International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 3.45 (SJIF-2015), e-ISSN: 2455-2585
Volume 4, Issue 5, May-2018

PERSPECTIVES OF COOLING SLOPE METHOD FOR SSF TECHNOLOGY

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Abstract— At present, the common techniques existing for large scale creation of semisolid slurry are mechanical stirring, electromagnetic stirring, etc. These suffer from problems like complex design, high cost, structural inhomogeneity and low efficiency. The cooling slope is treated to be a simple but effective method on account of its simple design and easy control of process parameters, low equipment and running costs, high production efficiency and reduced inhomogeneity. With this standpoint, the primary objective of the present research is to describe a cooling slope setup for experimental investigations of slurry and cast billets. In most casting applications, dendritic microstructure morphology is not desired because it leads to poor mechanical properties. Forced convection is one of the means to suppress these dendrites which flow away to form slurry. This slurry, consisting of rosette or globular particles, provides less resistance to flow even at a high solid fraction and can easily fill the die-cavity. The stated principle is the basis of a new manufacturing technology called "semi-solid forming" (SSF), in which metal alloys are cast in the semi-solid state. This method has several advantages over other prevailing commercial casting methods, such as decrease of macrosegregation, decrease of porosity and little forming dynamisms.

Keywords— Semisolid, Slurry, Cooling slope, Method, Casting.

I. INTRODUCTION

The mechanical stirrer is not appropriate mainly on account of unwarranted reaction between the impeller and the corrosive liquid metal, and entrapment of gases during agitation. Similarly, the usage of electromagnetic stirrer for SSF applications has its own drawbacks, because it is generally more energy intensive and technologically complex, leading to higher capital and running costs. Hence, there is a need for a cost effective and simple method of slurry production, and the cooling slope technique introduced in the present research work is most viable method for future commercialization. The cooling slope method of semisolid slurry preparation exhibits many advantages over the other methods.

Its advantages are:

(a) It is simple but effective method of slurry production

(b) There is low equipment and running costs

(c) high production efficiency

(d) reduced inhomogeneity

Considering the above, a systematic description of a cooling slope, taking account of the effects of initial melt superheat, slope angle, slope length, and slope cooling rate, is required. The most important feature of the current research work is a demonstration of the experimental arrangement of metal mould casting experiments using the cooling slope for liquid aluminum alloy, and appropriate instrumentation to realize this procedure. It also demonstrates the process variables influencing the ultimate properties of slurry and the cast semisolid billets.

II. DESCRIPTION OF PHYSICAL PROCESS

As portrayed in the schematic in figure 1, the molten alloy from a tundish with an initial superheat is poured on a cooling slope which is cooled from bottom by counter flowing water. The temperatures of molten alloy at different locations of cooling slope starting from slope inlet to slope exit are measured experimentally with K-type thermocouples mounted at different locations of cooling slope.

As already stated, in the solidification process used in the present study, a cylindrical stainless steel mould is considered for production of a cast billet. The cylindrical stainless steel mould is water cooled and is used to cool the liquid metal by extracting heat from the molten alloy. The top surface of the mould is open to atmosphere while the bottom surface is closed by an adiabatic ceramic plate. In the current study, molten A356 aluminum alloy (which is commonly used for casting applications) is preferred for solidification processing with a cooling slope. The initial temperatures of the alloy are predefined.

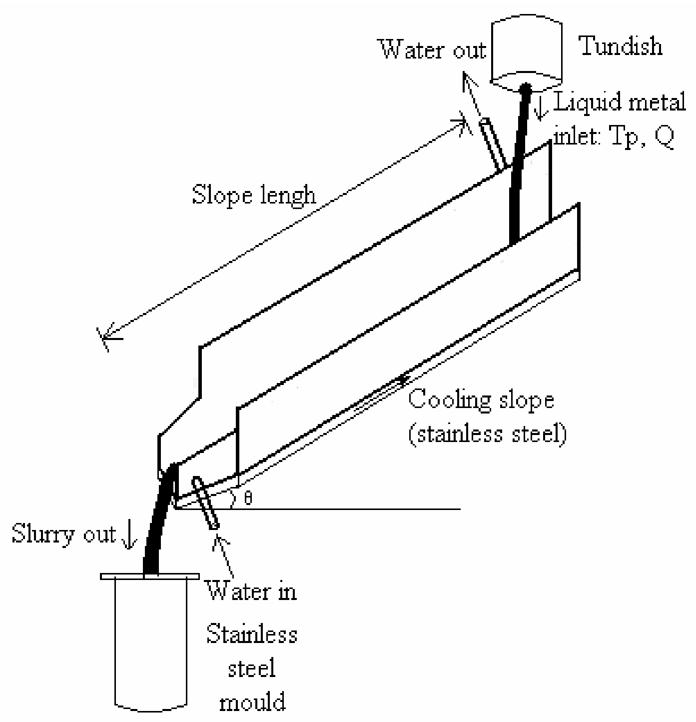

Fig 1. Schematic sketch of cooling slope setup

III. PROCESS PARAMETERS

The establishment of a cooling slope setup in line with the stated method of semisolid production process is derived from the rheological properties of the semisolid slurry which are influenced by fraction of solid, shear rate, and cooling rate throughout the alloy processing. For that reason, the key process parameters in the present practice of semisolid slurry preparation are, initial melt superheat, slope angle, slope length, and slope cooling rate, explained in details as follows.

The enhancement of flow complexity of semisolid slurry during the alloy processing is due to distinct behavior of semisolid slurry viscosity compared to that of pure liquid. The effective viscosity of the semisolid slurry is influenced by numerous process parameters. In actual practice, the slurry viscosity is a function of solid fraction and shear rate apart from other key influencing factors.

A. Melt Superheat

It is well understood that the initial melt superheat during semisolid slurry production is an important factor affecting the microstructure of the final cast products. Pouring temperature will affect the fluidity of the melt which, in turn, will affect the shear rate, exit solid fraction, macrosegregation extent and slurry particle size distribution.

B. Slope Angle

Slope angle directly affects the driving force for the forced convection under gravity. With other parameters remaining constant, higher slope angle will imply faster melt flow (high shear rate) but less residence time for solidification. It will be interesting to see how the final microstructure is affected.

C. Slope Length

Slope length will directly affect the residence time for solidification. For instance, longer slope will imply more solidification and cooler slurry exit. How this would affect the rheological properties and final microstructure would be a subject of study in this work.

D. Slope Cooling Rate

It is observed that slope cooling rate during semisolid slurry production is also a key variable affecting the microstructure morphology of the final cast products. In the current research investigations, the slope is cooled with different cooling heat fluxes (such as relatively lower, moderate, and higher heat fluxes corresponding to relatively lower, moderate, and higher water flow rate underneath the slope, respectively) with the purpose of examining the effect of cooling rate on the final slurry properties and microstructure.

A photograph of the cooling slope setup at an angle of 60° with respect to the horizontal plane is shown in figure 2.

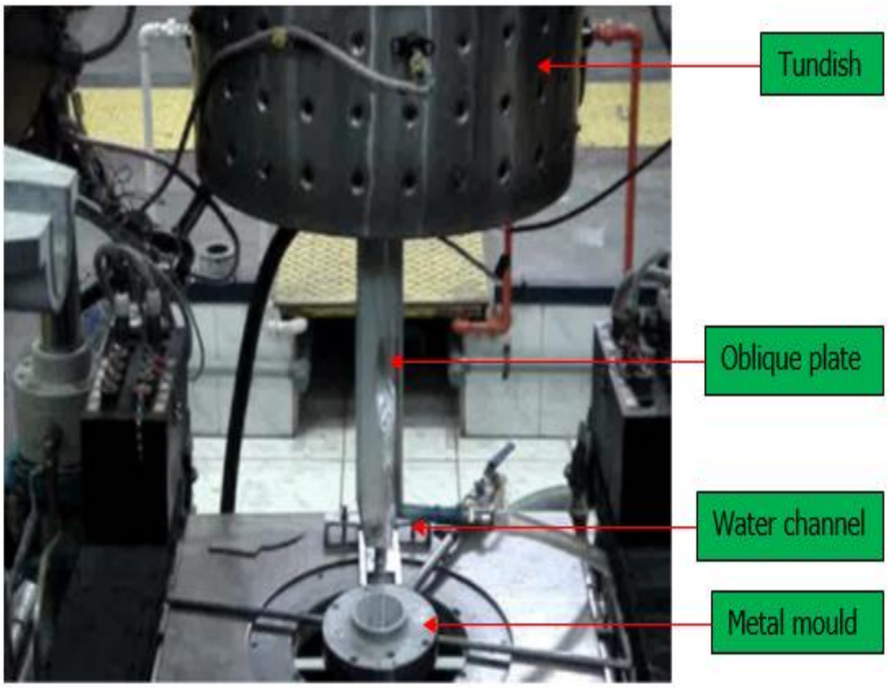

Fig 2. Photograph of cooling slope setup

IV. CONCLUSIONS

A comprehensive and detailed description of a cooling slope for molten alloys leading to the development of suitable cooling slope system is presented, and the various components of cooling slope geometry are illustrated. A simplified analysis of a cooling slope for solidification process based on a counter flow heat exchanger approach of the cooling slope for liquid aluminum alloy and the associated thermal design issues are presented. The experimental cooling slope system also considers the effects of process variables on the final properties of slurry and the cast semisolid billets. In other words, this also includes a description of the schematic of the experimental setup for melt preparation. Overall, the current research work illustrates the experimental setup and practices for metal mould casting experiments deploying the cooling slope for liquid aluminum alloy and suitable instrumentation to gather this technique.

Acknowledgments

The author would like to thank the editor and the reviewers for their kind considerations, valuable time and contributions for extending insightful reviews to the research article.

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