Processing and Effect of Heat treatment on Mechanical Properties of Gray Cast Iron

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Abstract **: - Gray cast iron belongs to materials used in production of casted products, which have wide application for different processing industries. Wide spectrum of properties of these materials is given by the structure of base metal matrix, which can be influenced with heat treatment. Generally the ferrous alloys which have carbon contents of more than 2% are treated as cast irons, from this family of cast irons which contains graphite in form of flakes and shows gray fracture are considered to be gray cast iron. Investigations are carried out to study the effect of heat treatment on micro structure and mechanical properties of gray cast iron. This study was carried out to determine a suitable heat treatment process which would give the best of gray cast iron in terms of mechanical properties. The casted gray cast iron product which is used to prepare glass beverage bottles are subjected to hardening and tempering heat treatments followed by oil quenching at elevated temperatures by which the variations obtained are briefly studied. This study reveals that the hardened gray cast iron shown high hardness value as compared to hardened and tempered gray cast iron.**

Keywords-Gray Cast Iron; hardening; tempering; micro structure

I. INTRODUCTION

Cast irons make up a family of ferrous alloys with a wide range of unique mechanical properties. It is an alloy of iron and carbon in which carbon varies between 2.0 -6.67 % i.e. more than solubility limit of carbon in austenite and less than the carbon content of cementite [1]. Based on microstructure and appearance of fracture it is classified into many types, based on requirement suitable form of cast irons are utilized for different processing industries. It is an alloy of iron, carbon and silicon that has been melted and poured into a mould to form a shape. If molten iron is allowed to cool normally the carbon comes out of solution and forms flakes of graphite which run through the ferrite/pearlite matrix [2-5]. Although, ferrous casting may have superior properties, gray iron offers a unique versatility at lower cost that can be obtained through microstructure control. Inoculation causes significant improvements in mechanical properties because the microstructure of the alloy is modified. There are various methods to introduce them into the liquid metal bath but the “in ladle” method has proven to be efficient and simple [6].These gray irons are produced and mostly used in the as-cast condition. The matrix of as-cast iron is determined by cooling rate, inoculation, pouring temperature, and addition of rare earth element and the content of pig iron in the charge [7]. The mechanical properties of gray iron depend on the microstructures developed during solidification [7, 8]. Inoculation at various levels was also done to be able to make a recommendation towards attaining the desired microstructure and properties [9]. Major constituents of gray cast irons are carbon in the range of 1.7-4.5% and silicon in the range of 1-3%. The carbon precipitates as either graphite flake or carbide during solidification; the free graphite expands on solidifying, giving sharp, well defined castings, hence enhances maximum machinability, but reduces the strength of the gray cast iron [10]. Also, graphite acts as a lubricant, improving wear resistance. On the other hand, the presence carbide in gray cast iron results in hardness [4, 8]. By controlling the cooling rate, it is possible to alter the properties of cast irons [11, 12].

The prime objective of the present study is to evaluate the effect of heat treatment such as hardening and tempering on the hardness of gray cast iron. All the experimental results are correlated with the help of micro structural analysis .

II. EXPERIMENTAL :

A . Materials :

The materials used for the present work is EF6 grade gray cast iron. The spectroscopic analysis of gray cast iron is given in table 1.

TABLE 1. COMPOSITION

S	C	si	Ni	mn	mb	ph	Fe
0.07	3.6	2.0	0.3	0.65	0.4	0.12	92.86

B. Processing of gray cast iron:

The induction melting furnace was pre- heated for about 35 minutes, thereafter the scraps were charged into it, melting of the scraps and tapping of the resulting liquid metal were achieved at temperatures of 1520ºC and 1650ºC respectively. Upon tapping into a ladle, 0.2% of ferrosilicon, desired constituents were added and the melt was quickly poured into the prepared moulds to avoid gasification of the molten liquid during cooling and solidification of the mould.

C. Specimen preparation:

Specimens of dimensions 19 cm length, face thickness 2 cm, face breadth 9 cm, depth 6.5 cm at top end that may result from overheating during cutting, they were continuously lubricated with water, eight specimens were produced in the process with eight from the as cast sample.

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D. Hardening:

Hardening is the process of heat treatment by which the gray cast iron is made hard by rapid cooling (Quenching) from high temperature of 870ºC. in GFC-1 furnace upto 6 hours later on followed by oil quenching upto 2 hours. This processing consists of Water quenching and Oil quenching samples using SAE40 oil.

E. *Tempering :*

The heating of material to the temperatures between 150 – 550°C, but under the lower transformation temperature A11 and the holding time is 1 hr. Character of tempered structures is changed from bainite to sorbite. Tempering temperatures between 100 – 200°C influence the hardness of hardened cast iron very low, but strength is increased a little bit. Therefore, the tempering up to 300°C is suitable for achieving of good wear resistance. To achieve the maximum strength it is suitable for non-alloyed gray cast iron to choose tempering temperatures 100 – 270 °C, for alloyed gray cast iron 300 – 500 °C .the operation for tempering is done in air circulation tempering furnace at 300ºC.

F. Quenching:

The result obtained shown that the rate of cooling in water is faster and non – uniform than the rate of cooling in oil because the specimen that was quenched in water showed a very hard structure which not fails at maximum load due to the martensitic structured that is present in the specimen. This is in agreement with the idea that martensitic structure is very hard and brittle. The hardness and brittleness of martensite is due to the fact that marten site is a super saturated solid solution of carbon trapped in a body centered tetragonal structure, which is a Meta stable condition. This highly distorted lattice is the prime reason for the high hardness of marten site.

The oil quenched sample , exhibited both the plastic and elastic regions distinctively. This can be attributed to slow, uniform cooling which allows the formation of graphite and pearlite in its microstructure. This reduces the hardness and makes it possible for the specimen to be ductile.

G. Hardness test :

The hardness test on gray cast iron sample is done by Brinell hardness testing apparatus and also done by Rockwell hardness apparatus, but due to availability the results are obtained from Brinell hardness testing apparatus in BHN units. The hardness values for both cast iron and reinforced composites were measured on the as-cast and the heat treated specimens. Brinell hardness tests at the 150 kgs load were performed on the side of matrix for all specimens.

TABLE 2. HARDNESS VALUE OF AS-RECEIVED GCI SPECIMENS

Sl.no.	Location	Observed values in HBW 2.5mm /187.5			
		Impression1	Impression2	Impression3	Average
1	On surface	144	144	147	145

TABLE 3. HARDNESS VALUE OBTAINED AFTER HARDENING OF MOULD

Sl. no	Location	Observed values in BHN			
		Impression1	Impression2	Impression-3	Average
1	On surface	292	298	290	293.33

TABLE 4. HARDNESS VALUE OBTAINED AFTER HARDENING AND TEMPERING OF MOULD

Sl.no.	Location	Observed values in BHN			
		Impression1	Impression2	Impression3	Aveage
1	On surface	285	285	278	282.67

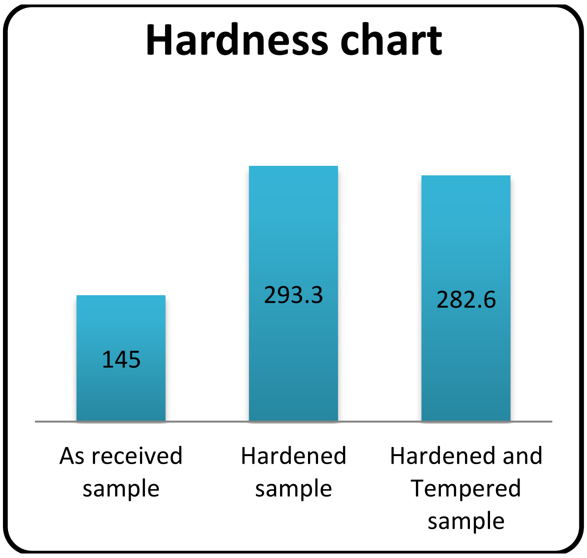

Fig 1. Comparision of hardness values of various gray cast iron as received/heat treated specimens

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H. Micro structure :

Specimens for microscopic studies samples were machined to dimensions of 30 mm length, 20 mm breadth and 10 mm thickness with lathe machine. They were mounted on thermosetting material known as bakelite in order to make them convenient for handling. Thereafter, the surfaces of the specimens were then flattened by filing and grinding using laboratory grinding and polishing machines with a set of sand papers of 240, 320, 400, 600, 1000 and 1200 microns and emery papers of 1/0, 2/0, 3/0 and 4/0 grade. The grinding was done in order of coarseness of the papers. As each specimen was changed from one emery papers to the other, it was turned through an angle of 90º to remove the scratches sustained from the previous grinding. After grinding, the specimens were polished using rotary polishing machine, to give it mirror like surface, a polishing cloth was used to polish the surface of the specimens, and in order to make a colored eutectic cell of the samples apparent when viewed under the computerized metallurgical microscope (Model FE PRO 900).

The microstructure observed after processing and preparing of casting mould is made to view under computerized metallurgical optical microscope after 10X magnification. Obtained microstructure before and after etching is shown in Fig.2.

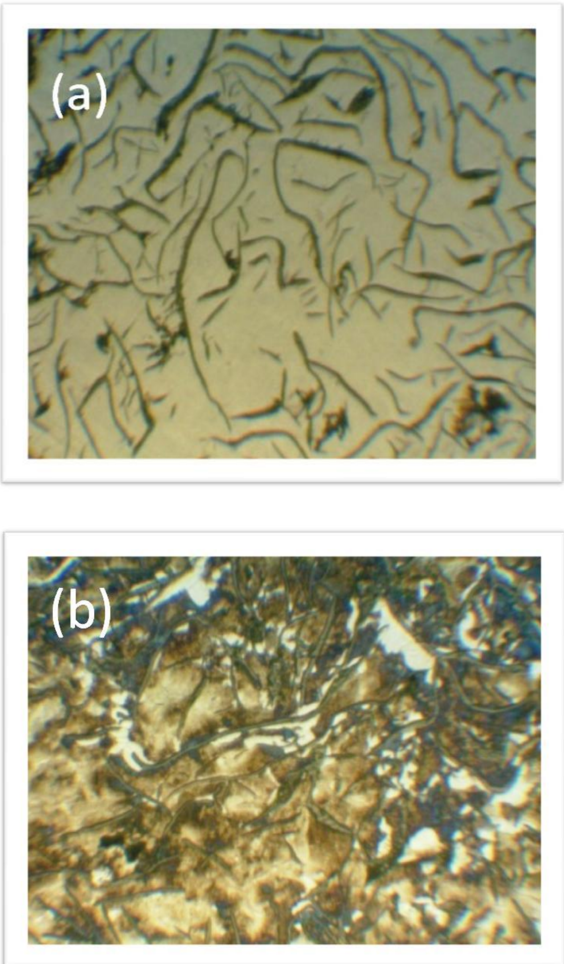

Fig 2. Optical micro structural of Gray Cast Iron
(a) before etching (b) after etching

Fig 3 . Optical micro structure of Hardened Gray Cast Iron

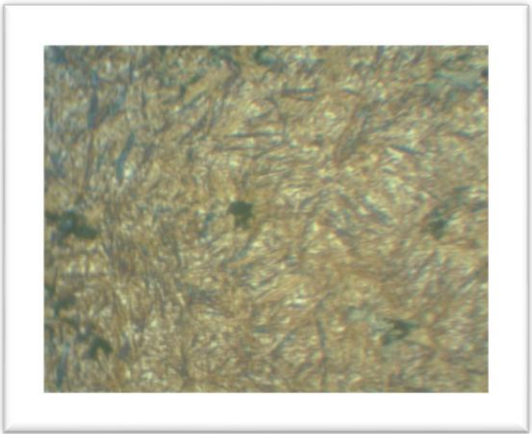

Fig 4. Optical microstructure of Hardened and Tempered Gray Cast Iron

III. RESULTS AND DISCUSSIONS:

Hardness testing has been carried out on as received specimens of gray cast iron and the same test carried out on hardened and tempered samples to evaluate the effect of heat treatment process (Fig. 1). It has been found that, BHN 145 for as received samples (Table 2). Whereas, for hardened samples, the hardness value is 100% more as compared to as received sample (Table 3). This is attributed to the fact that in the as received gray cast iron, the graphite is in form of flakes and produces more internal discontinuities and less interruption within the matrix.

In case of heat treated gray cast iron, the existing phase converted to martensite phase which is in form of acicular morphology which may be the primary reason for the increase of hardness significantly. So, this is clearly shown in the micro structural investigation. Fig. 3 clearly reveals more presence of graphite flakes, after hardening and tempering, the most of graphite flakes are converted into needle like structure and this is shown in Fig. 4, and the disappearance of the graphite flakes is the main reason for increment in hardness.

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This martensitic needle like structure decreases the damping capacity of gray cast iron which is the unique property of this cast iron.

IV. CONCLUSIONS :

(i) Processing of EF6 grade gray cast iron is successfully carried out using Induction melting furnace.

(ii) The hardness of the as received gray cast iron is significantly less as compared to the hardened gray cast iron. This may attribute to the fact that the absence of martensite phase.

(iii) The hardness of hardened gray cast iron is marginally greater as compared to the hardness of hardened and tempered gray cast iron .This is due to the fact the presence of internal discontinuities caused due to the distribution of graphite flakes in the matrix. All the experimental results were correlated with micro structural analysis.

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