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A Review on Gating System in Aluminum Casting for Housing after Cooler Engine Component

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Abstract:
Castings were the most important market aluminum following the commerciliasation of the reduction process firstly the applications of the casting process was limited to the certain applications such as house numbers, hand mirrors ,combs , brushes the cast iron cookware was the best welcomed material which was widely used instead of cast iron. Generally the gating system made of various materials such as wood and metal gate system which need to be considered, while manufacturing any casting it depends on size shape and weight of the application where it is to be utilized and the working conditions it has to resist such as the temperature and the various criteria's such as cooling of the molten metal , minimum defects so to reduce these defects it is important to work from initial working phase so that the rejections must as minimum as possible, sand casting is one of the oldest and largest method used for manufacturing of the casting so that castings are manufactured with lowest possible cost it consists of placing a pattern in the sand mold and producing an imprint in the sand and then a gating system is incorporated for filling the molten metal in the cavity allowing the uniform solidification of the molten metal if the solidification is not uniform the chills may be used in the region where solidification is not uniform for the defect free casting it is essential to have proper design of the gating system, if the gating system design is improper it can lead to rejections leading to heavy losses finally leading to shut down of the unit This review explain thermo mechanical model, heat thermal coefficient, ductile fracture and mechanical properties of aluminum casting.

Key words: *structural properties, chill effects, heat transfer coefficient, aluminium casting, and ductile fracture*

1. Introduction

Aluminum alloys in which aluminum is predominant material the typical alloying elements are copper, magnesium, manganese, silicon and zinc. There are two principal classifications, namely casting alloys and wrought alloys, both of which are further subdivided into the categories heat- treatable and non-heat-treatable. About 85% of aluminum is used for wrought products, for example rolled plate, foils and extrusions. Cast aluminum alloys yield cost-effective products due to the low melting point, although they generally have lower tensile strengths than wrought alloys. The most important cast aluminum alloy system is Al–Si, where the high levels of silicon (4.0–13%) contribute to give good casting characteristics. Aluminum alloys are widely used in engineering structures and components where light weight or corrosion resistance is required. Alloys composed mostly of aluminum have been very important in manufacturing since the introduction of metal skinned aircraft. Aluminum-magnesium alloys are both lighter than other aluminum alloys and much less flammable than alloys that contain a very high percentage of magnesium. Aluminum alloy surfaces will keep their apparent shine in a dry environment due to the formation of a clear, protective layer of aluminum oxide. In a wet environment, galvanic corrosion can occur when an aluminum alloy is placed in electrical contact with other metals with more negative corrosion potentials than aluminum, and an electrolyte is present that allows ion exchange.

The boundary conditions allotted to the metallic alloy casting can have a significant role on the solidification process mainly for manufacturing processes such as die casting, permanent mold casting and casting of thin sections by static or continuous processes, thermal boundary conditions are inherently changing during most widely used casting processes. Several modes of heat transfer occur at the metal mold interface, which are generally represented by a changing heat transfer coefficient. When metal and mold surfaces are brought into contact an imperfect junction is formed. While uniform temperatures gradients can exist in both metal and mold, the junction between the two surfaces creates a temperature drop, which depends upon the properties of the materials, the casting and mold geometry, the roughness of mold contacting surface. The microstructures will be affected by certain thermal parameters, i.e., the growth rate, the thermal gradient and the cooling rate model for the interfacial heat transfer coefficient for an Al casting solidifying against a copper chill, which took into account heat transfer by conduction at the points of interfacial contact and through the interfacial gas. castings can be manufactured by various methods depending on the type of casting to be manufactured also various types of casting manufacturing methods have been developed such as sand casting wax casting, green sand molding.

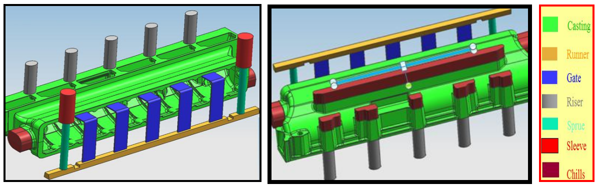

Figure 1: Schematic Representation of gating system

2. Casting Materials

After 19th century aluminum alloys were widely used because of the following properties of the aluminum in the many mechanical as well as other industries and were found most suitable than any other material ever used , the reason behind the popularity of aluminum were-

- Automotive researchers were looking for popular materials, the product forms to differentiate the performance and were worried about the look of the product, and solution was aluminum.
- Electrification demanded not only low density, corrosion resistance, high thermal conductivity wire and cable for which aluminum was best suited
- When the wright brothers' were succeeded in powering the flight engine and other parts with the use of aluminum the close relations were found out to make the use of aluminum widely in automobile applications.

3. Literature Survey

The importance of improved energy efficiency in recent decades reflects the increased gasoline and oil cost to consumer and graduated government mandated fuel efficient standards for automobiles and truck manufacturers environmental concern global competitiveness and raw material concerns, reinforce the incentives to reduce fuel consumption while preserving the product performance and cost objectives. The most effective means of addressing these changes have been substituted to light weight in existing and changing projected automotive designs. The objective has been to facilitate the transition to lighter weight materials and more fuel efficient performance.

The cast aluminum has been used successfully for many decades in power train applications including engine block, piston, transmission cases, and oil pans. In the first wave of light weight material the aluminum was found extensively useful. For maximum impact on fuel efficiency the role of cast aluminum substituted in most of material requiring qualification of new component design, material and production method. These applications include the use of cast iron, nodular iron, malleable iron and steel structures, suspension control arm, brackets, brake valves, rotor, calipers. The commercialization of intense automobile design can result in 20lb less automotive emission, over the life of automobile foe each pound of steel replaced by lower density aluminum with correspondingly significant reduction in fuel consumption. New aluminum intensive automotive construction concept include cast fittings or nodes for extruded assemblies and development of new energy absorbing thin wall cast wall space frames. The most significant barrier to the acceptance to cast aluminum in these and many structural applications has been its reputation for variability. Aluminum casting will play an important role in the future when inevitable electric, hybrid or fuel cell technology.

3.1. A Thermo Mechanical Model

Diego J. Celentano [1] studied the A thermo mechanical-micro structural model for the analysis of aluminum alloy solidification processes is presented. This model is defined in a finite strain thermo plasticity framework considering microstructure-based liquid–solid phase-change effects for the solidifying alloy. Temperatures, displacements and microstructure results predicted by the model are validated with laboratory measurements of a gravity casting in a permanent composite mold. A thermo mechanical-micro structural model for the analysis of aluminum alloy solidification processes has been presented. This model has been defined in a finite

Strain thermo plasticity framework, including microstructure evolution during the liquid-solid phase-change through nucleation and growth laws applied to both dendritic and eutectic formations occurring in the solidifying alloy. Several original aspects of this proposed formulation have been discussed. In particular, the material description of the liquid, mushy and solid phases existing in the solidification and cooling stages of the alloy in a unified formulation, the gap-dependent heat transfer conditions present at the casting-mold interface, the effect of volumetric expansions due to metallurgical transformations, and the possibility to capture large geometric distortions

Especially at high temperatures and the influence of the coupled dendritic eutectic microstructure formation on the temperature-dependent constitutive laws are important features considered in this work. The corresponding finite element model has been also derived and briefly presented. In addition, some strategies to achieve numerical stable and convergent solutions have been proposed. The performance of the proposed model has been evaluated in the analysis of an aluminum alloy gravity casting in a composite permanent mold subject to two different external cooling situations: natural and air-forced boundary conditions. Temperatures, displacements and microstructure results predicted by the model have been satisfactorily validated with available laboratory measurements. Many

Important aspects of this problem have been also discussed in detail. However, there are still many developments to be made in the multidisciplinary field of thermo mechanical-micro structural simulation of solidification processes. In particular, further research may be focused on the material description at high temperatures, the possibility to correlate cooling curves with microstructures and with possible defect formation.

3.2. Chill Material and Size Effects on HTC Evolution in Sand Casting of Aluminum Alloys

Meneghini, L. Tomesani [2] carried out an extensive experimental investigation on the heat transfer coefficient (HTC) during sand casting of aluminum alloy is presented here the variation in time of the HTC in the whole cooling process was reconstructed with many kinds of chills, different in size and material. Cast iron, aluminum and copper were used as chill materials, the HTC between aluminum and sand also being considered. In particular, typical foundry practice regarding melt treatment, sand preparation and chill manufacturing and assembly within the mold is considered throughout the analysis, in order to obtain the most reliable HTC values. The evaluated HTC are then put in relation with cast and chill temperature, in order to allow the easiest transportability to simulation codes for foundry. Relevant points of HTC curves and physical behaviors of the interfaces are also discussed.

An experimental investigation on the HTC during sand casting of A356 alloy was performed, evaluating the effect of chill material and size. It was found that Copper chills have the greater cooling effect, ranging from 4 to 8 kW/m2K depending on the size; aluminum chills range from 3 to 6 kW/m2K, gray cast iron ones range from1 to 2 kW/m2K • Copper chill size has a direct effect on HTC value, while aluminum and cast iron chill showed an inverse correlation between size and HTC. • Copper chills were effective up to temperatures of the casting of 375–400 ◦C; aluminum chills up to 400–420 ◦C; cast iron chills up to 490–530 ◦C. below these temperatures the HTC drops dramatically.

3.3. Comparison of Ductile Fracture Properties of Aluminum Castings Sand Mold Vs. Metal Mold

Paper compares mechanical properties of two types of cast aluminum components made in sand molds and cast iron molds, respectively. For each type of the castings, a total of 12 fracture tests are performed under a wide range of stress states including 6 tensile tests on notched and un-notched round bars and 6 biaxial loading tests on butterfly specimens. Using a combined experimental–numerical approach, the plasticity and fracture properties of the components are characterized in terms of the true stress–strain curve and the ductile fracture locus. It is found that the sand-molding component is of higher yield resistance and lower ductility than the metal-molding one. Meanwhile, the fractographic study reveals that there exist two competing failure mechanisms: the internal necking of the matrix at high positive stress tri-axialities and void sheeting due to shear at negative stress triaxialities. The transition of the failure modes occurs in the intermediate range. This suggests that a ductile fracture locus formulated in the space of the stress triaxiality and the effective fracture strain consist of three branches rather than a monotonic curve. The present paper studies the mechanical properties of the two types of the cast aluminum components using the combined experimental–numerical approach. The castings were made in sand molds and cast iron molds, respectively. A comparison was made to investigate the effect of the solidification rate on the plasticity and ductility.

3.4. Design of Mechanical Properties of Al-Alloys Chill Castings Based on the Metal/Mold Interfacial Heat Transfer Coefficient

Solidification thermal parameters such as the growth rate and the cooling rate depend on the metal/mold heat transfer efficiency, usually characterized by an interfacial heat transfer coefficient, hi, and determine the arrangement of the solidification microstructure, including its morphology and scale. The mechanical properties can be correlated with the micro structural parameters such as the cellular and dendritic spacing's and hence with the instantaneous value of hi. In the present investigation, it is shown that hi varies in time according to an expression of the form hi ¼ atm, where m < 0.5. Directional solidification experiments are carried out, and interrelations of thermal parameters, microstructure and tensile properties are established. Linear relationships between the ultimate tensile strength and hi have been determined for hypoeutectic Ale-Fe and Ale-Sn alloys Cellular and dendritic growth models and experimental growth laws can be used in order to permit correlations between the scale of cellular and primary dendritic arm spacing's and solidification thermal parameters to be established. The mechanical properties Can be correlated with these micro structural spacing's and hence with hi which was shown to vary in time according to an expression of the form hi ¼ atm, where m < 0.5. In the present study, linear relationships between the ultimate tensile strength and hi have been determined for Ale-Fe and Ale-Sn alloys and can be used in the pre-programming of the metal/mold thermal contact of chill castings with a view to permitting a desired level of mechanical properties to be achieved.

3.5. Optimization of Parameters for an Aluminum Melting Furnace Using the Taguchi Approach

To achieve high thermal efficiency, less pollutant emission and high quality products, a study on a regenerative aluminum melting furnace was carried out. The effects of the vertical angle of burner (A), height of burner (B), secondary flue (C), swirl number (D), horizontal angle between burners (E), air preheated temperature (F), natural gas mass flow (G) and air-fuel ratio (H) on the performance of aluminum melting furnaces were investigated. RSD (relative standard deviation) of aluminum temperature (Y1), melting time (Y2) and RSD of furnace temperature (Y3) were designed for evaluation criteria. An orthogonal array was used to arrange CFD experimental plan for above factors. CFD technique, in association with the Taguchi method and cross-table-based analysis of variance were employed for parameter optimization of melting process of the aluminum melting furnace. The optimum condition which may be used to reduce energy consumption and pollutant emission is A2B3C3D3E2F1G3H1. The obtained results were confirmed by statistical analysis method. This paper has presented an application of the parameter design of the CFD-Taguchi combined method in the optimization for melting process of the aluminum melting furnace. The following conclusions can be derived:

- By comparing the results of heat balance test with the numerical simulation for a regenerative aluminum melting furnace, it is showed that the hypothesis of the CFD model is proved to be reasonable. Therefore, the melting features of the aluminum melting furnace may be further studied by the CFD model.
- It is indicated that numerical simulation of the aluminum melting furnace is successful through the confirmation experiment. And the results are accurate and reproducible. The product quality and robustness of process development with the optimal parameter may be improved.

4. Discussion

The main aim of proposed study is to improve the quality of aluminium casting by reducing the defects which are likely to take place due to improper gate and riser design also to improve the overall quality of aluminium casting. The proposed study is to be carried out for standard newly designed gating and riser system for minimum losses.

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