ABSTRACT

Casting is one of the most commonly used manufacturing practices to produce Aluminium alloy components with near perfect shape, which would else be challenging and/or inefficient to make by other methods. The properties and quality of cast products are considered as the best with the formation of well-refined grains, controlled profile of solute segregation and the uniformity of microstructural features. The way in which the casting solidifies defines the quality of the castings produced. The microstructural features of the final cast products are determined to a great extent by the nature of the solidification process itself. Higher solidification rate, due to higher heat transfer between cast and mold, offers the superior strength that is required for components used in majority of engineering applications.

To achieve higher heat transfer rate, metallic molds widely used than sand molds, especially for Al-Si alloy castings. In die casting, the heat transfer through the interfaces between metal-mold and mold-ambient directly influences the solidification rate. While pouring the molten metal into the mold, initially the metal will have good contact with the mold. Consequently, an air gap forms between the metal and mold interface and gets widen, as the cast shrinks and the mold expands. This air gap acts as a thermal barrier and affects the subsequent heat transfer from cast to mold. In a similar fashion, the condition of the interface between the mold and ambient will also affect the overall heat transfer.

The majority of the previous research work assumes uniform heat transfer coefficient at the metal-mold interface and ignore the spatial variation of heat transfer. But in practical conditions of metal castings, the heat transfer is complex due to mold filling transients, varying interfacial conditions with

respect to time and location and the intricate shape of the casting. Hence, the present study was intended to assess the spatial variation of heat transfer at the metal/mold interface during solidification. The multiple interface heat flux components along the vertical length of the casting were computed using Inverse Heat Conduction Problem based solver, and the same was used as a critical parameter for assessing the spatial variation of interfacial heat transfer during solidification.

The primary objective of this research work was to conduct experiments for investigating the effect of different cooling conditions on spatial variation of interface heat flux during the casting of chosen Al-Si alloys in a gravity die casting setup. Attempts were made to coorelate the computed interface heat flux values with the resultant microstructure and mechanical behavior of the Al-Si alloy castings.

To achieve the above objectives, air cooling and water cooling mold setups were designed to acquire the thermal histories of the mold and casting during melt pouring and successive solidification. A series of casting experiments were conducted on two different Al-Si alloys with those two different cooling conditions. The thermal history of different regions of the mold and casting were logged during mold filling and subsequent solidification using computer-interfaced data acquisition card. Measured temperatures were used as input for computing the transient variation of multiple interface heat flux components at the metal-mold and mold-ambient interfaces. Both experimentally measured temperature data and computation results have been used to describe the (i) cooling behaviour of the casting (ii) interface heat flux, (iii) microstructure evolution and (iv) mechanical behaviour as functions of time and location.

The computational results clearly indicate an existence of spatial variation of interfacial heat flux along the vertical direction of the air-cooled

mold during the solidification of both the Al-Si alloys considered for the present study. The magnitude of the interfacial heat flux progressively decreases from the bottom towards the top of the mold. Spatial variation noticed in the microstructure of the air-cooled casting along the vertical length aided by the spatial variation of interface heat flux. Increased cooling rate with water-cooling technique almost eliminated the spatial variation in the interfacial heat flux and microstructure. Further, the results reveal that the magnitude of interface heat flux values of water-cooled casting was to be much greater in all the regions compared to the corresponding regions of air-cooled casting which in turn refined the microstructure and enhanced the mechanical properties of the castings.

***Keywords**:* *Al-Si alloy castings; Cooling rate; Solidification rate; Interfacial heat flux; Spatial variation; Air gap; Air-cooling; Water-cooling; Microstructure; Mechanical behaviour; Wear behaviour.*