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On the Analysis of Molten Metal Flow through Sprue in Casting Process

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Abstract

In many cases it controls the flow of molten metal into the mould. In sand mould casting the passage through which the molten metal, from the pouring basin, reaches the mould cavity is known as sprue. To investigate the Flow pattern of molten metal (Al-Si alloy) at 704 ^{0}C in sprue for different shapes (tapered and straight) and optimum shape will be obtained with the help of CFD simulation, and, velocity contours, pressure contours and velocity vectors have been obtained for different Reynolds No.

For designing of modelling and meshing of sprue geometry GAMBIT version 6.3.16 has been and for flow analysis FLUENT version 6.2.26 has been used.

Keywords: sand casting, sprue, aspiration effect, FLUENT Version

I. INTRODUCTION

Casting means pouring molten metal into a mould with a cavity of the shape to be made, and allowing it to solidify. When solidified, the desired metal object is taken out from the mould either by breaking the mould or taking the mould apart. The solidified object is called the casting. By this process, intricate parts can be given strength and rigidity frequently not obtainable by any other manufacturing process.

The mould, into which the metal is poured, is made of some heat resisting material. Sand is most often used as it resists the high temperature of the molten metal. Permanent moulds of metal can also be used to cast products.

The assembly of channels which facilitates the molten metal to enter into the mould cavity is called the gating system (Figure1). Alternatively, the gating system refers to all passage ways through which molten metal passes to enter into the mould cavity. The nomenclature of gating system depends upon the function of different channels which they perform.

- Down gates or sprue
- Cross gates or runners
- Ingates or gates

The metal flows down from the pouring basin or pouring cup into the down gate or sprue and passes through the cross gate or channels and ingates before entering into the mould cavity.

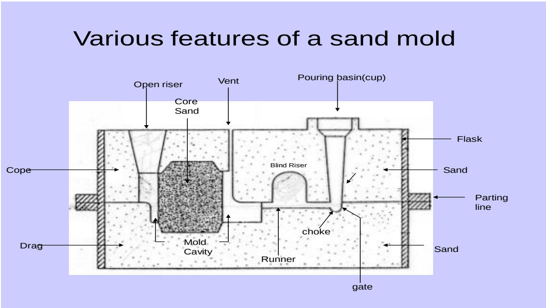

Fig. 1 Mould Section showing some casting terms

II. PRINCIPLES OF HDRAULIC USED IN THE GATING SYSTEM

1) Reynold's Number

Nature of flow in the gating system can be established by calculating Reynold's number

$$Re = \frac{\rho V D}{\mu} \quad \text{.......................(1)}$$

Re = Reynold's number
V = Mean Velocity of flow
D = diameter of tubular flow
μ = Kinematics Viscosity = Dynamic viscosity / Density
ρ= Fluid density

When the Reynold's number is less than 2000 stream line flow results and when the number is more than 2000 turbulent flow prevails. As far as possible the turbulent flow must be avoided in the sand mold as because of the turbulence sand particles gets dislodged from the mold or the gating system and may enter into the mould cavity leading to the production of defective casting. Excess turbulence causes

- Inclusion of dross or slag
- Air aspiration into the mold
- Erosion of the mold walls

2) Sprue design (Alloy)

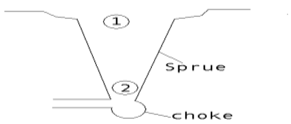

Fig. 2 Tapered sprue

The design of the downsprue is crucial in order to avoid initiation of turbulent flow in the rigging system. Turbulent metal flow might cause an increased area to be exposed to air, and thus an increased oxidation of the metal. Those oxides may rise to the top of the casting to form a rough surface for the casting, or they may be trapped in the casting and create imperfections. Turbulent flow may also cause erosion of the sand mold.

III. LITERATURE REVIEW

Standard sizes and shapes of sprues :

Swift et al. [2] suggest that an ideally tapered sprue of length 10 in.

Sprues should be tapered by approximately 5% minimum to avoid aspiration of the air and free fall of the metal. (25.4 cm) and exit area 1.90 cm^2 should have an entry area of 5.16 cm^2 at the bottom of the sprue basin and 23.01 cm^2 at the top of the sprue. If the sprue length is 15.24 cm, the entry area for the bottom of the sprue basin and the top of the sprue must be 4.52 and 18.4 cm^2, respectively. The profiles for the sprues suggested by Swift et al.[1] are not linear.

Hill et al [4] suggested well area for the sprue box is two to three times the area of the sprue exit.

Swift et al [2] studied rectangular and round-shaped sprues with cross-sectional areas ranging from 1.27 to 3.81 cm^2. Generally, rectangular sprues are used to avoid vortex problems. However, round sprues with small height and radius do not cause vortex problems, are easier to make and, thus, are more economical for small castings.

Extreme sizes for sprue should be 1/2x3/16 in. (1.27x0.48 cm) for "small castings" and 1x4 in. (2.54x10.16 cm) for "large thin panels.'' [1]

Sprues can be tapered slightly more than required to provide a factor of safety for aspiration of air.[2].

IV. OPTIMIZATION OF MOLTEN METAL FLOW THROUGH SPRUE IN CASTING PROCESS

There are several commercial CFD codes such as CFX, FLOWTRAN, FLUENT, STAR CD, PHOENICS etc. which are available for analyzing the complex flows. But in the present investigation the commercial CFD code "FLUENT" version 6.2.16, based on the cell centered finite volume technique is used to investigate the molten metal flow through sprue. Since Navier-Stokes equations are elliptic and nonlinear, it is necessary to resort to numerical solution of the equations. This has been achieved by breaking the flow domain into large number of the small unit say cells, discretizing the equation in these cells to give a set of algebraic equations rather than partial and ordinary differential equations set and solving them which involves inverting the large matrix. For the turbulent flows, this case becomes worst as the significant increase in number of variables occurs due to presence of the turbulence fluctuating quantities.

This section explains the modeling of molten metal flow through sprue using FLUENT package version "FLUENT 6.2.26", it also explains the run conditions and boundary conditions that were adopted during the modeling process.

Properties of Fluid (molten metal) used in the analysis:

For present work, Al-Si alloy at 704^0 C is used as the fluid

Density of fluid (ρ) = 2700 kg/m^3

Dynamic viscosity of water (μ) = 0.00273kg/m-sec.

A. Analysis of molten metal flow through straight sprue

1) Sprue dimensions for straight sprue

Length of sprue=20cm

Top height of sprue=10cm

Sprue diameter=3cm

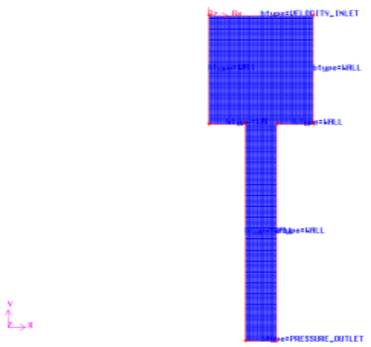

Fig.3 Meshed geometry of straight sprue in GAMBIT

2) Grid Size information

Level	Cells	Faces	Nodes	Partitions
0	16000	32400	16401	1

Case-1

Inlet velocity, V=0.1 m/s

Operating pressure = 1 atm

At V=0.1 m/s, ρ = 2700 kg/m^3 and μ = 0.00273kg/m-sec.
Calculating from equation (1)
Re=9890 (turbulent)

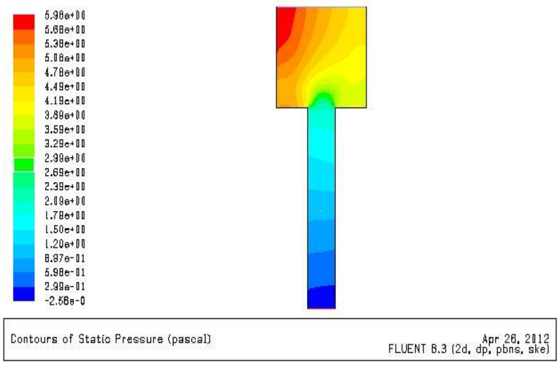

Fig. 4. Contours of static pressure at Inlet velocity, V=0.1 m/s

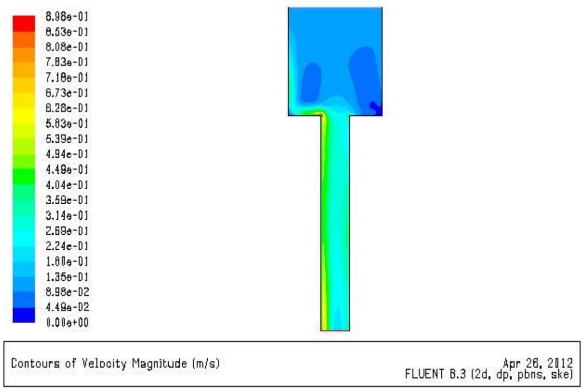

Fig. 5 Contours of velocity at Inlet velocity, V=0.1 m/s

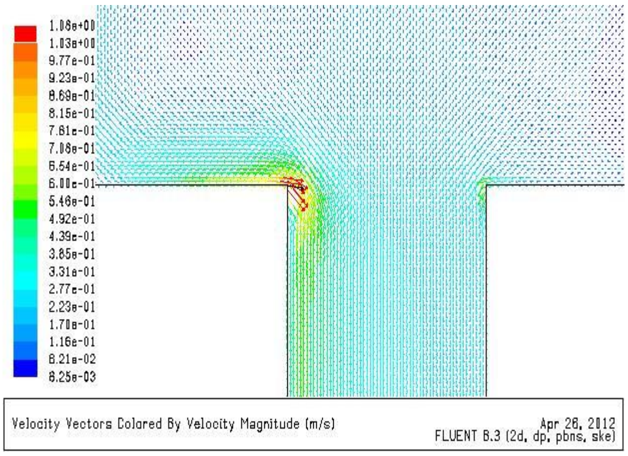

Fig. 6.Velocity vectors near sprue entrance at Inlet velocity, V=0.1 m/s

Case-2

Inlet velocity, V=2 m/s

Operating pressure = 1 atm

At V=2 m/s, ρ = 2700 kg/m^3 and μ = 0.00273kg/m-sec.
Calculating from equation (1)
Re=197802 (highly turbulent)

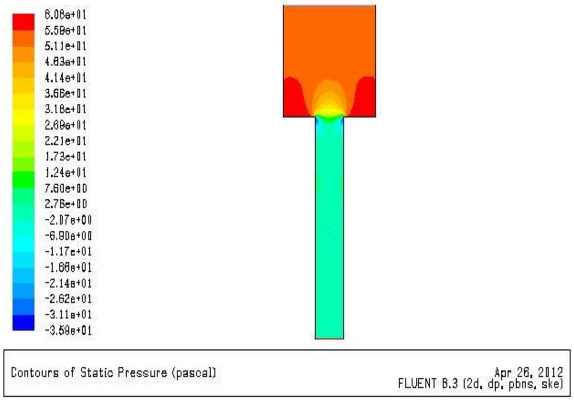

Fig.7. Contours of static pressure at Inlet velocity, V=2 m/s

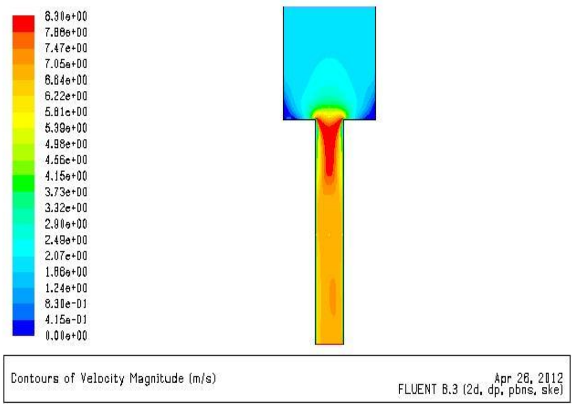

Fig. 8 Contours of velocity at Inlet velocity, V=2 m/s

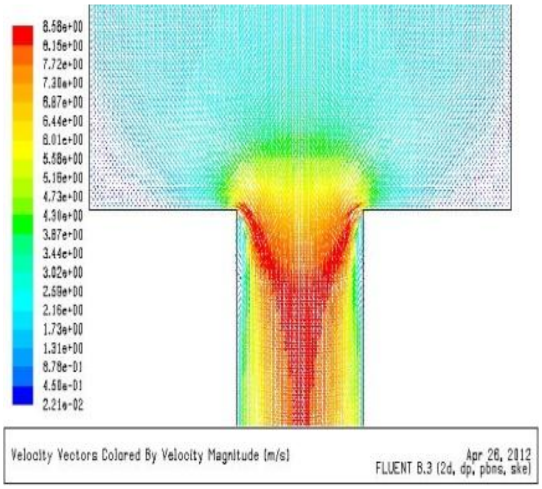

Fig. 9 velocity vectors near sprue entrance at Inlet velocity, V=2 m/s

B. *Analysis of molten metal flow through Tapered sprue*

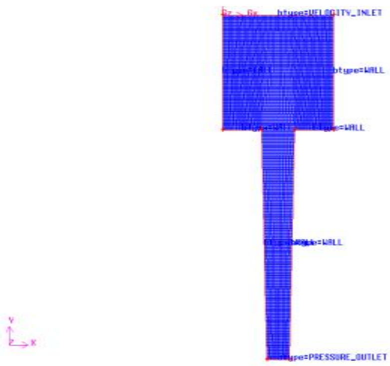

Fig.10 Meshed geometry of tapered sprue in GAMBIT

1) *Sprue dimensions for tapered sprue*

Length of sprue=20cm
Top height of sprue=10cm
Sprue diameter at top=3cm
Sprue diameter at bottom=2.5cm

2) *Grid Size information*

Level	Cells	Faces	Nodes	Partitions
0	14400	29200	14801	1

Case-1

Inlet velocity, V=0.1 m/s

Operating pressure = 1 atm

At V=0.1 m/s, ρ = 2700 kg/m^3 and μ = 0.00273kg/m-sec.
Calculating from equation (1)
Re=9890 (turbulent)

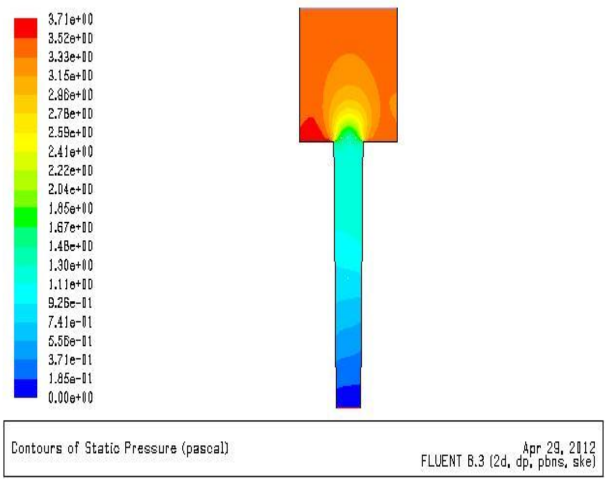

Fig. 11 Contours of static pressure at Inlet velocity, V=0.1 m/s

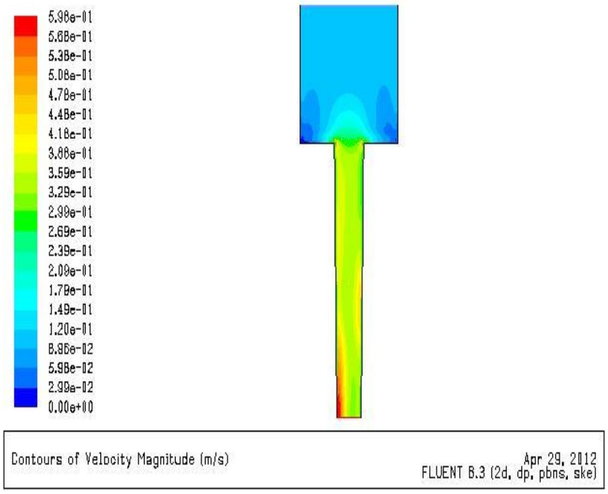

Fig. 12 Contours of velocity at Inlet velocity, V=0.1 m/s

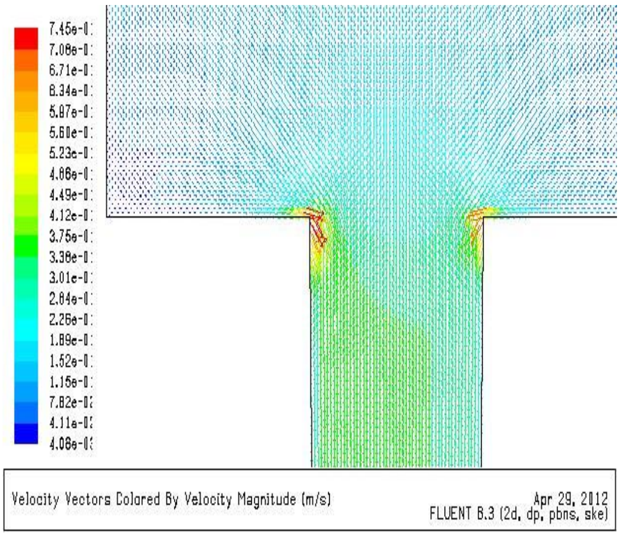

Fig. 13 velocity vectors near sprue entrance at Inlet velocity, V=0.1 m/s

Case-2

Inlet velocity, V=2 m/s

Operating pressure = 1 atm

At V=2 m/s, ρ = 2700 kg/m^3 and μ = 0.00273kg/m-sec.
Calculating from equation (1)
Re=197802 (highly turbulent)

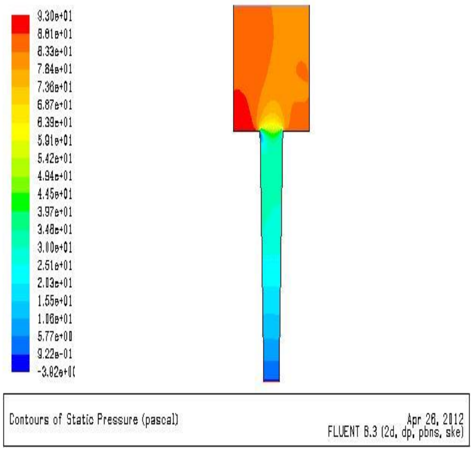

Fig. 14 Contours of static pressure at Inlet velocity, V=2 m/s

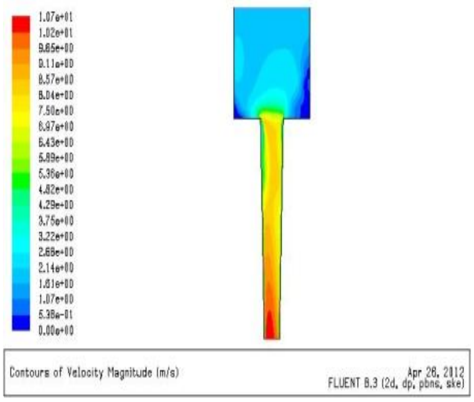

Fig. 15 Contours of velocity at Inlet velocity, V=2m/s

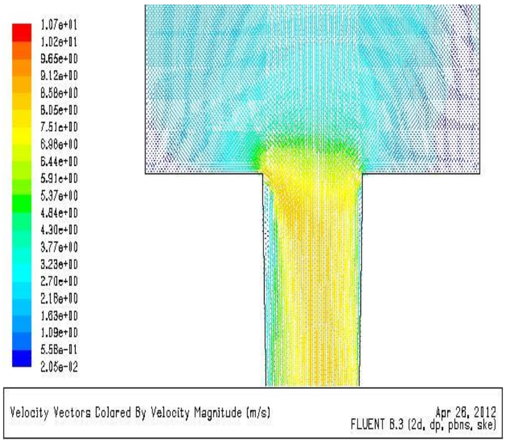

Fig. 16 velocity vectors near sprue entrance at Inlet velocity, V=2m/s.

V. RESULTS/DISCUSSIONS/ CONCLUSIONS

From the above analysis following conclusions can be made:

1. For straight sprue (when no taper is provided), from fig. 4 for V=0.1 m/s, pressure contours show that pressure is negative at the entrance of sprue and along the length of sprue, and this negative pressure may create aspiration effect, which, in turn, produces casting defects, and, same is the case when inlet velocity is 2 m/s fig. 7
2. When sprue is tapered by 2.5 cm at the bottom, and flow has been simulated, the pressure contours fig.11 show, that no negative pressure is created at the entrance of sprue, negative pressure is created only at the exit of sprue (bottom of the sprue), and, same is the case when inlet velocity is 2 m/s.

On the basis of above CFD results we can say that tapering on sprue is necessary to avoid aspiration effect or to avoid casting defects due to negative pressure inside sprue.

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