883-02(optical microscopic images). Specimen's micro structures have been investigated by optical microscope (Olympus, PMG3 model) and austenite grain size determined in according to with the ASTM Code E112-06.Macro hardness test has been carried out by Brinel machine.

TABLE II
WEIGHT PERCENT OF CHEMICAL COMPOSITION

sample	Austenising temperature (˚C)	Austenising time (hour)	Quenching solution
1	1000	1.5	Water-0% salt
2	1050	2	Water-0% salt
3	1100	3	Water-0% salt
4	1000	1.5	Water-1.5% salt
5	1050	2	Water-1.5% salt
6	1100	3	Water-1.5% salt
7	1000	1.5	Water-3% salt
8	1050	2	Water-3% salt
9	1100	3	Water-3% salt

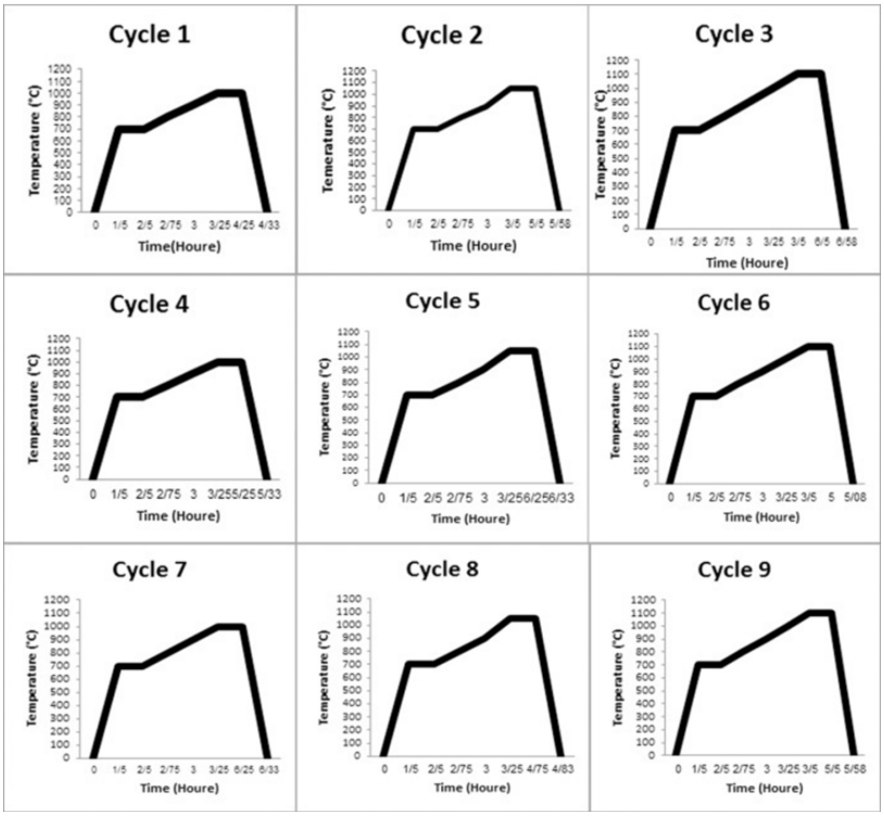

Fig. 1 Heat treatment cycles of samples, cycle1: sample 1, cycle2: sample 2, cycle3: sample 3, cycle4: sample 4, cycle 5: sample 5, cycle6: sample 6, cycle7: sample 7, cycle8: sample 8, cycle9: sample 9

III. RESULT AND DISCUSSION

Fig. 2 illustrates heat treated microstructures. Within mentioned figure, carbide volume difference is well pointed out. Table III and Fig. 3 illustrate mentioned amount. As it is specified carbide percentage of cycle no. 3, 6 and 9 has been removed which may be for the reason of holding time and quenching rate. Table IV and Fig. 4 were showed hardness amount. Table V and Fig. 5 illustrate heat treated grain size according to ASTM number. As per result, cycle no. 6 & 9 found as most proper cycle, since considering modification within austenising temperature and time and quench environment, continues carbide has been thoroughly introduced and hardness and grain size are adequate. Considering the hardness and grain size, probably toughness will be in standard range, after treatment.

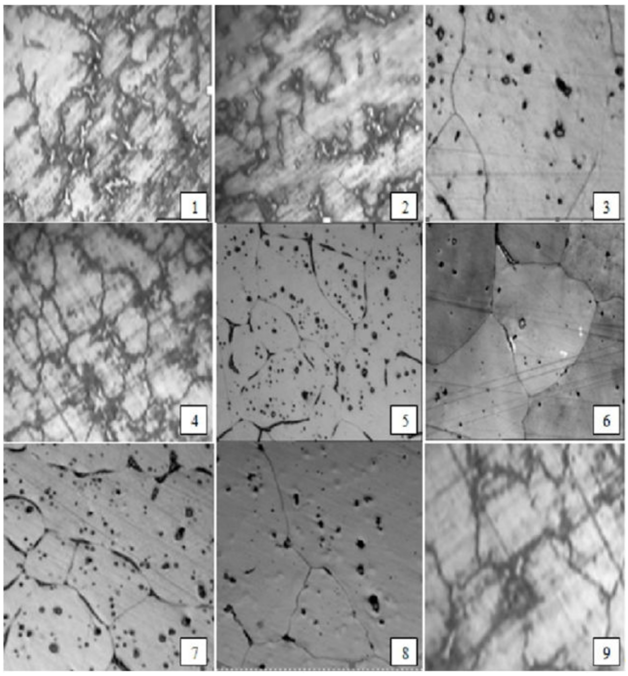

Fig. 2 Heat treated microstructures. (1) sample 1, (2) sample 2, (3) sample 3, (4) sample 4, (5) sample 5, (6) sample 6, (7) sample 7, (8) sample 8, (9) sample 9

TABLE III
THE CARBIDE VOLUME

Sample No.	Carbide volume	Carbide type
1	42%	Fiber, disperse in grain boundary, inter granular
2	30%	Fiber, disperse in grain boundary, inter granular
3	13%	Very fine and disperse
4	24%	Fiber, disperse in grain boundary
5	15%	Fiber, disperse in grain boundary
6	8%	Very fine and disperse
7	18%	Fiber, disperse in grain boundary
8	12%	Fiber, disperse in grain boundary
9	5%	Fiber, disperse in grain boundary

TABLE IV
HARDNESS OF EACH SAMPLE

Sample no.	1	2	3	4	5	6	7	8	9
Hardness	265	245	218	233	223	213	227	217	210

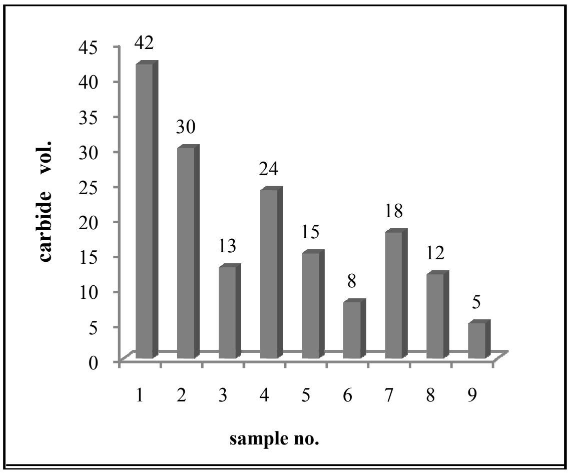

Fig. 3 Carbide volume of each sample

TABLE V
THE GRAIN SIZE OF SAMPLES

Sample no.	1	2	3	4	5	6	7	8	9
ASTM No.	4	3	6	6	6	2	4	2	6

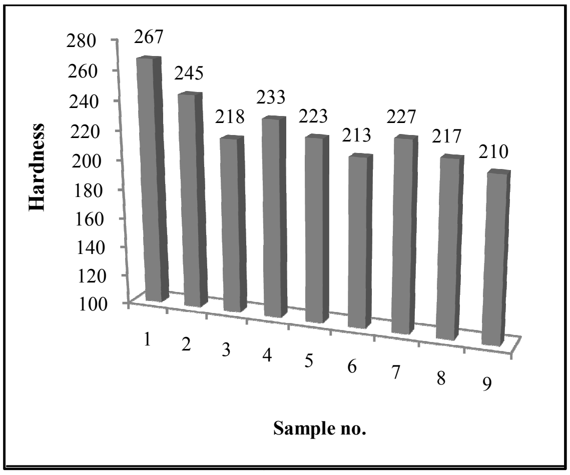

Fig. 4 The hardness of each sample

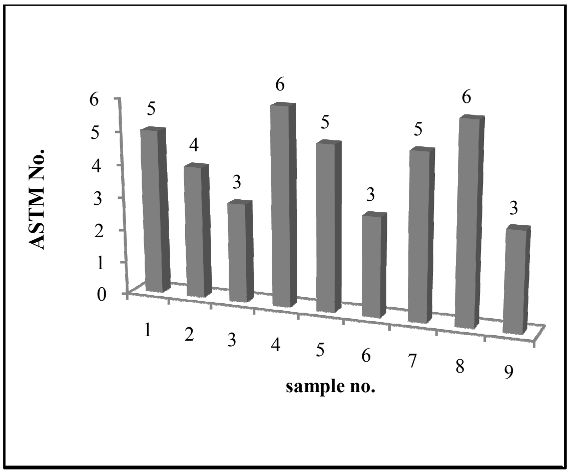

Fig. 5 The grain size of samples

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