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Minimizing of the Time in Heat Treatment Cycle of Manganese Steel (Hadfield)

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Abstract—*Manganese Steels (Hadfield) have extensive application in industries due to their good wear resistance, high work hardening capability as well as high toughness and ductility. Traditional heat treatment for these steels is defined as solution annealing and quenching in water bath. This heat treatment is aiming to carbides removing and has many costs due to taking a long time of operation. Within present research, 5 different heat treatment cycles to achieve shortest time with proper structure without carbide has been assessed. Microstructure and impact energy of specimens with different heat treatment was investigated. Concluded results showed that, the best cycle is austenitizing to 1080˚C with determined rate and holding time of 2 hours and then quenching in water, so it takes lesser time and the final structure is completely austenite.*

Keywords*: Manganese Austenite steel, Heat treatment, Austenitizing Temperature, Austenitizing Time, Quenching Solution*

1. INTRODUCTION

Manganese Austenite steel was first explored by Robert Hadfield in 1882. These steels are famous in industries due to their particular specification as good resistance against wearing among high toughness and good ductility and high workability. Their main composition are including of 1 to 1.4% Carbon, 10 to 14% manganese with ratio of 1 to 10[1]. In parts which are impose to heavy striking and wearing in type of gouging like hammers, it would be preferred to use 10.5 to 11 (means lesser carbons) and for ones that are exposing to pressure and wearing (as abrasions) such as jaws and concaves it is preferred range of 10 to 10.5 (More carbons). Nowadays, main consumer of casting part made of Hadfield steels are mining, cement, mineralization, material transportation and rail ways industries [2-4]. Casting structure of these steels is including of carbides as $(Fe,Mn)_3C$ that through appropriate heat treatment, it could be achieve full austenitic structure from these steels [5-7]. Traditional heat treatment for these steels is solution annealing and quenching in cold water bath. However, completely austenitic structure without any carbide phase is desired, but such these structures particularly within thick parts are always unachievable [8]. Manganese austenite steel thermal conductivity is about 1.4 times and its thermal expansion coefficient is 1.5 times in related to normal carbon steels, for this reason, the heating rate shall be performed slowly. Austenitizing temperature defined as 950 to 1100˚. After holding time, the parts will be quenched in water. This heat treatment takes long time working which is resulting to cost enhancement [9]. Within present research, to reduce heat treatment time, and in same time obtaining completely austenitic structure, 5 different heat treatment cycles were chosen. Within these various methods, the mechanical properties and micro structure of specimens was investigated.

2. MATERIALS AND METHODS

First a Foam Model as Y Block has been made. Casting Operation has been done by chromites Sands as Sodium Silicate method and CO_2 gas. To prevent burning and to obtain a high-quality surface, proper coating material called Moldcoat was used. Induction furnace was used to melt the steel. First charge for furnace was including of traditional steel scrap. Desired Chemical Composition has been controlled by Ferro-alloys. Table 1 illustrates the chemical composition of final sample analyzed by Spectrolab model quantometer. Manganese samples heat treatment was performed within electrical furnace with 5 different cycles (Fig.1).

Table 1: Chemical composition of steel (wt%).

C	Mn	Si	Cr	Ni	Mo	P	S
1.17	13.4	0.77	1.6	0.12	0.01	0.045	0.008

Metallographic examination has been done in accordance to the ASTM E3-01(metallographic samples preparation), ASTM E407-99 (metal micro-etching) and ASTM 883-02(optical microscopic images). Specimens microstructures have been investigated by optical microscope (Olympus, PMG3 model) and austenite grain size determined in according to with the ASTM Code E112-06. Impact test has been also done according to the ASTM E112-06 by an impact machine of 300J capacity and Charpy method.

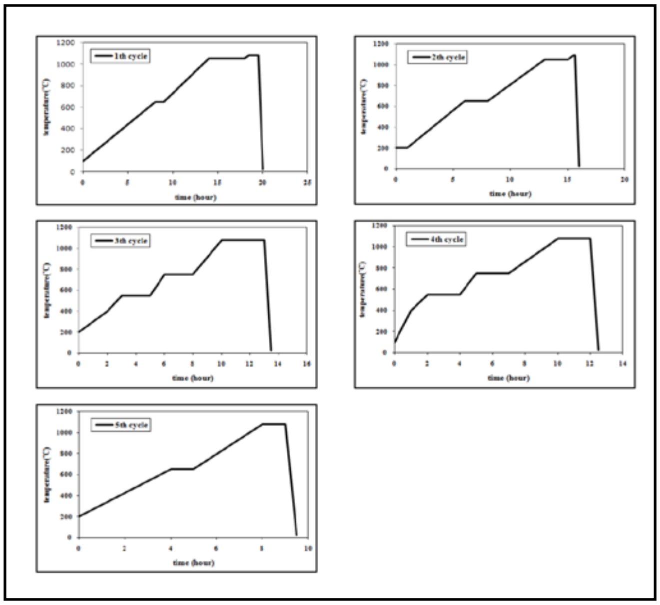

Fig. 1: Five different heat treatment cycles.

3. RESULTS AND DISCUSSION

Fig. 2 shows the microstructures of heat treated specimens. As it could be observed, in cycle 1 to 4, obtained structure is completely austenitic and desired. But within 5th cycle, resulting microstructure are differed from other cycles and it could be observed some frosted grain inside austenite grains and sometimes on their surface. It would be happened when austenitizing time was not proper or water temperature is high. Since the water temperature is constant for all samples and only cycles have been changed, it would be concluded that carbides have not been resolved within austenite matrix completely, and such frosting grain have been remained such as unresolved carbides which caused to reduce related parts life or sometimes its fracture. Reducing of Parts lifetime meaning that these frosting component have been operate as micro hard particles and in wearing operation cause to caving from surface and more wearing and consequently parts reducing life time. Carbide amount measured in this cycle as 35 percent.

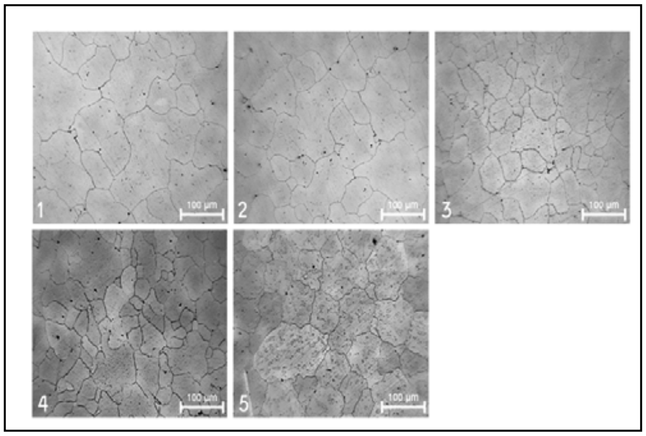

Fig. 2: Different heat treatment cycles microstructures

Result of austenite grain size illustrated in table 2 and fig.3. As it can be seen, in 3th and 4th cycle, the grain size is appropriate and in other cycles the grain is coarse.

Table 2: ASTM austenite grain size within different heat treatment cycles.

cycle	No. 1	No. 2	No. 3	No. 4	No. 5
ASTM grain size	3	3-4	5	5	4

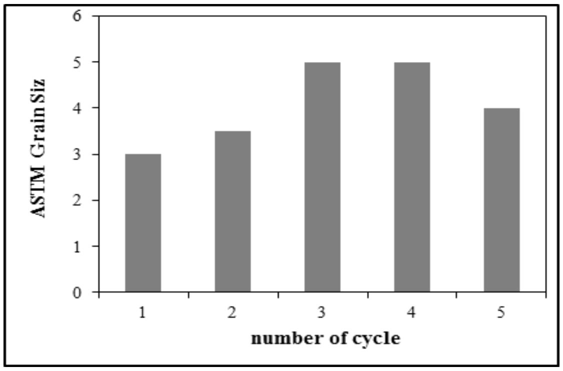

Fig. 3: ASTM austenite grain size variation within different heat treatment cycles.

Results of impact testing have been figured out within fig.4. Manganese Steels normally will not break under impact and only will be bending. Resulting obtained from impact testing of cycle 1 to 4 with complete austenite structure, illustrate that, the samples have been cracked from notch zone and bend which such a crack probably existed because of hard working of notch making on samples and within 5th cycle, the samples fractured with lesser impact energy in related to 4 mentioned samples.

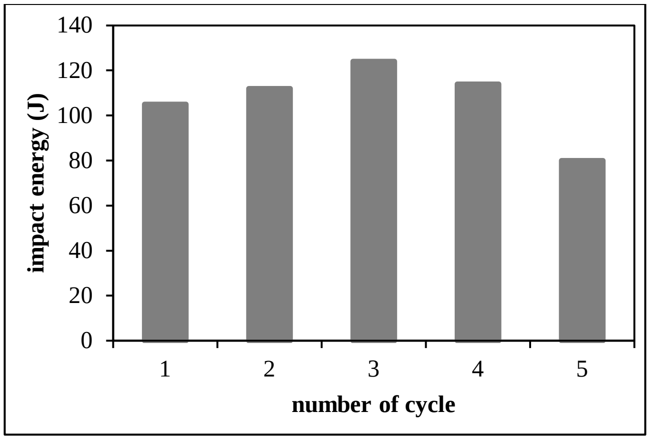

Fig. 4: Impact energy variation within different heat treatment cycles.

Considering resulting microstructure and impact testing on obtained samples, the 4th cycle has been preferred in view of time consuming (economic aspect) and desirable structure without any carbide as best heat Treatment cycle for manganese austenite steels.

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