Semi Solid Processing of High Chromium Cast Iron

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***Abstract*— Semi-solid processed 10% Cr cast irons were produced by slope casting method in a sand mold. Experiments were carried out to clarify the effect of cooling slope on microstructure and hardness. To compare the effects of cooling slope, castings were also made by conventional casting method in a sand mold. The semi-solid processed and the conventionally cast 10 wt%Cr cast iron were studied by optical microscopy and their microstructures and hardness values were compared. In the semi solid processed condition, the primary proeutectic austenite was round in shape while the conventionally cast condition, primary proeutectic austenite was in dendritic in shape. The results show that semi solid processed 10% Cr alloys possess better hardness than conventionally cast 10% Cr alloys due to change in microstructure.**

Keywords: semi-solid processing, high chromium cast iron, microstructure, hardness, slope casting

I. INTRODUCTION

The liquid metal cast in semisolid sate that is when temperature is in between liquidus and solidus temperature under external influence is called semisolid casting. In this technique dendrite crystallization formation of primary phase is prevented during solidification of alloy. Therefore conditions are prevailed to obtain rheological characteristics [1]. In semi solid casting techniques golubrization of primary phase takes place by fragmentation of dendrite and the eutectic size is reduced. The work was initiated by Fleming at MIT in seventies [1]. Till date, numbers of investigator are working in this field. There are number of techniques of semisolid processing. They can be divided into two groups: rheocasting and thixocasting. If the casting is formed from the liquid slurry directly after melting under the action of shearing/stirring the process is called rheocasting. If the casting is made from the previously prepared (by cutting off) ingot with globular structure after heating the stock to semi-solid state, the process is called thixocasting.

Maximum works of semisolid processing are carried out on low melting point alloy like aluminium and magnesium. The studies on semi-solid processing of high-melting alloys like cast irons and steels are less compared to low melting point alloy of non ferrous. This is due to the difficulty in preparing cast iron with globular microstructure and problems related to complexity to handle at high temperature [7]. However, development of cooling slope techniques of semisolid processing attracts researchers towards semisolid processing of cast irons and steels [2-3]. The cooling slope method, the liquid alloy flowing over the inclined plate [4-5], and hence it is economical and simple from the previous processes based on stirring. Based on requirements, the pouring temperature of the alloy on the cooling slope should be slightly higher than the point of liquidus temperature, while final temperature should be in between liquidus-solidus temperatures.

Numbers of nuclei of primary phase are formed during flow of liquid metal over cooling slope, which diminishes the conditions for a dendritic growth of the primary phase under free flowing of liquid metal [4]. Therefore, the slope casting method is a simple and economic to produces non dendritic casting with greater homogeneity and dispersion of the primary phase than the process stirring.

High-chromium white iron is an erosion resistant ferrous alloy mainly used in mining, milling, earth-handling and manufacturing industries which require materials with exceptional wear and corrosion resistance, imparted by the hard alloy eutectic carbides present in the microstructure [6]. The high percentage of chromium retards the formation of graphite and stabilizes the carbides. Copper, nickel, manganese and molybdenum are normally added to suppress the formation of pearlite during cooling [4-5]. High chromium cast irons wear behavior has been well investigated [7] and the microstructure and properties relationship has also been extensively studied [8-9]. In this work Semi-solid processing was carried out by using refractory coated semi-circular channel. The microstructure and hardness of semi solid processed 10% Cr cast iron were compared with those obtained by ordinary casting.

II. EXPERIMENTAL

The schematic image of a slope casting set up is shown in Figure. 1. The set up was equipped with thermocouple for continuous temperature measurement of liquid metal and temperature measurement at the end of the plate. High chromium cast iron samples were prepared and melted in an induction furnace. The composition of cast iron investigated is shown in Table 1. After melting to a temperature above the liquidus, the liquid metal was taken out of the furnace and poured under the two conditions; the ordinary sample was poured directly into a sand mold while in the other condition for semi-solid processing poured over a one meter long semi-circular channel made from mild steel and inclined at 150, into a sand mold as shown in Figure 1. The flow channel was provided a layer with refractory lining of alumina of 10mm thickness. A thin layer of graphite coating over lining was provided to prevent sticking of solidified iron. The liquid metal was poured over slope into stepped bar sand mold. The

3-dimensional schematic sketch of stepped bar is shown in the Figure 2. The metallographic examinations using a optical microscope were the basis for the test analysis. The microstructure of high chromium cast iron obtained by normal casting method and semi-solid processing were investigated using samples cut off from stepped bar. The 3-dimensional view of stepped bar is shown in the Figure 2 and dimensions were 50X50X12mm and 50X50X5mm. Vickers hardness was measured and averaged over for five points in every condition.

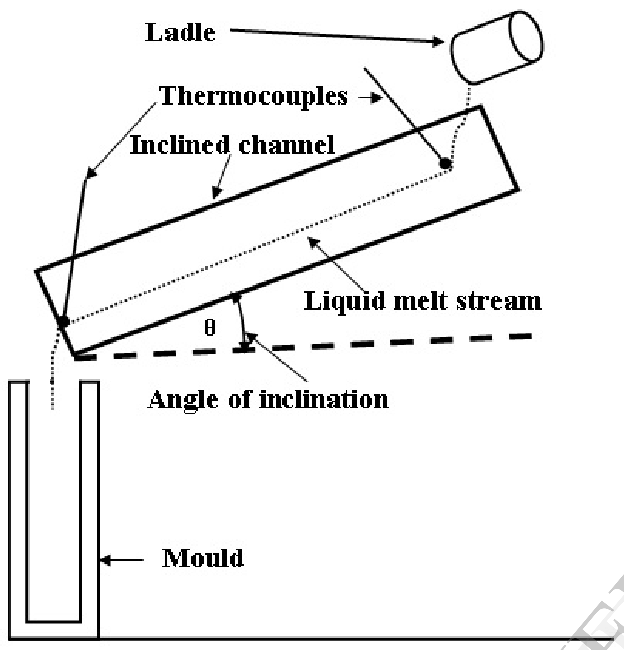

Fig. 1. Schematic Sketch of inclined channel casting (Semi solid processing)

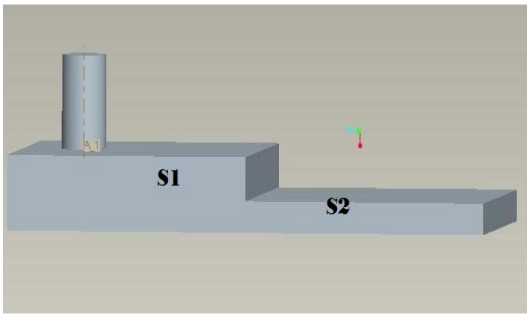

Fig. 2. 3D model of Stepped bar

A. Microstructure

Samples were cut off from each stepped bar of the specimens. Specimens for metallographic examination by optical microscopy (OM) were cold mounted in resin and polished using series of abrasive paper and then clothe polishing Hiffin fluid and diamond paste. The 2% Nital etchant was used to reveal the microstructure. The microstructures were studied using an Olympus optical microscope.

B. Hardness measurement

The specimens prepared for optical microscope were also used for the hardness measurements. Vickers hardness testing was performed on unetched specimens. The mean values are based on 5 different areas.

III. RESULTS & DISCUSSIONS

A. Chemical Composition

The chemical composition of cast iron was determined using a spectrometer. The chemical composition of cast sample is presented given in the Table 1.

TABLE I. CHEMICAL COMPOSITION CAST SAMPLES

%C	*%Si*	*%Cr*	*%Mn*	*%P*	*%S*	*%Mo*	*%Ni*	*%Cu*
3.5	*3.2*	*10*	*0.33*	*0.12*	*0.04*	*0.006*	*0.13*	*0.04*

B. Microstructure

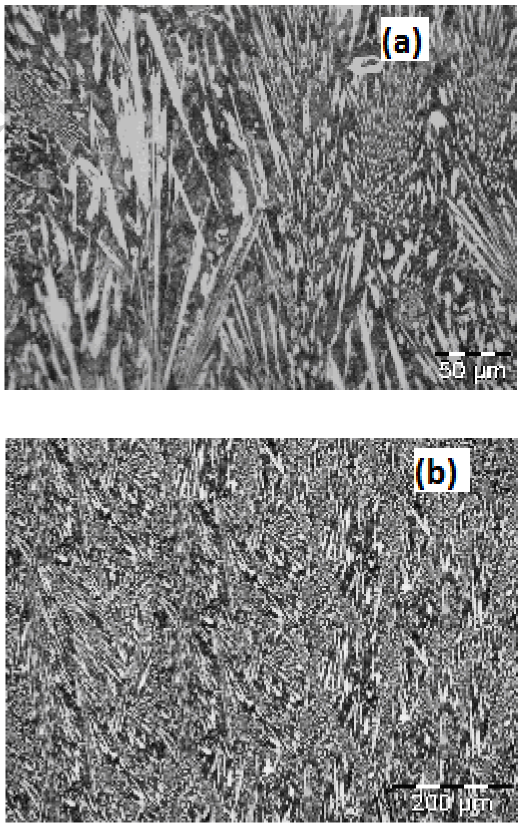

Fig. 3. Microstructure of conventionaly cast stepped bar (a) 50X50X12 mm plate & (b) 50X50X5mm plate of 10wt% Cr cast iron

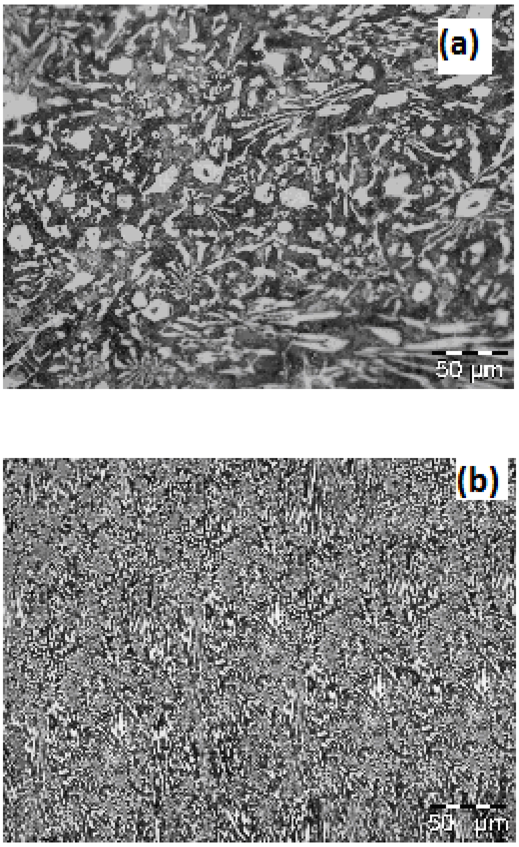

Fig. 4. Microstructure of semi solid processed stepped bar (a) 50X50X12 mm plate & (b) 50X50X5mm plate of 10wt% Cr cast iron

In this work, the metallographic studies were the basis for the investigation of the effectiveness of a semi-solid slope casting. The output was realized by comparing the microstructure of Fe-10wt%Cr cast iron poured into the mold conventionally under gravity and with microstructure of the same cast iron poured into mould using inclined channel. The primary phase precipitates austenite's morphology was examined in samples prepared for the examinations after etching. The samples cut out from castings poured from metals processed in the inclined channel process are characterized by globular form of the structure of an austenite primary phase and/or by the granular structure considerably refined. The samples cut out from castings poured conventionally after melting of the same metals have a dendritic structure of the austenite phase. High chromium cast iron starts solidification with the formation of primary austenite, followed by the monovariant eutectic reaction as liquid transforms into austenite and a carbide M7C3[10]. In this work using an inclined slope, molten Fe-10wt%Cr cast iron was poured over an inclined channel at room temperature. Heat was lost through the channel-wall and consequently nucleation was initiated along the melt channel contact surface as the melt flowed. Due to the melt-flow action, the nucleated crystals were drawn into the melt stream before they come into contact with adjacent crystals to form solid shell. A coating of graphite was applied on the surface of inclined channel to ensure that precipitating crystals separate easily from the channel wall.

Figures 3 ((a) & (b)) and 4((a) & (b)) show the microstructures of the 10wt% Cr samples cast conventionally and semi solid processed respectively, as observed under optical microscopy. In the as-cast condition the matrix of 10% Cr iron in Fig. 3((a) & (b)) for ordinary metal mold casting) shows the presence of primary dendrites of austenite and carbide eutectic. The matrix of as-cast semi-solid sample in Fig. 4((a) & (b)) was composed of spheroidal primary austenite crystals and carbide eutectic.

C. *Hardness testing:*

In almost all cases, the hardness of semi-solid chromium cast iron was higher than that of conventional as-cast iron due to the effect of microstructure obtained by semi-solid processing. Average hardness of both conventionally cast and inclined slope casting of samples were measured using Vickers Hardness tester. The sample prepared by semisolid casting methodology showed higher hardness than the conventionally cast samples due to the markedly change in morphology of carbide of semi solid process casting samples compared to conventionally cast samples. The hardness values of samples are given in Table II. Thinner section of stepped in both the process showed higher hardness due to higher rate of cooling compare to thicker section of stepped bar. The high cooling rate produced very fine microstructure than slow cooling rate.

TABLE II. HARDNESS (VICKERS HARDNESS)

Description	**Average Vickers Hardness**
Semi solid sample of thickness 5mm	***705.05***
Semi solid sample thickness of 12mm	***688.65***
Conventionally cast sample of thickness 12mm	***650.00***
Conventionally cast sample thickness of 5mm	***749.85***

IV. CONCLUSIONS

A. From the results it is it is possible to develop a thixo-tropic structure in cast iron, i.e. the structure with globular precipitates of the primary phase, by inclined slope casting in high chromium iron. Semi-solid processed 10wt% Cr cast iron structure consisted of primary spheroidal austenite particles and eutectic carbide structure.

B. Hardness of semi-solid chromium cast iron was higher than that of ordinary as-cast iron due to the characteristic microstructure of semi-solid processed cast iron.

C. The hardness of thinner sample in each type of casting process has shown higher hardness value. This is due to faster cooling rate.

D. Semisolid casting process for high chromium cast iron proved to be a better manufacturing method as it improves the mechanical properties of the materials and also lessen the defect caused due to turbulence or higher pouring temperature.

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