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Solidification Effect on Aspect Ratio, Grain Size and Dendrite Arm Spacing of Hypoeutectic Chilled Cast Iron

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ABSTRACT

This paper presents the solidification effect on aspect ratio, grain size and dendrite arm spacing of hypoeutectic chilled cast iron beside the length of the casting. Microstructure analysis is done involving sub-zero water cooled with copper, water-cooled with copper, copper, mild steel, cast iron, silicon carbide and graphite end chills specimens. The effect of solidification of different specimens by selecting the material from chill end to riser end, to study variation in the property. The aspect ratio, grain size and dendrite arm spacing measurements are taken from polished specimens using software image analyser and compared with same chemical proportion specimen which are casted without using chill. Grain size significantly affects the mechanical properties of casting. It is generally consider that fine grained castings give a better combination of strength and toughness, while coarse grained castings have better machinability. It is revealed from the above investigation that the grains in the chilled cast iron, are excellent but the grains are very clumsy in case of chill less sand casting. The excellent dimension of the grains in the freezed cast iron results in the quality of casting and hence results inhuge toughness and strength. In sub-zero and water-cooled chilled cast iron, the experimental results shows that dendrite development is the main cause in find out the toughness and strength. It is a well-known phenomenon that the rate of chilling is inversely proportional to grain size. Accordingly sub-zero water cooled cast iron (highest chilling value) has more number of grains at the chill end and gradually it decreases for unchilled cast iron, where rate of chilling is decreased. There is a straight forward relationship between dendrite arm spacing, particle aspect ratio and grain size. It is observed that there is a direct relationship with chilling rate and location of the specimen. It is observed that the number of grains are more for chilled specimen A and is keep on decreasing followed by specimens B,C,D,E,F,G and H. It is also observed that the grain size number keeps on decreasing from chilled end to riser end.

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Introduction

Hypo-eutectic chilled cast ironpossess high toughness, hardness, strength and resistance against wear. For a metallurgist, there is adequate data available on ordinary sand casting method. In spite of, there is few data available on the method chilled casting solidification of Hypo eutectic cast iron and its outcome onaspect ratio, grain sizeand dendrite arm spacing and the outcome of this on toughness and strength. This encourage the reporter of this paper to emplaneabout a sequence of verification to analyse the affinity among these limitations in the case of sub-zero water cooled with copper , water-cooled with copper , copper , mild steel , cast iron, silicon carbide and graphite end chills specimens.. The inferenceback of the choice of this group of Hypo eutectic cast iron for the current observation is that a high amplitude of fracture toughnessand strength characters can be achieved with different microstructures and cell dimensions [3].

Effect of cooling rate during solidification

Generally in direct casting, rate of cooling is controlled by thermal nature and casting design. Moulds of metals generally offering higher chilling action during solidification due to their thermal conductivity. Therefore higher cooling rate influences excellent properties casting in case of chilled casting. Benefit of chills backing up the rectification of microstructure, altering the thermal gradients and helps in directional solidification. When melt to lower temperature (under cooling) enhances the number of adequate nuclei for solidification in relation to the amount of growth, finally the amount at which heat transfers of crystallization being restricted. Adversely, delay in cooling increases the augmentation from a less nuclei solidification and yields clumsy grain structures. The repercussion of augmented freezing rate applies to the sub structure and fundamental grain size. Thus, there is a excellent effect on aspect ratio, dendrite arm spacing, grain size and microstructure over cooling rates and accordingly on the mechanical characteristics. For hypoeutectic cast iron Copper was considered as an essential element because of its enormous power as a grain cleaner [2].

Past research

The rate of cooling can be altered by using different artificial methods. By using external fins, extract the heat from the mould thus changes the structure. The permanent metal mould process increases rate of production, good surface, environmental cleanliness, gain dimensional stability and better mechanical properties[1].

Hillert M. et al found that quenching and coloration etching technique combination, gives best results to study solidification related problems and primary dendrite growth and eutectic cells in cast iron [4].

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T.J. Baker in his investigation the dendrite arm spacing of materials is a very important micro structural feature that impacts the mechanical properties of cast products. During solidification, increasing the cooling rate refines dendrites. The dendrite arm spacing of materials is the gap between neighboring dendrite arms. Investigation indicates that the tendency of chilling of iron depends upon minimum eutectic temperature for down ward cooling and repercuss the cell numbers stimulate the freezing action. Grater dendritic interrelation range in case of freezed cast iron repercuss the link of dendrites buttoned up eutectic cells that adequately bond the eutectic cells concurrently. Because formation of dendrites originating elementary austenite, they have excellent tensile strength than eutectic carbon. Here, due to freezing, dendrites do not consists flake carbon. Rather than they contain cementite with it the pearlite matrix. Baker [5].

Orlowicz A. W., found that fracture toughness and tensile strength decreases in straight line with increasing eutectic cell size [6].

A. Almansour et al., reveals that the rapid solidification influences formation of pearlite and ferrite by controlling the distribution of the carbon in the matrix [8].

Experimental

Fabrication of material

The composition of alloy of cast iron is shown in Table- 1 and it is casted at 1440°C at 8 different rates of cooling. It is marked by specimen A (sub-zero water cooled with copper chill), specimen B (water-cooled with copper chill), specimen C (copper chill) ,specimen D (mild steel chill), specimen E (cast iron chill), specimen F (silicon carbide chill), specimen G (graphite chill) and specimen H (sand cast with no chill).

Table 1: Composition of cast iron tested

Element	Composition
C	3.07
Si	1.59
Mn	0.44
S	0.168
P	0.010
Cu	1.5
Fe	Balance

Casting procedure

Figure 1 shows diagram of the mould used for making the different lump cast along sub-zero water cooled with copper chill , water-cooled with copper chill, copper chill, mild steel chill , cast iron chill, silicon carbide chill , graphite chill, (Specimen A ,specimen B specimen C, specimen D, specimen E, specimen F and specimen G) respectively. For specimen H, no chill was used to the same type of mould for sand cast. The moulds are prepared by using a pattern of teak wood size 225×150×25 mm, providing with standard allowance of pattern. The moulds are constructed by using silica sand with moisture 5% and bentonite 5% as a binder. After preparing the Mould it is dehumidified by an air furnace at 60°C for 8 hours. After pouring the molten metal in the mould and are cooled starting with one end chill fixed in the mould. In the case of sub-zero water-cooled chilling, water cooled chilling, circulation was created in the copper chill to circulate ice cooled water (at -3°C) and water (at 23°C) respectively. Water circulation and ice cooled water circulation was carry out until the end of pouring.

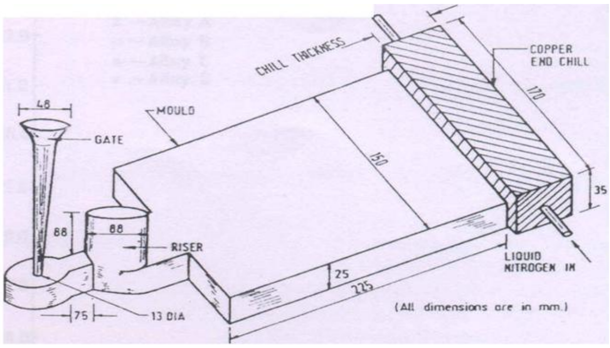

Figure 1: Mould used for casting specimens

Specimen preparation

Specimens for aspect ratio, grain size and dendrite arm spacing were fabricated according to ASTM standards for all the eight various specimens by picking the material from the chilled end. Specimens are also picked besides the length of the casting (chill end to the riser end) to study the variation in the property. Aspect ratio, grain size and dendrite arm spacing specimen dimensions are as shown in Fig. 2.

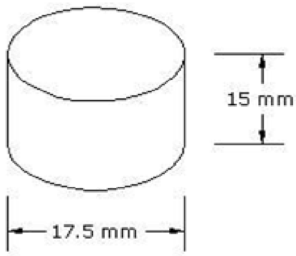

Figure 2: Aspect ratio, grain size and dendrite arm spacing specimen

Aspect ratio

The polished specimen for aspect ratio measurement was set up for all the eight different specimens by considering the material from the chilled end to the riser end, to study the changes in the property. The measurement was done as per ASTM E 1520-99standard.

Grain Size

For grain size measurement "Standard test methods for determining average grain size" method is used according to ASTM standard E112. These methods have been described by [Napolitanio. R. E., http//mse.iastate.edu].

To determine the grain size number (G). Intercept method is used. The shining specimens for grain size measurement are prepared for all the eight various specimens by picking the material from the chilled end to the riser end, to study the variation in the property.

Dendrite Arm Spacing (DAS)

The shining specimens for DAS measurement were fabricate for all the eight various specimens by picking the material from the chilled end to the riser end, to study the modification in the property. The measurement was done by using Metallographic Image Analyzer.

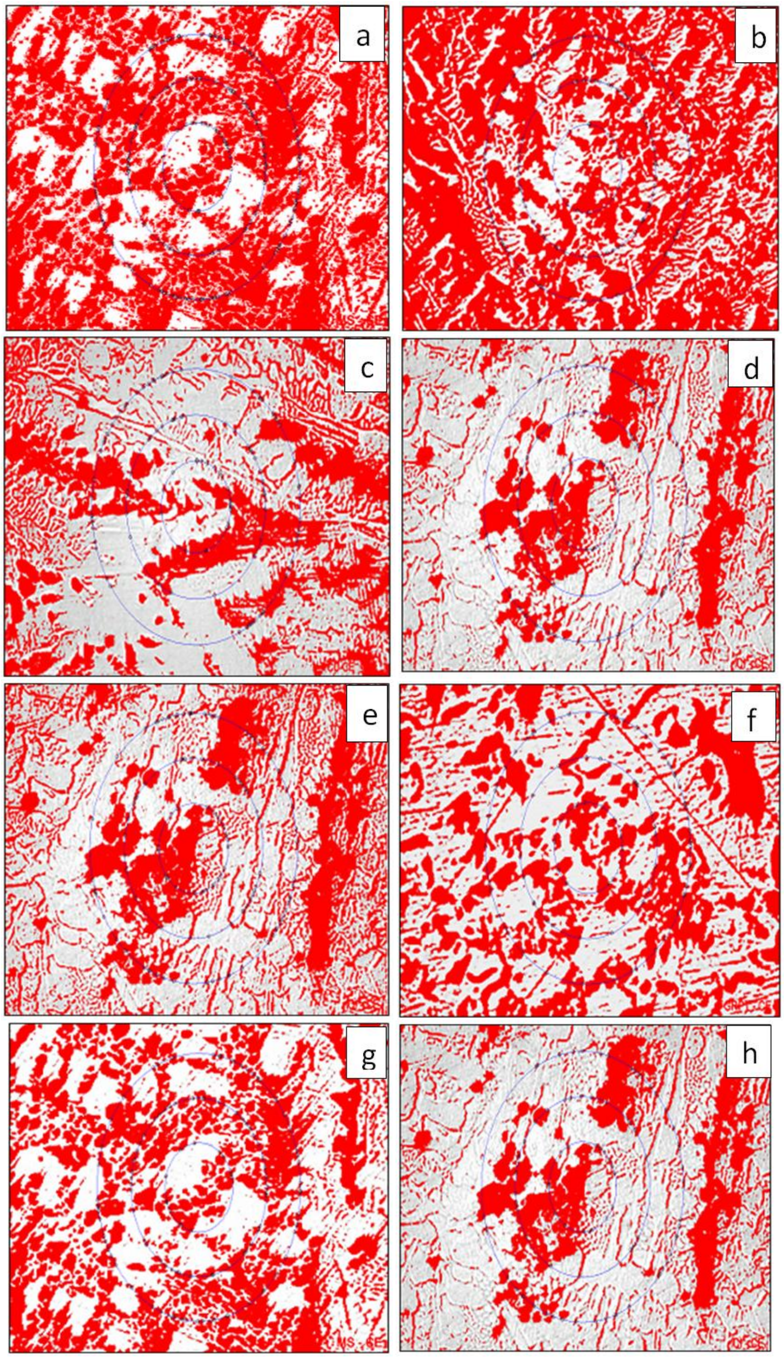

Figure 3: Grain Size number measurement for (a) Sub-Zero water cooled copper chilled specimen, (b) water cooled copper chilled specimen (c) copper chilled specimen, (d) mild steel chilled specimen, (e) cast iron chilled specimen, (f) silicon carbide chilled specimen, (g) graphite chilled specimen, (h) sand cast (without chill) specimen; (30 mm from chill end and at 100X magnification)

Results and Discussion

Close observation of the photomicrographs of Fig.3a-h shows that in case of chilled cast iron results, grains are very excellent but very clumsy in ordinary sand cast method without a chill. Hence chilled cast iron results in very good quality of the casting and results in high toughness and strength. In sub-zero and water-cooled chilled cast iron, from the results, dendrite structure is the main cause in achieving the toughness and strength and but not the structure of graphite. It is a well-known phenomenon that the rate of chilling is inversely proportional to grain size as shown in Fig. 4. Accordingly sub-zero water cooled cast iron (highest chilling value) has

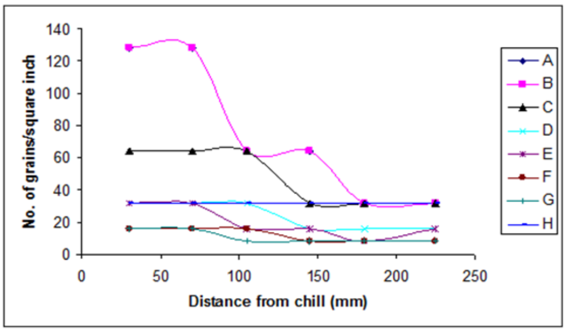

Figure 4: Grain size of various specimens verses the distance from chill

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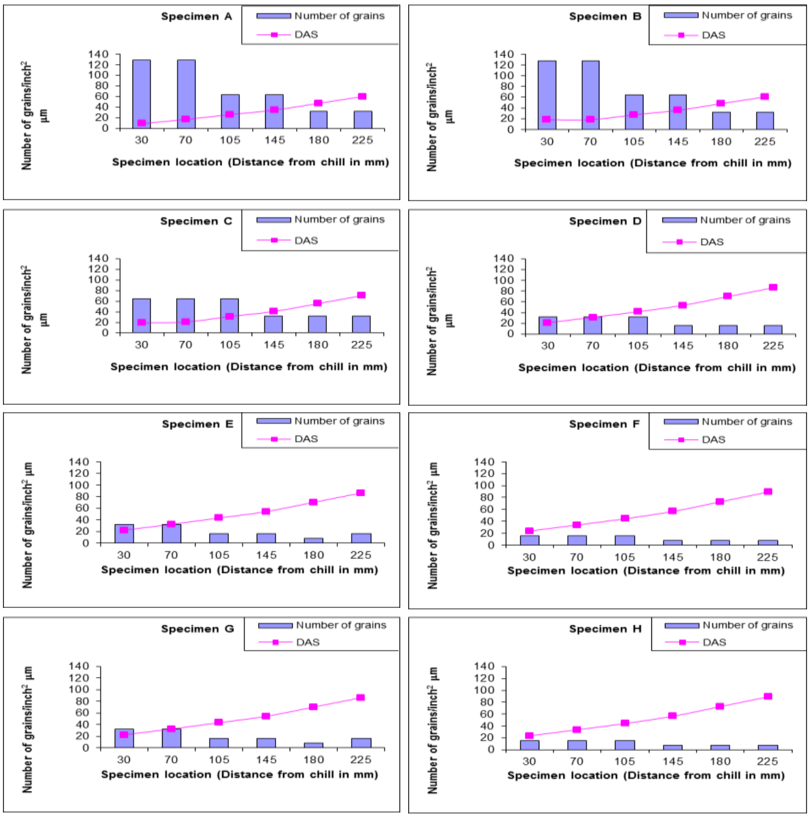

Figure 5: Dendrite arm spacing and Number of grains as a function of the distance from the chill

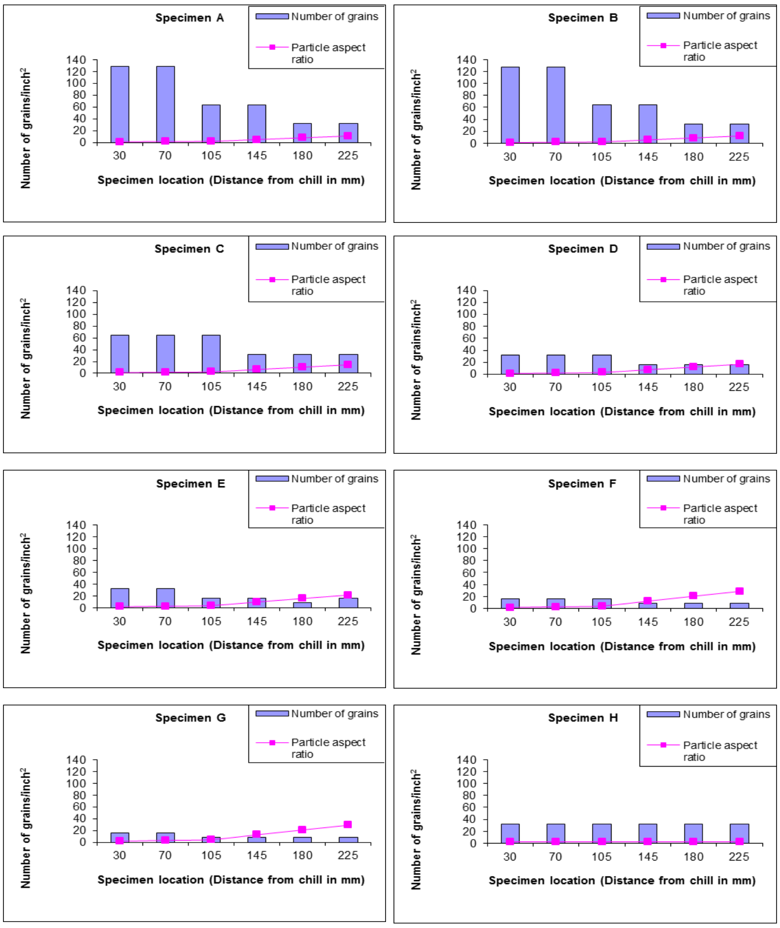

Figure 6: Particle aspect ratio and Number of grains as a function of the distance from the chill

more number of grains at the chill end and gradually it decreases for un chilled cast iron, where rate of chilling is decreased. It is observed from the Fig. 5 and Fig. 6, there is a direct relationship between dendrite arm spacing, particle aspect ratio and grain size. It is seen that there is a direct relationship with the rate of chilling and the spot situation of specimen. It is observed that the number of grains are more for chilled specimen A and is keep on decreasing followed by specimens B,C,D,E,F,G and H. It is also observed that the grain size number keeps on decreasing from chill end to riser end. Aspect ratio and dendrite arm spacing is very less for chilled specimen and it keeps on increasing from specimen A to specimen H. Also observed that the particle aspect ratio and dendrite arm spacing keep on increasing from chilled end to riser end. Particle aspect ratio for various specimens verses distance from chill is shown in Fig. 7.

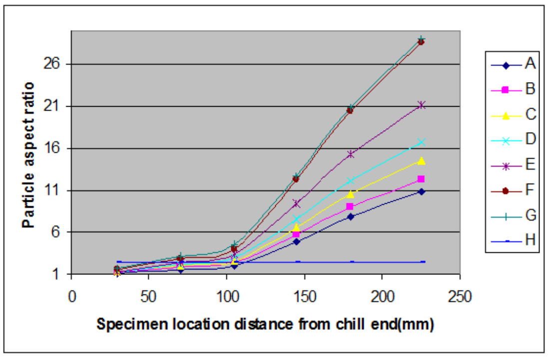

Figure 7: Particle aspect ratio for various specimens verses distance from chill

Dendrite Arm Spacing

Dendrite arm spacing of different chilled cast iron beside the length of the casting are plotted as shown in Fig 8. It is observed that the rapid cooling action produces excellent and highly sensible dendrites, delay in cooling results in huge and clumsy dendrites. The main requirement for dendrite growth is solidification over a thermal range. In case of sub-zero water cooled chilled and water cooled chilled cast iron due to under cooling leads to higher reciprocal action. The eutectic cell solidify across these austenite dendrites and it leads to effect microstructure and the dendrite size and number. The Dendrite Arm Spacing (DAS) reduces as the cooling rate increases as a result there is short time accessible for dispersion of the solute. Accordingly, it is concluded that dispersion dominate the dendrite arm spacing [9].

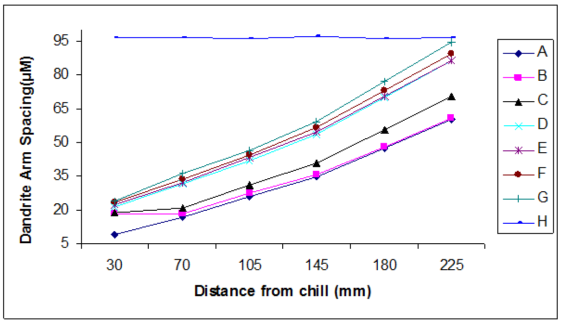

Figure 8: Dendrite Arm Spacing for various specimens along the distance from the chill

Conclusions

Experiments have been performed using the grain size numbers an index of graphite nucleation and the effect of these on properties and structure during solidification. The following conclusions were made.

1. In event of chilled cast iron, the grains are very excellent but the grains are very clumsy in case of ordinary sand cast without chill.
2. The excellent grain size in occurrence of chilled cast iron results in the quality of the casting and thus results in huge toughness and strength.
3. In sub-zero and water-cooled chilled cast iron, shows that dendrite structure is the main cause in finding the toughness and strength but not the structure of graphite.
4. It is observed that, there is a direct relationship between dendrite arm spacing, particle aspect ratio and grain size. It is observed that there is a direct relationship with rate of chilling and the specimen position.
5. Aspect ratio and dendrite arm spacing is very less for chilled specimen and it keeps on increasing from specimen A to specimen H.
6. It is observed that the rapid cooling results fine and supremely aligned dendrites, at the same time delayed in cooling developed large and clumsy dendrites.
7. The Dendrite Arm Spacing (DAS) reduces as the cooling rate increases because there is short time accessible for dispersion of the solute. Hence, it is concluded that DAS is controlled by diffusion.

References

1. J William D. Callister., Material Science and Engineering an Introduction, Fourth Edition, John Wiley and Sons Inc., 1997, New York.
2. Read Hill.B.E, Physical Metallurgy Principles. New Delhi, India, East West Press,1974, pp. 665.
3. Copper G. ,Roebuck A. , Bayati H., Elliott R., The influence of nodule count on the austempering kinetics of a Mn-Cu ductile iron, International journal of cast metals Research,1999,11, 227 – 235.
4. Hillert M., Comments on Eutectic Solidification of Gray Cast iron, Scripta Materialia, 2005, 52, 249-250.
5. Baker T. J. , International Journal of Materials in Engineering Application, 1978, ,1,13-18.
6. Orlowicz A. W., Effect of Rapid Solidification on Sliding Wear of Iron castings, Wear, 2003, 254,154-163.
7. Gogne M., The combined effect of Manganese and chromium on the microstructure of ductile iron castings, AFS Transactions, 1987, 84-83, 387-393.
8. Almansour A., Kazuhiro M., Hatayama T., Yanagisawa O., Simulating Solidification of Spheroidal Graphite Cast iron of Fe-C-Si systems, Materials Transaction JIM, 1995, 36 (12), 1487-1495.
9. Heine R.W., Loper C. R., On Dendrite and Eutectic cell in Gray Cast iron, Trans AFS., 1969, 77, 185.