International Journal of Engineering Research
Volume No.5 Issue Special 2, pp: 452-455

ISSN:2319-6890)(online),2347-5013(print)
11-12 Feb. 2016

Numerical Simulation To Determine The Mould Filling Ability Of Aluminum Alloy In Semi Solid Metal Processing

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Abstract : The term fluidity refers to the ability of a material to flow before it solidifies. This is a very significant factor which will determine the filling up of castings with complex and intricate shapes. Mould filling ability is a parameter that is used to determine the fluidity of a material in conventional castings. At semisolid temperatures the metal exists in the form of slurry. Hence fluidity of the material in the freezing range is very important. In the present study numerical simulations are carried out to determine the mould filling ability values and compared with casting fluidity parameter. The process parameters that were used in the simulations include billet temperature, ram speed and preheating of die.

Keywords: Semisolid metal processing, mold filling ability, aluminium alloy, numerical simulation

I. INTRODUCTION

Semisolid metal processing [SSMP] is relatively a new technology for production of near net shaped components[1]. This process is carried out at a temperature range between its liquids and solidus temperature. At thixo-temperatures, the metal exists as a mixture of solid and liquid phases in the slurry form.

Thixotropy is a time-dependent shear thinning property where the metal is thick at static conditions but will flow when subjected to shear stress. The simulation of the process was carried out using finite element application software. Some of the materials which are suitable for carrying out the SSMP process are alloys of aluminum, copper and magnesium. The typical components produced commercially include engine suspension mounts, air manifold sensor harness, engine blocks and oil pump filter housing using alloys of aluminum like A356, A357, A390 and Al 6061[2]. Because of the commercially available alloys of aluminum at low prices and their extensive usage in the automobile industry it is appropriate to study the parameters that influence the quality of casting.

This process is also known as thixoforming or thixocasting depending on the initial condition of the billet and process adopted. The process combines a number of advantages of casting and forging. Compared to casting from the liquid state SSMP provides a more stable filling front, places lower thermal loads on the metal dies and less shrinkage. Compared to forging it permits the filling of more complicated shapes and thinner sections.

SSMP allows production of porosity free components having excellent mechanical performance. The SSMP process allows producing parts with tight tolerances and low shrinkage rates. Typical solid fraction suitable for this process is about 35 percent. Modeling of the thixoforming process has been attempted earlier for aluminum alloys [3]

Fluidity

The term fluidity is normally used in foundry to designate the casting materials ability to fill the mould cavity. There are a number of properties that affect the fluidity parameter [4]. Numerical simulations were carried out on aluminum alloy to determine the fluidity in aluminum alloy [5]. Semisolid metallic slurries undergo a structural change wherein spheroidal particles replace primary dendrites under vigorous stirring [6]. Semisolid metallic slurries have higher viscosities than fully liquid melts which results in laminar filling of die cavity rendering higher integrity of semisolid cast components. Gravity casting of lower fluidity slurries is highly difficult. High pressure die casting has been successfully used wherein mechanical force is exerted to push such viscous slurries along the running system and into the die cavity. Because of high cost of manufacturing of dies mass production is more economical. The properties of casting materials which affect the fluidity to a great extent are viscosity and heat content of the melt, freezing range, specific weight and surface tension of the liquid metal [7]. The lower the coefficient of viscosity of molten metal, the higher would be the fluidity. In general, the alloys, which have a narrow freezing range, have a higher fluidity compared to the wide freezing range ones. The mould properties that affect the fluidity are thermal characteristics, permeability and the mould cavity surface.

Mould Filling Ability

Mould filling ability is influencing considerably the heat transfer and solidification of the metal. Mould filling is a critical parameter in the production of quality castings, especially in the case of complex shaped castings where section thickness varies considerably [8]. The die used for

ISSN:2319-6890)(online),2347-5013(print)
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the present study was modeled based on Engler and Ellerbrok design [9].

II. METHODOLOGY ADOPTED FOR CALCULATING MOULD FILLING ABILITY

The hot metal poured into the die fills the curved cavity between the two cylindrical cores having a line contact at the center, but solidifies before filling up the complete casting. The inverse of the diameter of curvature of the edge tip of the fin gives the value of the mould filling ability. The diameter at the tip of the fin gives the meniscus diameter of the liquid metal at the time of solidification as represented in the fig 1. It is difficult to measure the diameter of the tip of the edge and hence an indirect way of calculation has been used.

From Figure 1

$R^2 + (r+x)^2 = (r+R)^2$ ……………………Equation (1)

By solving Equation (1) we get,

$1 / 2r = (R-x) / x^2$ (since $2r = d$)

So, $1 / d = (R-x) / x^2$ ………………… Equation (2)

Where R = Radius of the sand core in mm,

r = Radius of the meniscus (2r = d) in mm,

2x = Distance between edges in mm,

1 / d = Mould filling ability, 1 / mm or mm^{-1}

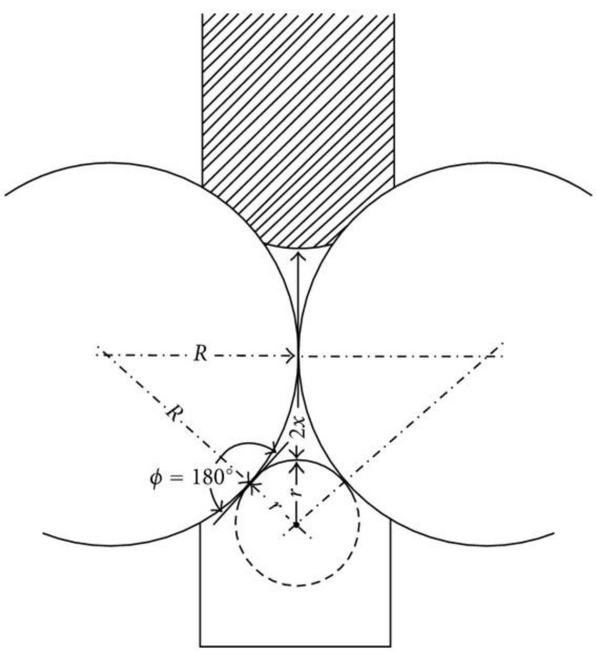


Fig 1 Measurement of mould filling ability

methodology are to be validated with values obtained from casting fluidity [10] another measure for determining the fluidity. Casting fluidity is defined as the distance to which the metal can flow in a given test mold before solidification. Simulation of die filling for calculating mould filling ability using both methods is explained in the following section.

III NUMERICAL SIMULATION

The mould filling ability during casting was investigated for A356 alloy by carrying out the following simulations. The simulations were carried and the fluidity parameter was found out using both methods.

Using the first methodology simulations were carried out for billet temperatures of 580^0C and 600^0C. The top die speeds of 10mm/s, 15mm/s and 20mm/s were considered. The die was preheated to temperature of 250^oC for two runs and one run at room temperature. The size of the billet was taken as 91 X 32 X 45 mm. The above considered process parameters, billet size and positioning of billet on the die was arrived at after conducting several trial runs based on the shape of the final component and under fill at the end of simulation.

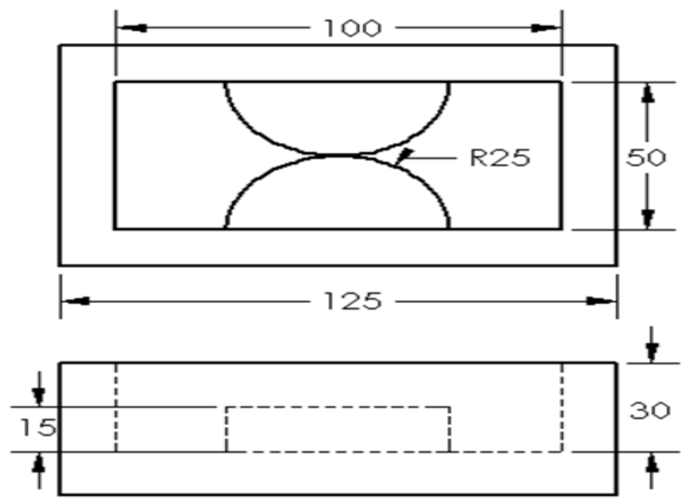


Fig 2a Schematic representation of die used for measuring the measuring the mold filling ability value

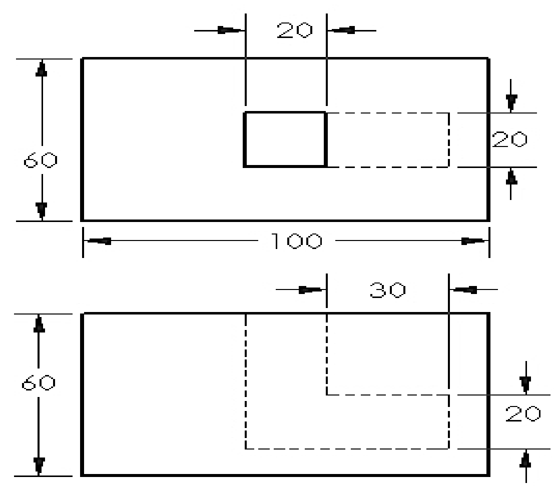


Fig 2b Schematic representation of die used for casting fluidity value

doi : 10.17950/ijer/v5i2/036

IV RESULTS AND DISCUSSIONS

The mould filling ability value was calculated using equation 2.

Mold filling ability, $1 / d = (R-x) / x^2$

The average distance 2x between the edges was measured and mold filling ability values for the three simulations at different process conditions were computed and given at table 1. Similarly simulations were conducted for determining the casting fluidity for similar process conditions as in first case. Figures 3a and 3b show the deformed billet at the end of simulation using the two methodologies. The results are also tabulated in Table 1. Figure 4 represents the comparison graph between the two approaches

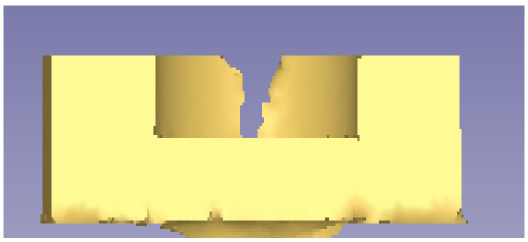


Fig 3a Deformation of billet at the end of simulation when measuring the mold filling ability value

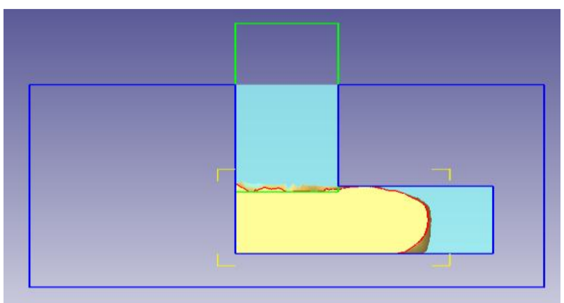
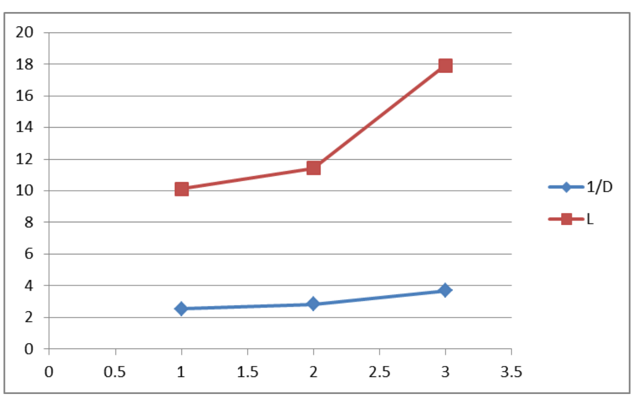


Fig 3b Deformation of billet at the end of simulation when measuring the



casting fluidity value

Figure 4 Comparison of Mould Filling Ability 1/D vs. Casting fluidity

Table 1 Mold Filling Ability and Casting Fluidity values for different process conditions

RUN NO	TEMP OF BILLET	RAM SPEED	DIE TEMP	AVERAGE VALUE OF X	MOLD FILLING ABILITY 1/D (1/MM)	CASTING FLUIDITY L (MM)
1	600	10	250	2.94	2.55	10.12
2	580	20	30	2.80	2.84	11.43
3	580	15	250	2.47	3.69	17.9

V. CONCLUSIONS

Fluidity is an important parameter that determines the quality of components in forming operations. It is observed from the results that for run 3, the process conditions favored a higher mold filling ability value of 3.69 mm^{-1} than at other runs. It is also observed from the results that for run3 the length of casting fluidity has a value of 17.9mm which is the maximum. The results are in conformity and validating the methodology adopted to measure the fluidity parameter. However these results are to be confirmed experimentally.

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