ABSTRACT

Hypo-eutectic chilled cast iron belongs to a group of metals possessing high strength, hardness, toughness and wear resistance. In general, the cooling rate during casting is largely governed by the design and thermal nature of the casting procedure, one significant factor being the casting condition. Metal moulds generally offer higher chilling action on the solidifying mass due to their heat diffusivity. Therefore, the influence of higher cooling rate is normally responsible for the superior properties of chilled castings. The use of chills firstly favours the refinement of microstructure and secondly, steepens the temperature gradients making solidification directional. The influence of very high cooling rates in producing fine structures offers the possibility of future development of cast irons possessing high strength, high hardness and fracture toughness. The under-cooling of a melt to a lower temperature increases the number of effective nuclei for solidification relative to the growth rate, the latter being restricted by the rate at which the latent heat of crystallization can be dissipated. Conversely, slow cooling favors the growth from a few solidification nuclei and produces coarse grain structures. The refining effect of enhanced cooling rate applies both to the primary grain size and to the substructure, although in the latter case, the effect is on the growth process rather than on nucleation. Thus, there is a marked effect on dendrite, grain size, cell size and microstructure over a wide range of cooling rates and consequently on the mechanical properties. Copper was selected as an important alloying element for the hypoeutectic cast iron in view of its tremendous potential as a grain refiner.

For a metallurgist, there is sufficient information available on the solidification mode and cell size of ordinary cast iron, cast in sand moulds. However, there is a serious lack of information on the mode of solidification of chilled cast iron and its effect on cell size, grain size, microstructure and the effects of these on strength, hardness and wear resistance. This has promoted to embark upon a series of experiments in the present research to study the relationship between these parameters on chilled cast irons that will be developed using different metallic and non metallic chills. The reason behind the selection of this series of chilled cast iron in the present investigation is that, a wide range of mechanical properties can be obtained with different cell size, grain size and microstructures.
Cast iron of the required composition are cast with eight different cooling rates were produced by casting at 1440°C in the form of ingots. They shall henceforth be designated 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 carbonate chill), specimen G (graphite chill) and specimen H (sand cast without any chill). Apart from the usual alloying elements like Si, Mn, S and P, ferro-silicon was added as an inoculants and copper was added to improve machine ability as well as to act as a grain refiner.

The tensile tests were carried out on computerized Universal Testing Machine (UTM) of 2 tonne capacity. The Specimen dimensions were as per ASTM standards and tested along the length of casting. It is observed that, subzero water cooled and water cooled chilled cast iron has the highest strength because of fine grains and formation of cementite in pearlitic matrix. Further it is also observed that the effect of chilling is present only up to a distance of 100 mm from chill end.

Vickers micro hardness tests were performed on all samples of chilled hypoeutectic cast iron along the length of the casting. Polished samples were subjected to micro hardness tests using Shimadzu Micro hardness tester. A load of 100 g for a period of 10 sec was applied on the specimens. Hardness was determined by recording the diagonal lengths of indentation produced. Tests were carried out at five different locations in order to negate the possible effect of indenter resting on the harder particles. The average of all the five readings was taken as hardness of sample. It is observed from that sub zero water cooled copper chilled cast iron posses excellent hardness properties and hence it has minimum wear rate. Where as for water cooled and other chilled cast iron it has decreased monotonically and finally unchilled cast iron has the least value of hardness.

The Grain size measurement was done on polished specimens by using image analyzer software (Dewinter Masterial plus 4.1), as per ASTME 1382-97/E112 Standards, by using circle Intercept method. It is a well known phenomenon that the rate of chilling is inversely
proportional to grain size. Accordingly subzero 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.

Fracture toughness tests were carried out on ASTM standard specimens (with a chevron notch in the middle) all of which were selected along the length of the casting tested using Materials Testing System (MTS). All tests were done in accordance with ASTM 399-1990 test standards. A three-point bend fracture toughness specimen was pre-cracked by fatigue loading and finally fractured by static loading to find its fracture toughness. It is observed that the property continuously decreases from chill end to riser end of the casting. This indicates that the rate of chilling has an effect on fracture toughness.

The friction and wear behaviour of hypo eutectic chilled cast iron along the length of the casting were evaluated using computerized pin-on-disk friction and wear test rig as per ASTM G 95 standards. Tests were carried out for different loads and for constant speed at room temperature for a duration of 20 minutes. It is observed from that percentage wear loss is very minimum up to a load of 20N and it also be observed that increase in load beyond 20N, there is a steep rise in percentage wear loss. This means that chilled casting material exhibit high wear resistance as compared with other castings (without chill).

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The Eutectic cell count measurements were carried out on polished specimens by using image analyzer software (Dewinter Material plus 4.1), as per ASTM Standards, with Nital as the etchant. It is observed that a number of eutectic cells are significantly larger in the chill end and continuously decreased from chill end to riser end of the casting. It indicates that Eutectic cell count directly proportional to the rate of chilling.
The Dendrite arm spacing, pearlite percentage, nodule count and Aspect ratio measurements were carried out on polished specimens by using image analyzer software (Dewinter Material plus 4.1), as per ASTM Standards. It is observed that the dendrite arm spacing reduces as chilling rate increases. It is also observed that, the pearlite content increases as the rate of chilling increases, and also number of nodule count is slightly larger at the chill end and continuously decreased from chill end to riser end of the casting. It is also observed that, aspect ratio decreases as rate of chilling increases.

The following conclusions were finally drawn from the present Research.

1. UTS and Hardness was found to be more in the case of sub zero chilled cast iron followed water cooled, Metallic chilled and Non Metallic chilled cast iron because of the variation in microstructure.

2. Microstructure reveal that there is excessive carbide formation in fine pearlite matrix for sub zero chilled cast iron and carbide content decreases as chilling rate decreases and there by pearlite content becomes coarse.

3. The number of eutectic cells is significantly larger in the case of chilled cast iron than in the case of sand cast iron cast without a chill.

4. It has been established that the number of eutectic cells affects both the structure and properties of the material. Eutectic cell counts were found to be a major factor that affects UTS and fracture toughness. In the cast iron studied, the larger the number of eutectic cells, the greater will be the UTS and fracture toughness.

5. Fracture toughness was found to be maximum in the case of sub zero chilled cast iron, near the chill end due to fine grain formation in pearlitie matrix.

6. Wear resistance was also maximum in the case of sub zero water cooled cast iron because of excessive carbide content due to chilling. Wear resistance of sub-zero water cooled copper chilled cast iron is highly dependent on the chilling rate of the material. Increase in the rate of chilling of the material results in an increase in the hardness as well as the wear resistance of the cast iron. Wear resistance also increases with hardness and tensile strength.