International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 7, July - 2014

Mechanical Property and Microstructural Variation in Semi-Solid Processed High Chromium Cast Iron

[1]Nazir Hussain, [2]Amitesh Kumar, [3]P. Vijayanand
[1.] Cambridge Institute of Technology, Ranchi, India,
[2]National Institute of Foundry & Forge Technology, Hatia, Ranchi
[3]Research Scholar in Ranchi University, Ranchi

Abstract - High chromium cast irons (HCCI) find its application in industries like mining, earth-handling and areas where exceptional wear resistance and hardness is required. HCCI show these properties because of the presence of chromium carbides in a higher amount. The carbide percentage and chromium percentage in the matrix control the mechanical properties & microstructure of HCCI. In the present work comparative study of slope casting and conventional gravity mold casting were carried out. Fe-10wt% chromium was cast in both cases from the same melt. In this work attempts have been made to investigate the microstructure and hardness of cast samples. The results show that semi solid processed 10% Cr alloys possess better hardness than conventionally cast 10% Cr alloys due to change in microstructure.

INTRODUCTION

High chromium cast irons (HCCIs) are mainly used in mining, milling, earth-handling and manufacturing industries which require materials with exceptional wear and corrosion resistance. High-chromium cast iron since shows good wear and corrosion resistance properties and are widely used in making components that demands these properties. The exceptional wear resistance of high chromium cast irons is due to the high volume fraction of hard chromium carbides, although the toughness of the matrix also contributes to the wear resistance [1-3]. The high controlled percentage of chromium helps to retard the formation of graphite and stabilize the carbides. In the mean time 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 [6,7] and the microstructure and properties relationship has also been extensively studied [2,8,9].However, the comprehensive explanation regarding the resistances of HCCI, one of the most important industrial materials, to its remarkable wear, corrosion resistance is still incomplete and the information provided in literature is limited [4,10,11].In the present work semi-solid processing ; in which molten metal is cooled and solidified partially before it is poured in the mould has bright future in many industrial fields [12].Semi-solid processed alloys do not contain dendritic structures as in conventional castings. In this kind of metal alloys processing the solidifying metals contain primary phase which is nearly spherical. This leads to the creation of a slurry-like form that allows the semi-solid alloy to behave as a fluid of low viscosity when flowing under shear during the casting operation. The microstructure features of semi-solid processed high chromium cast irons such as 10 wt% chromium are of concern so as to improve the lives of wear parts in mining and mineral industry, especially when combined erosion and corrosion resistance is required. Although the effects of heat treatments on general microstructure and some information on properties of semi-solid processed 27wt% chromium irons have been reported [13-14], a detailed examination of microstructure has not previously been attempted. Nowadays interest is being shown in developing the semi-solid process and making it technologically simple and viable process. One such route suggested is processing the alloys in inclined controlled heated plates or cooling slopes [15-28]. The sloping plate can provide very strong under-cooling and cause a large quantity of nuclei to form, which creates fundamental conditions for fine spherical grain formation [29-30]. Final microstructure is being controlled by various parameters involved in the process like melt superheat, slope angle, mold material, slope length. The studies did so far have been helpful to some extent in understanding the complicated microstructure evolution during the shear processing of the alloys. But detailed explanation of micro-structural evolution during low shear inclined slope semisolid processing is still not available. However, the inclined slope process is attractive due to flexibility and the ease of processing that has been the limiting factor to great extent in the development of semisolid processing. In the current study the cooling system used is of 1 meter in length inclined at an angle to provide sufficient amount of shear force so as to avoid dendritic grains in the final structure. The 1 meter length channel is of mild steel on which a definite amount of alumina coating is applied , the thermal properties of alumina and mild steel is also taken into account to study the effect of sloped channel on the morphology of 10wt% chromium iron melt when it passes through the channel. Then optimizing the operating parameters of the setup such as angle of the slope, superheat, slope temperatures to ensure non-dendritic morphologies. The effect of modification on the structure and mechanical properties of low shear semisolid high chromium cast iron has to be studied. The experimental result is then validated using simulation software platform, and the results obtained after simulation were in good agreement with the experimental ones.

Experiment

Methods & Experimental details

Sand mould was made silica sand of AFS 70 grain fineness number, 5% bentonite and water were added. The mixture was prepared in sand Muller. After the molding the pattern was resealed and allowed to dry for 5 hours. 3-D solid model of bar is shown in the Figure 1.Dimensions of each stepped are given in Table 1 and table 2.

Table 1: Dimension of stepped bar (semisolid cast)

Step number	Label	Dimension (mm)
1	S1	50 x 50 x 12
2	S2	50 x 50 x 5

Table 2: Dimension of stepped bar (conventionally cast)

Step number	Label	Dimension (mm)
1	S3	50 x 50 x 12
2	S4	50 x 50 x 5

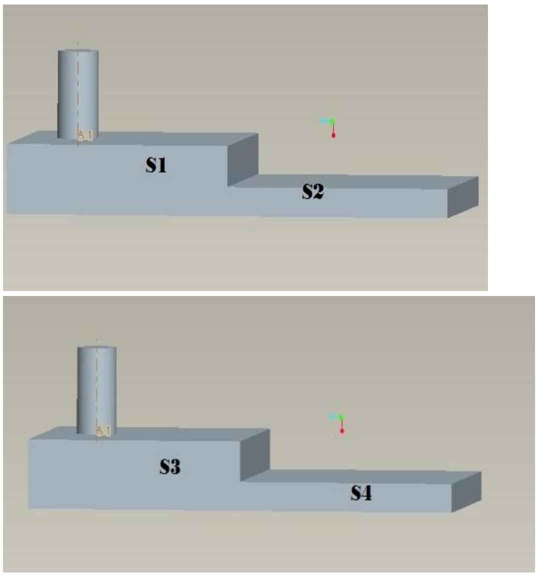


Fig.1: 3D model of Stepped bar.

The composition of melt is investigated and is shown in Table 5. As soon as the melt reaches to a temperature above liquidus temperature, the melts were taken out of the furnace and poured under the different conditions; conventionally poured sample and semisolid processed sample were made. For making semisolid melt the molten metal was poured in a semi-circular channel made of cast iron and a specific amount of alumina was applied over it, the channel was inclined at an optimum angle so that a sufficient amount of shear stress acts on the flowing metal. The alumina layer is painted with graphite in its inner radius to prevent sticking of the liquid metal being poured through it. The paint is air dried well before pouring.

In conventional method the melt was directly poured in the mold but in the semisolid method the melt traverse a length of 1 meter till it reaches the pouring basin made in the mold.

The physical and thermal properties of materials used in modeling of the slope setup are given in Table 3 and Table 4 .

Table 3: Thermal properties of Alumina.

Heat transfer coefficient	2.2345 W/m^2-K
External emissivity	0
Wall thickness	0.02 m
Density	3950 Kg/m^3
Cp	1131.537 J/Kg-K
Thermal Conductivity	8 W/m-K

Table 4: Thermal properties of Air wall.

Heat transfer coefficient	40 W/m^2-K
External emissivity	1
Wall thickness	0.02 m
Density	1.225 Kg/m^3
Cp	1006.43 J/Kg-K
Thermal Conductivity	0.0242 W/m-K

RESULTS & DISCUSSION:-

Chemical Composition: The chemical composition of cast iron was determined using a spectrometer. The chemical composition of cast sample is given in table 5.

Table 5: Chemical composition cast samples

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

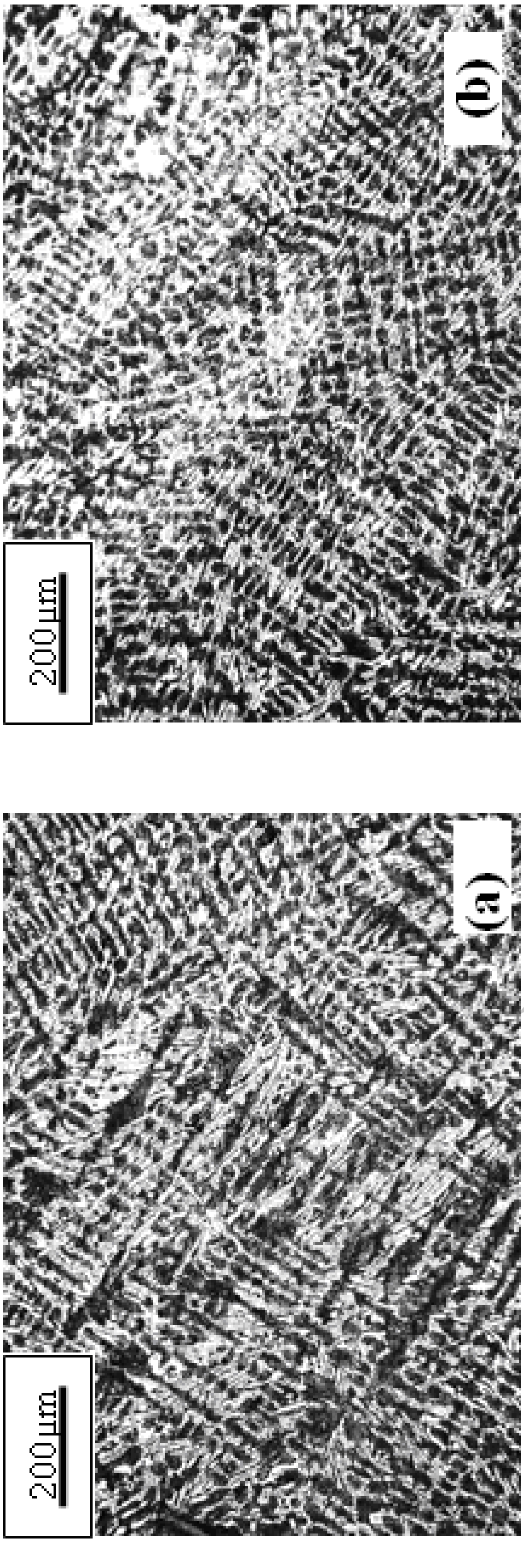
Microstructure:

In this work, four different thickness of plate of high chromium cast iron (HCCI) containing 10 wt. % of chromium were cast by conventional method as well as semi solid process. Semi solid process was carried out on an inclined slope. Their microstructures were characterized using image analyzer. Microstructues are shown in the Figure 2. The carbides formed in the HCCI with carbon content (3.5 wt. %) were identified as cubic-face centred $M_{23}C_6$.For the conventional casting the structure was found to be dendritic and the percentage of carbide formed was not appreciable to overcome the properties obtained in semisolid casting samples. In semisolid samples the structure can been seen clearly in the microstructure (Fig. 2 (b) & (d)) which is more rounded than conventionally cast samples.

Hardness testing:

Average hardness of both conventionally cast and inclined slope casting of samples were measured using Vicker 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 6. 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.

ISSN: 2278-0181
Vol. 3 Issue 7, July - 2014



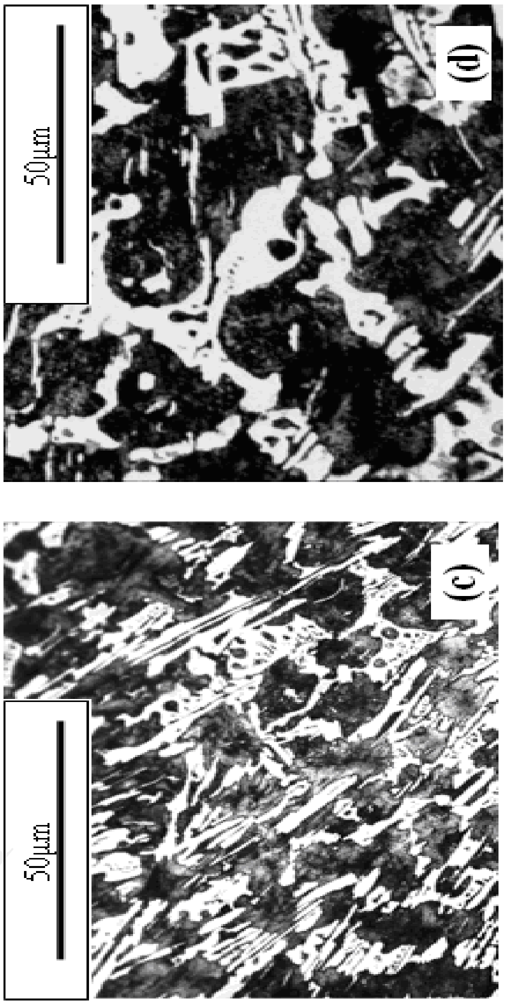


Fig.2: Microstructure of (a) & (c) Conventionally cast, (b) & (d) Semisolid Sample of 10wt% Cr cast iron

Table 6: Hardness (Vicker Hardness)

Description	**Sample Number**	**Vicker Hardness**
Semi solid sample of thickness 5mm	S2	705.05
Semi solid thickness of 12mm	S1	688.65
Conventionally cast sample of thickness 12mm	S3	650
Conventionally cast thickness of 5mm	S4	749.85

CONCLUSON:-

1. Spheroidal structure can be obtained by Slope casting method.

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

3. 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.

REFERENCES:-

1. G. O. Young, "Synthetic structure of industrial plastics (Book style with paper title and editor)," in Plastics, 2nd ed. vol. 3, J. Peters, Ed. New York: McGraw-Hill, 1964, pp. 15–64.
2. W.-K. Chen, Linear Networks and Systems (Book style). Belmont, CA: Wadsworth, 1993, pp. 123–135.
3. H. Poor, An Introduction to Signal Detection and Estimation. New York: Springer-Verlag, 1985, ch. 4.
4. B. Smith, "An approach to graphs of linear forms (Unpublished work style)," unpublished.
5. E. H. Miller, "A note on reflector arrays (Periodical style—Accepted for publication)," IEEE Trans. Antennas Propagat., to be published.
6. J. Wang, "Fundamentals of erbium-doped fiber amplifiers arrays (Periodical style—Submitted for publication)," IEEE J. Quantum Electron., submitted for publication.
7. C. J. Kaufman, Rocky Mountain Research Lab., Boulder, CO, private communication, May 1995.
8. Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interfaces(Translation Journals style)," IEEE Transl. J. Magn.Jpn., vol. 2, Aug. 1987, pp. 740–741 [Dig. 9th Annu. Conf. Magnetics Japan, 1982, p. 301].
9. M. Young, The Techincal Writers Handbook. Mill Valley, CA: University Science, 1989.
10. J. U. Duncombe, "Infrared navigation—Part I: An assessment of feasibility (Periodical style)," IEEE Trans. Electron Devices, vol. ED-11, pp. 34–39, Jan. 1959.
11. S. Chen, B. Mulgrew, and P. M. Grant, "A clustering technique for digital communications channel equalization using radial basis function networks," IEEE Trans. Neural Networks, vol. 4, pp. 570–578, July 1993.
12. M.C. Flemings, Metall. Trans. A. 22 (1991) 957-981.
13. N. Poolthong, H. Nomura, M. Takita, Int. J. Cast Met. Res. 16 (2003) 573-578.
14. N. Poolthong, H. Nomura, M. Takita, Mater. Trans. 45 (2004) 880-887.
15. Flemings M. C.(1991), Behavior of metal alloys in the semisolid state, Metallurgical Transactions A, vol. 22, no. 5, pp 957-981.
16. Haga T. and Suzuki S.(2001), Casting of aluminum alloy ingots for thixoforming using a cooling slope, Journal of Materials Processing Technology, 118, pp. 169-172.
17. Haga T. and Kapranos P. (2002), Simple rheocasting processes, Journal of Materials Processing Technology, 130-131, pp. 594-598.
18. Dhindaw B. K., Lankesh Kumar, Amer Alkarkhi N.C., Hasse Fredricksson (2005), Microstructure development and solute redistribution in aluminium alloys under low and moderate shear rates during rheo processing, Material Science and Engineering A, 413-414, pp. 156-164.
19. Ramadan M., Takita M., Nomura H. and El-Bagoury N. (2006), Semi-solid processing of ultra high-carbon steel castings, Materials Science and Engineering A 430, pp. 285-291.
20. Samantaray S. K., Dhindaw B. K., Ghosh S. (2006), Semisolid processing of cast iron under low convection conditions, Proceedings of eigth international symposium on science and processing of cast Iron, Beijing, China, October 16-19, pp. 348-353.
21. Movahedi M., Karimi Taheri A. and Nimanesh H. (2007), Combined effect of cooling slope angle and mould vibration on semisolid microstructures of wrought aluminium alloy 7075, International journal of Cast metals Research, vol. 20, no. 4, pp. 221-227.
22. Birol Y. (2008), Cooling slope casting and thixoforming of hypereutectic A390 alloy, Journal of Materials Processing Technology, vol. 207, pp. 200-203.
23. Taghavi F. and Ghassemi A.(2008) Study on the effects of the length and angle of inclined plate on the thixotropic microstructure of A356 aluminium alloy, Materials and Design, article in press.
24. Legoretta E. C., Atkinson H. V. and Jones H. (2008), Cooling slope casting to obtain thixotropic feedstock II : observations with A356 alloy, Journal of Materials Science, vol 43, pp. 5456-5469.
25. Lima Filho D. P. and Yamasaki I. (2006), Evaluation of strip rolling directly from the semisolid state, Solid State Phenomena, vol. 116-17, pp. 433-436.
26. Kido F. and Motegi T. (2008), Semisolid continuous casting of AS41B magnesium alloy using inclined cooling plate, International journal of Cast Metals Research, vol. 21, no. 1-4, pp. 105-108.
27. Shirasaki K., Takita M. and Nomura H. (2008), Effect of semisolid casting process with cooling plate technique on microstructure and properties of high speed steel with high vanadium and carbon contents, International journal of Cast Metals Research, vol. 21, no. 1-4, pp. 45-48.
28. Poolthong N., Nomura H. and Takita M. (2004), Effect of heat treatment on microstructure and properties of semi-solid chromium cast iron, Materials Transactions, vol. 45, no. 3, pp. 880-887.
29. Nili-Ahmadabadi M., Pahlevani F. and Babaghorbani P. (2008), Effect of Slope plate variable and reheating on the semi-solid structure of ductile cast iron, Tsinghua Science and Technology, vol. 13, no. 2, pp.147-151.
30. Guan R. G., Cao F. R., Chen L. Q., Li J. P. and Wang C. (2009), Dynamical solidification behaviors and microstructural evolution during vibration wavelike sloping plate process, Journal of Materials Processing Technology 209, pp. 2592-2601.
31. Taghavi F. and Ghassemi A.(2008) Study on the effects of the length and angle of inclined plate on the thixotropic microstructure of A356 aluminium alloy, Materials and Design, article in press.
32. Legoretta E. C., Atkinson H. V. and Jones H. (2008), Cooling slope casting to obtain thixotropic feedstock II : observations with A356 alloy, Journal of Materials Science, vol 43, pp. 5456-5469.
33. Lima Filho D. P. and Yamasaki I. (2006), Evaluation of strip rolling directly from the semisolid state, Solid State Phenomena, vol. 116-17, pp. 433-436.
34. Kido F. and Motegi T. (2008), Semisolid continuous casting of AS41B magnesium alloy using inclined cooling plate, International journal of Cast Metals Research, vol. 21, no. 1-4, pp. 105-108.
35. Shirasaki K., Takita M. and Nomura H. (2008), Effect of semisolid casting process with cooling plate technique on microstructure and properties of high speed steel with high vanadium and carbon contents, International journal of Cast Metals Research, vol. 21, no. 1-4, pp. 45-48.
36. Poolthong N., Nomura H. and Takita M. (2004), Effect of heat treatment on microstructure and properties of semi-solid chromium cast iron, Materials Transactions, vol. 45, no. 3, pp. 880-887.
37. Nili-Ahmadabadi M., Pahlevani F. and Babaghorbani P. (2008), Effect of Slope plate variable and reheating on the semi-solid structure of ductile cast iron, Tsinghua Science and Technology, vol. 13, no. 2, pp.147-151.
38. Guan R. G., Cao F. R., Chen L. Q., Li J. P. and Wang C. (2009), Dynamical solidification behaviors and microstructural evolution during vibration wavelike sloping plate process, Journal of Materials Processing Technology 209, pp. 2592-2601.