Effect of heat treatment on Jaw and cone crusher of Hadfield Manganese steel castings for better wear life

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***Abstract*-Austenitic manganese steel has a high toughness, high ductility, high strain hardening capacity and an excellent wear resistance. This grade of steel is mostly used in the mining industry for crushing and loading equipment. The present paper highlights the effect of heat treatment onwear property of high manganese steel casting like jaw crusher or cone crusher. Currently the challenges faces like rate of work hardening. This is due to the crushing efficiency of modern jaw and cone crushers. This limits the rate of work hardening produced on the surface of the metal thus resulting in low wear resistance. Due to this challenges faced, researchers were motivated to come up with innovative ideas and new development that will increase the hardness and wear resistance of the said steel, resulting in longer service life of the components. These developments include the introduction of a new heat treatment procedure and effect on Hadfield manganese steel parts.Here we briefly discuss and study the effect of heat treatment on High percentage manganese steel cast parts.**

Keywords - Austenitic Manganese steel, Wear resistance, Hardness

INTRODUCTION

Hadfield steel was invented by Sir Robert Hadfield in 1882. This type of steel with its austenitic matrix at ambient temperature has high toughness, high ductility, high strain hardening capacity and excellent wear resistance. As a result these casting parts have been widely used for many years in a variety of applications such as: earthmoving, mining, railways, quarrying, dredging and oil/gas drilling. Due to such application the hadfield manganese steel casting required long life. Had field manganese steel casting suffering from both impact load as well as wear. As we all know some application need high impact load and good wear resistance for example, Jaw crushers and cone crushers used for primary crushing equipment, whileother applications needs moderate or no impact at all and high resistance to wear for the secondary and tertiary crushing equipment.

Heat treatment cycle for hadfield manganese steel casting

1. Raise the temperature from 200 to 700 °C @ 120°C per hour.
2. Hold at 700°C for 3 hours.
3. Raise the temperature from 700 to 1100 °C @ 120°C per hour.
4. 1 inch/1 hr + 1 hr =soaking time of individual castings.
5. After soaking, water quench immediately within 40 seconds inside the agitated water.
6. Water temperature should not rise above 40 °C and circulate cooling water.
7.

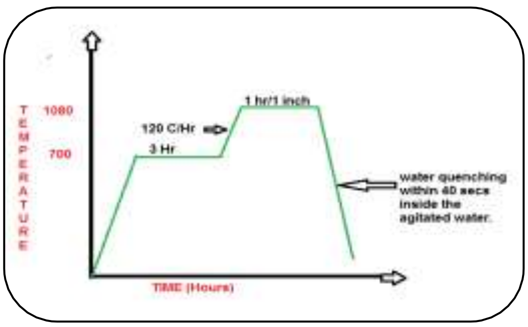


Fig -1 Heat treatment cycle of Hadfield Mn steel casting.

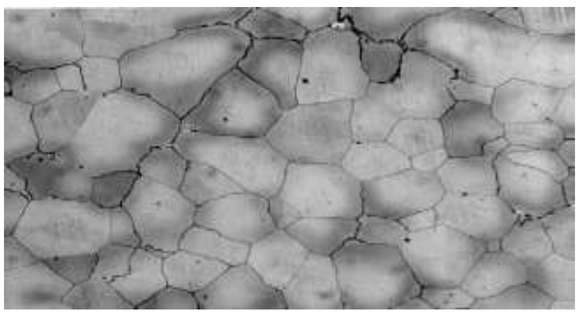
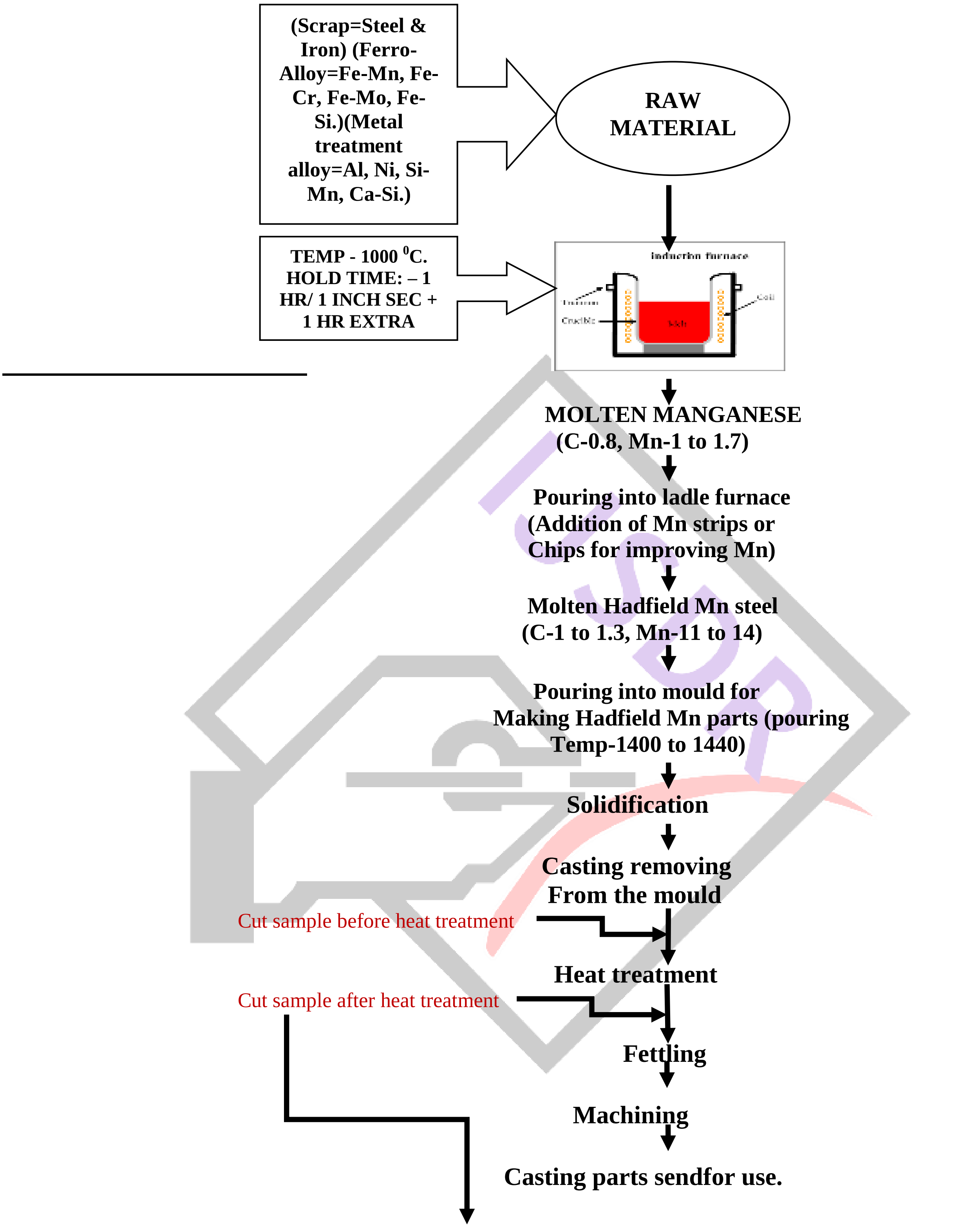


Fig -2 Microstructure of Hadfield Mn steel shows black dotte of Mn carbide and Austenitic Grains.

FLOW CHART FOR THE MANUFACTURING OF HADFIELD MN STEEL PARTS



Before heat treatment and after heat treatment parts sample taken for following testing

1- **Metallography**
2- **Hardness Test**
3- **SEM**
4- **EDS**

EXPERIMENTAL PROCEDURE

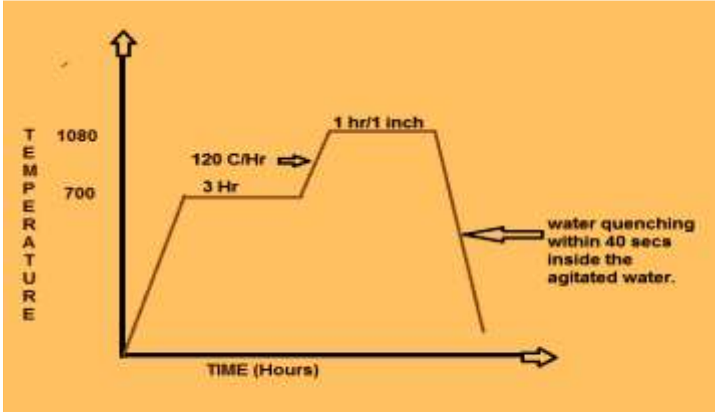


Fig -3 Heat treatment cycle for **Hadfield Mn Steel.**

Fig-4 Cone crusher

Fig- 5 jaw crusher

In above mentioned experimental work heat treatmen cycle applied for getting better mechanical properties of hadfield mn steel. First heating the Mn steel to the temperature of 200 to 700^{0}C at 120^{o}C/hr speed than holding at that temperature for 3 hours. After holding for 3 hours the temperature should be raise to 700 to 1100^{O}C at 120^{0}C per hour. Here, important feature is that to hold at that temperature for 1 hour extra per 1 inch sample size increase. Further, sample go for quench immediately under water within 40seconds insides agitated condition. It must be noted that the tempearture of water above 40^{0}C. In the experiement, we take 2 sample grade(XT-610 and XT-710) for understanding the actual effect of heat treatment on hadfield mn steel jaw and cone crusher part to improve the wear ability. Heat treatment strenghtens austenitic manganese steel so that it can be used safely and reliably in a wide variety of mining application like jaw and cone crusher etc. The standard toughning heat treatment involving solutionizing temperature is higher enough so complete solution of carbon is assumed. This can be achieved by achieving the temperature range higher than upper critical temperature line (i.e 30 to 50^{0}C above the Ac3 line). The time at this temperature is not critical, since above 1100^{0}C equilibrium is probably established within 20- 30 minutes. Also extra 1 hr applied to complete for better achievemnet of heat treatment properties.

Variation of this treatment can be used to enhance specific desired properties such as yield and wear resistance. Finally as shown in microstructure fig.7, fully austenitic structure essentially free of carbide and totally homogenious with the respect to carbon and manganese is desired in the heat treatment condition.

Here two different grade Mn steels parts under applied for the same heat treatment and see the following result. In the grade XT-610 carbon- 1.22%, Mn-12.47%, and P-0.04%. as the same in grade Xt-710 carbon- 1.33%, Mn-18.20%, and P-0.046%.

GRADE XT-610 (Hadfield Mn steel)

- **Chemical Composition :-**

Before heat treatment **After Heat Treatment**

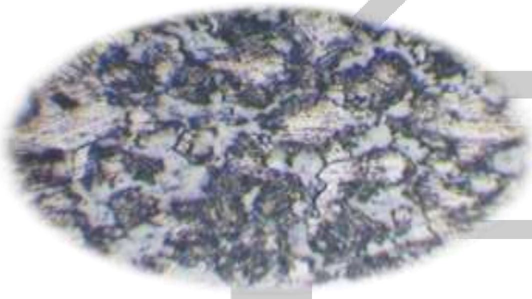
CARBON	1.22 %	CARBON	0.68 %
MANGANESE	12.47 %	MANGANESE	13.26 %
SILICON	0.79 %	SILICON	0.63 %
SULPHUR	0.006 %	SULPHUR	0.008 %
PHOSPHURUS	0.04 %	PHOSPHURUS	0.02 %
CHROMIUM	1.80 %	CHROMIUM	1.54 %
IRON	BALANCE	IRON	BALANCE

Table 1. Chemical composition of grade XT-610 Hadfield Mn steel Before H/T.
Table 2. Chemical composition of grade XT-610 Hadfield Mn steel After H/T

We can see that from the above table 1 and 2, after the heat treatment Phosphorus percentage of sample decrease, Sulphur percentage decrease & Carbon percentage decrease in Hadfield Mn steel but the manganese percentage increase. Here cr % is also heplful for better wear property.

- **Micro structures :-**

Before Heat Treatment After Heat treatment



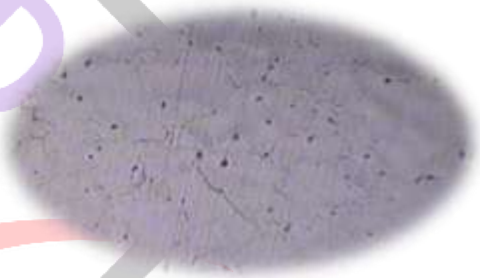


Fig.6 microstructure shows white ferrite and black pearlite Fig.7 microstructure shows Austenitic grain and Mn carbide

From the above Fig. 6 and 7 the Microstructures of heat treated Mn steel see that after heat treatment we can get proper microstructure of Hadfield manganese steel with proper visual grain boundary & Mn-carbides.

GRADE XT-710 (Hadfield Mn steel)

- **Chemical Composition :-**

Before Heat Treatment **After Heat Treatment**

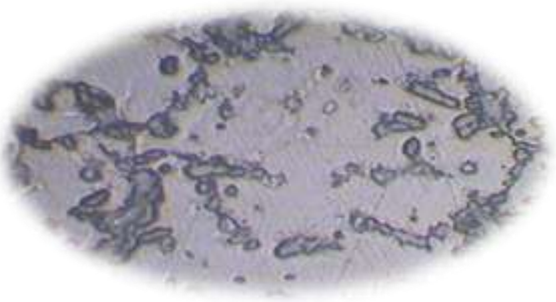
CARBON	1.33 %	CARBON	0.92 %
MANGANESE	18.20 %	MANGANESE	17.56 %
SILICON	0.83 %	SILICON	0.66 %
SULPHUR	0.002 %	SULPHUR	0.003 %
PHOSPHURUS	0.046 %	PHOSPHURUS	0.040 %
CHROMIUM	2.21 %	CHROMIUM	1.54 %
IRON	BALANCE	IRON	BALANCE

Table 3. Chemical composition of grade XT-710 Hadfield Mn steel Before H/T.
Table 4. Chemical composition of grade XT-710 Hadfield Mn steel After H/T.

We can show that from the above tables.3 and 4, after heat treatment Phosphorus percentage of sample decrease, Sulphur percentage decrease & Carbon percentage decrease in the Hadfield Mn steel.

- **Micro structures :-**

Before heat treatment



After Heat Treatment

Fig.8 microstructure shows white ferrite and black pearlite

Fig.9 microstructure shows Austenitic grain and Mn carbide

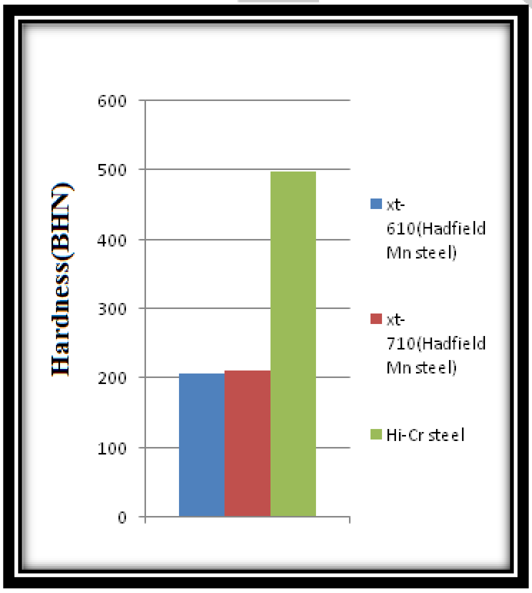
From the above microstructures 8 and 9, we can know that after heat treatment we can get proper microstructure of Hadfield manganese steel with proper visual grain boundary & Mn-carbides at the grain boundary.

- **Hardness of sample:-**

	Hadfield Manganese steel			
Grade	XT-610		XT-710	
	Before heat treatment	After heat treatment	Before heat treatment	After heat treatment
Hardness (BHN)	207	234	212	233

- **Charts of hardness:-**

Before Heat treatment



After Heat treatment

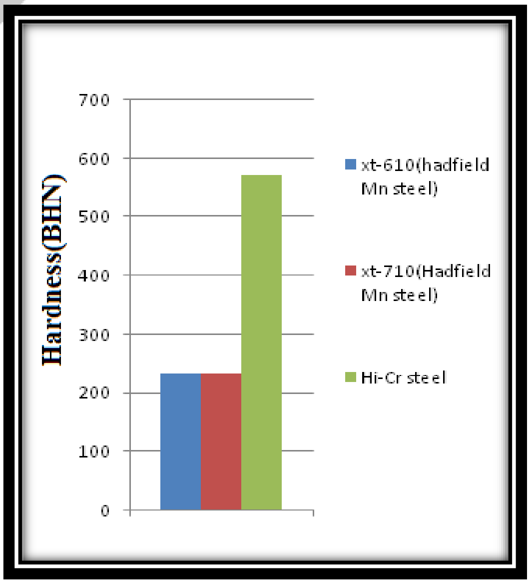


Chart-1 and 2 comparision of Before heat treatment and after heat treatment of grade Xt-610, Xt-710.

- **SEM test:-**

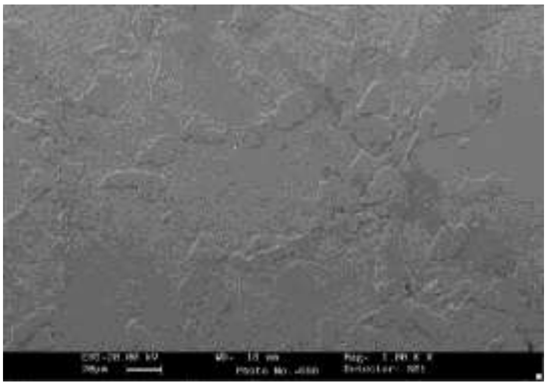


Fig. 10 Microstructure of Hadfield Mn steel grade 610 (before H/T), magnification 20µm

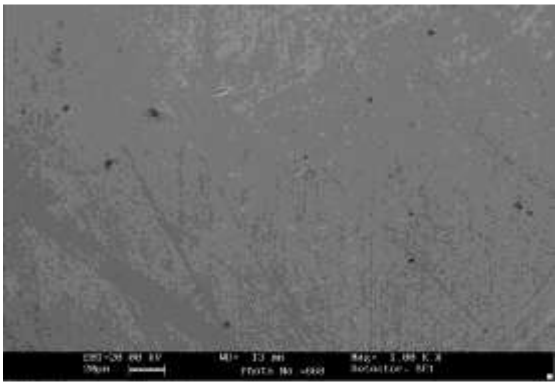


Fig 11 Microstructure of Hadfield Mn steel grade 610 (after H/T), magnification 20µm

SEM micrographs of xt-610 before heat treatment samples shows that there is development of Mn enriched phase. We can easily see grain boundaries are SEM micrographs. It is also shows needle of martensite.

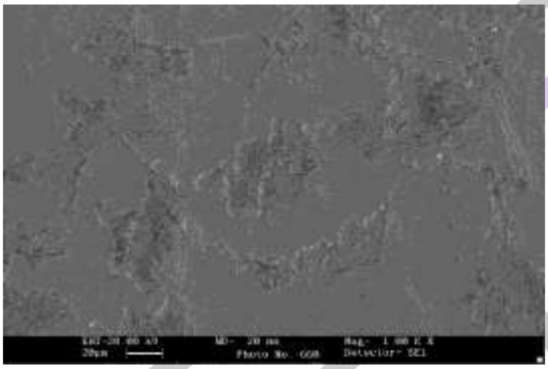


Fig. 12 Microstructure of Hadfield Mn steel grade 710 (before H/T), magnification 20µm

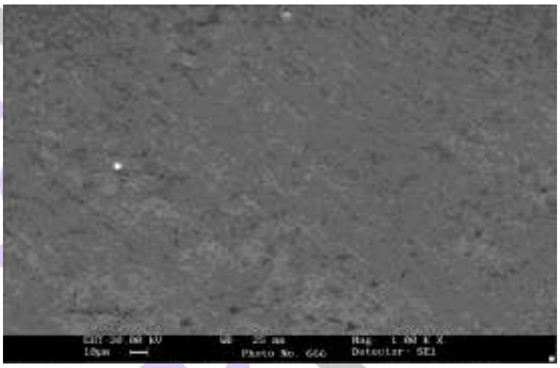


Fig. 13 Microstructure of Hadfield Mn steel grade 710 (after H/T), magnification 20µm

SEM micrographs results of samples xt-710 before heat treatment shows Mn enriched region at grain boundaries in SEM micrographs.

RESULT AND DISCUSSION

The result of heat treatment on hadfield Mn steel shows that the effect of heat treatment on various test like chemical test (spectro), microstructure, hardness , SEM and EDS. Generally heat treatment process works for better achievment of properties in the Mn steel to resist excellent wear property for minning application. In the result of hardness it is clearly observed that grade XT-610 and XT-710 increase hardness of component after heat treatment. Hardness aries in the range between 233 to 234 BHN. Furthermore, heat treatment also work effectively for chemical composition and microstructure etc as mentioned above.

In the chemical compositionof grade Xt-610 and Xt-710. It is easy to observe that the element like carbon, silicon, and chromium get resude in content and Manganese content will increaase after heat treatment. Also by the study of microstructure it can be illustrate the grain boundry of austenite and Mn- carbide enrichment in grain shows after heat treatment. Before heat treatment in microstructure pearlite and ferrite shows in said steel. As shown in Fig- 11 and 12 grade XT-610 before heat treatment and after heaat treatment shows the Mn carbide enriched into grain boundry and needle martensite. By the deep study with chemical composition it is study that Phosphorus element is very dangerous above the sertain limit (i.e 0.05%).

Fig- 12 Phosphors % higher at grain boundry as Phophite.

Not accepted structure (> 0.05% P)

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