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INVESTIGATION OF EFFECT OF SPRUE PROFILE ON AIR ASPIRATION EFFECT

Engineering

KEYWORDS: air aspiration effect, sprue design, modelling.

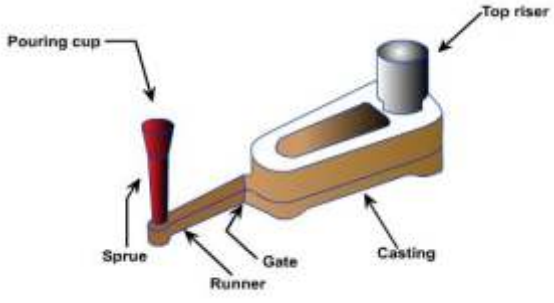
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ABSTRACT

Numerous products are manufactured using casting process as it offer advantages of being economical and since molten material can flow into very small sections, intricate shapes can be made with ease. One can optimize the virtual castings using casting software's so that defect free real castings can be guaranteed every time during product cycle. A good gating design should ensure proper distribution of molten metal without excessive temperature loss, turbulence and gas entrapping. Pressure in the liquid metal stream should be maintained above atmospheric, failing which results in porous castings, called air aspiration effect. Air aspiration along with several other defects may result in a damaged product. Therefore analysis and simulations were done on different sprue profiles to enhance the quality of the final casting. In this paper, after creating different geometries, FLUENT has been used for further analysis.

INTRODUCTION

By exercising good control on pattern, method of moulding, composition of the metal and melting procedure, it is possible to produce sound casting. However, sound castings could not be produced if the design of gating system is poor. One of the most important components of a gating system is sprue. Sprue is a vertical passage that passes through the cope and molten metal from the pouring basin reaches the mould cavity through the sprue as shown in Fig. 1. In a straight sprue, when liquid metal is poured, the cross sectional area of the flowing stream at sprue base will be less than that at the top of the sprue. Thus, velocity of flow increases and low pressure area would be created around the metal flow in the sprue. Consequently, air will be aspirated from the surrounding mould which results in porous castings and this is known as air aspiration effect. A tapered sprue confirming to the dimensions of the descending stream would result in producing casting that will be free from air aspiration effect. [1] provided a systematic methodology to optimize the gating system design for maximizing filling rate of molten metal in sand casting using SQP optimization algorithm. [2] studied the flow pattern of molten metal (Al-Si alloy) at 704°C in sprue for different shapes (tapered and straight) and optimum shape was obtained with the help of CFD simulation. This paper focuses on studying the effect of tapering the walls of the sprue on air aspiration effect and it was found after simulation results that on tapering the walls of the sprue by approximately 1.5 degrees on either side of the horizontal, the effect of air aspiration was significantly reduced.



COMPUTATIONAL MODELLING

The basic governing equations used for modeling a steady-state, incompressible flow is:

Bernoulli's Equation: This equation represents that total energy or total head of a flowing fluid remains constant under ideal conditions.

$$p/\rho g + V^2/2g + z = \text{constant}$$

Continuity Equation: This equation is based on principle of mass conservation as

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

After geometrical modelling and meshing of sprue geometry, flow analysis has been done using FLUENT. The input variables considered in the analysis are dimensions of sprue and pouring basin as listed in Table 1. Velocity and pressure gradient within the sprue are considered as constraints for the design problem.

Table 1: Important dimensions of different sprue profiles

Sprue Profile	Straight	Tapered1	Tapered2
Diameter of the pouring basin(cm)	11	11	11
Length of pouring basin(cm)	10	10	10
Inlet diameter of sprue(cm)	3	3	4
Outlet diameter of sprue(cm)	3	4	3
Length of sprue(cm)	20	20	20

Table 2 list the properties of molten metal used in the analysis.

Table 2 : Material properties of molten metal

Molten metal	Density, ρ	Dynamic viscosity of fluid, μ
Cu alloy	7.5 g/cc	3.1 mPa.s

Sprue geometries have been subjected to two different combinations of inlet velocity and operating pressure as listed in Table 3.

Table 3

	Inlet Velocity(m/s)	Operating Pressure(bar)
Set1	2	1
Set 2	0.2	1

The straight profile geometry is shown in Figure 2 and variation of static pressure (in Pascal) and velocity (in m/s) along the length of sprue for straight profile under conditions of Set1 and Set2 is shown in Figure 3 to Figure 6. Different shades of colors show different magnitude of pressure and velocity at that cell of mesh.

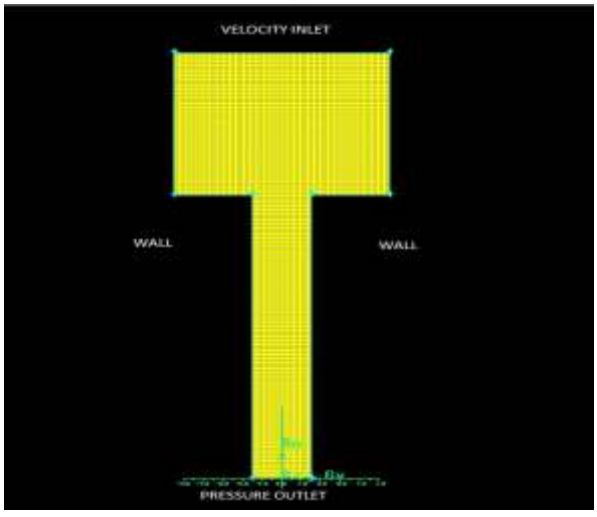


Figure 2:Straight sprue profile

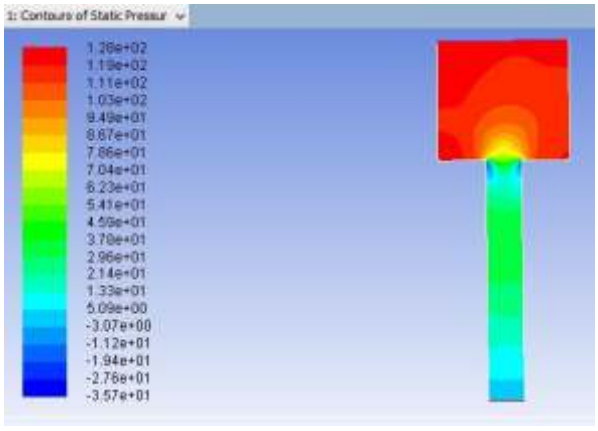


Figure 3: Variation of static pressure under Set1

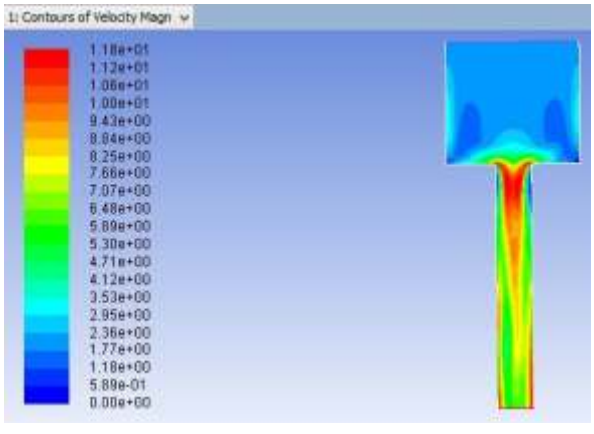


Figure 4: Variation of velocity magnitude under Set 1

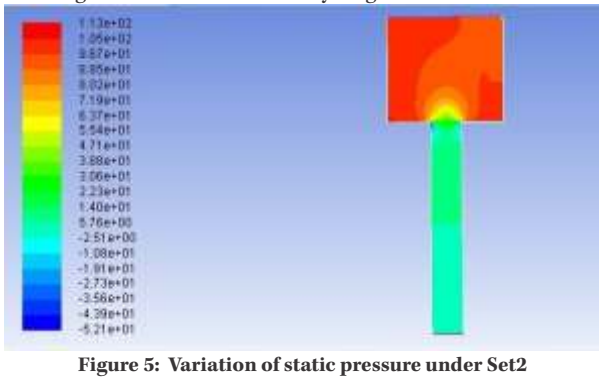


Figure 5: Variation of static pressure under Set2

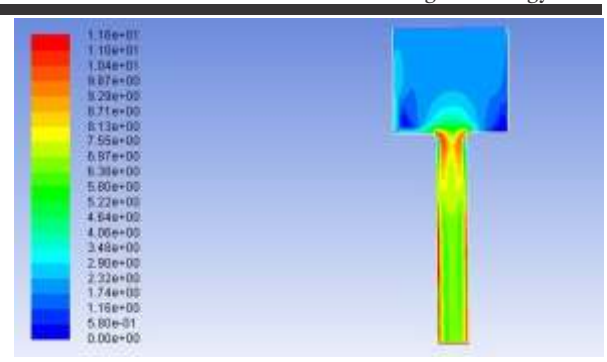


Figure 6: Variation of velocity magnitude under Set 2

The tapered sprue profile 1 geometry is shown in Figure 7 and the variation of static pressure (in Pascal) and velocity (in m/s) along the length of sprue for Tapered sprue profile 1under conditions of Set 1 and Set 2 is shown in Figure 8 to Figure 11.

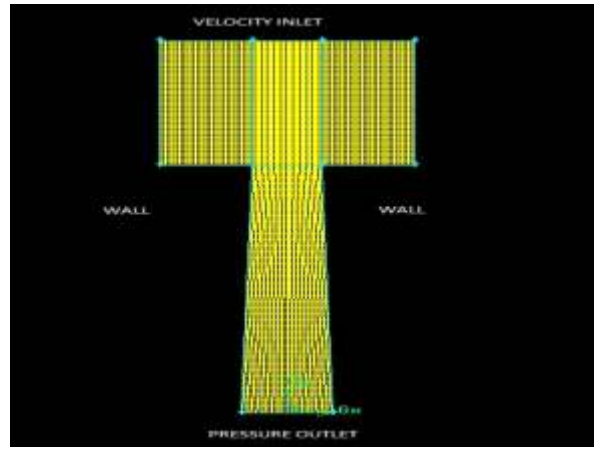


Figure 7: Tapered Sprue 1

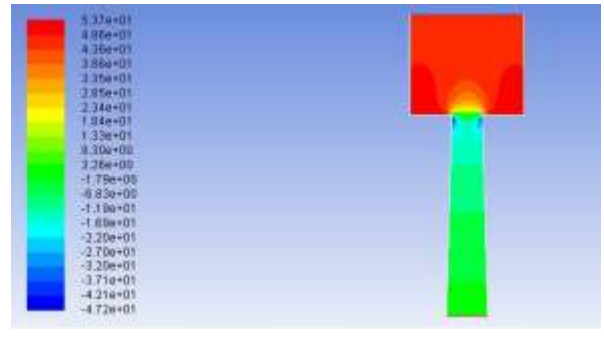


Figure 8: Variation of static pressure under Set1

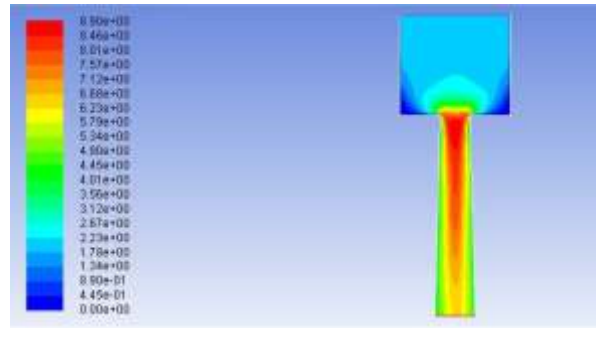


Figure 9: Variation of velocity magnitude under Set 1

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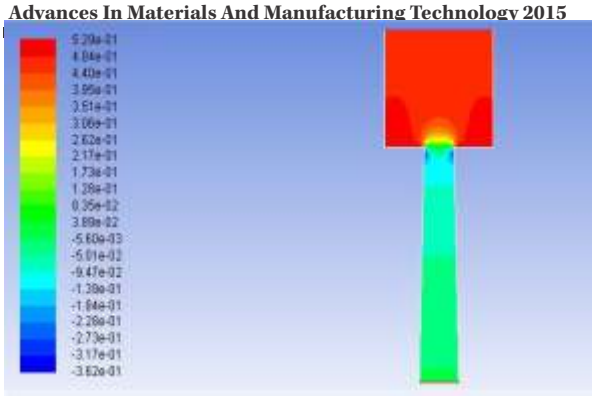


Figure 10: Variation of static pressure under Set2

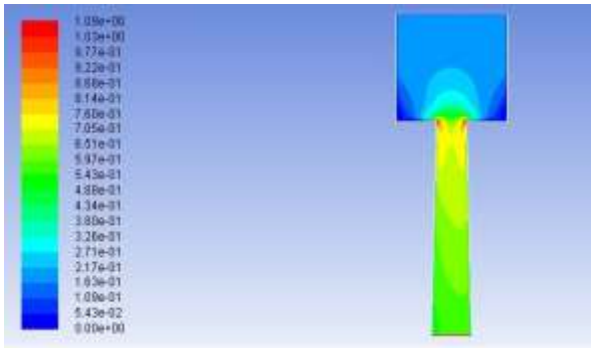


Figure11: Variation of velocity magnitude under Set2

The tapered sprue profile 2 geometry is shown in Figure 12 and the variation of static pressure (in Pascal) and velocity (in m/s) along the length of sprue for Tapered sprue profile 1under conditions of Set 1 and Set 2 is shown in Figure 13 to Figure 16.

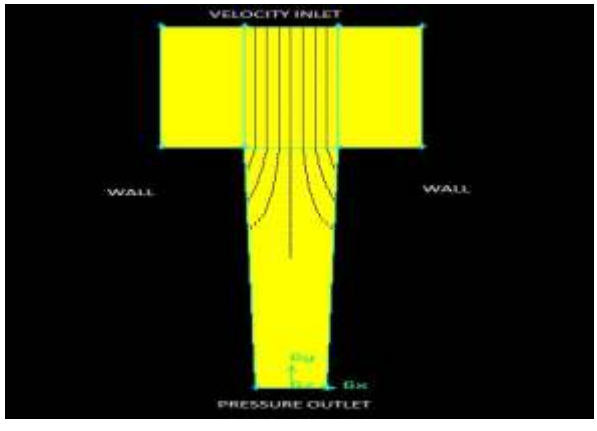


Figure 12: Tapered Sprue 2

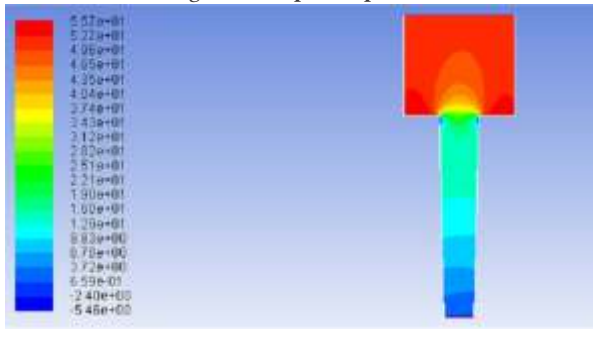


Figure 13: Variation of static pressure under Set1

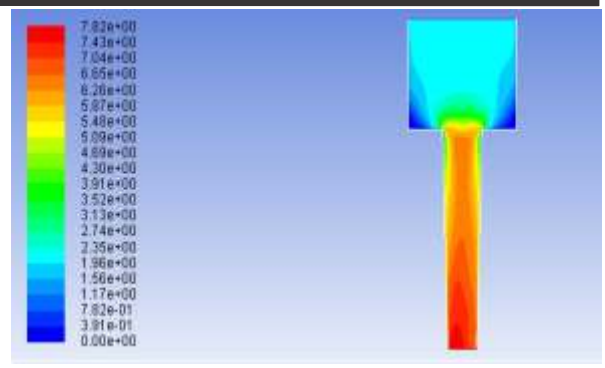


Figure 14:Variation of velocity magnitude under Set1

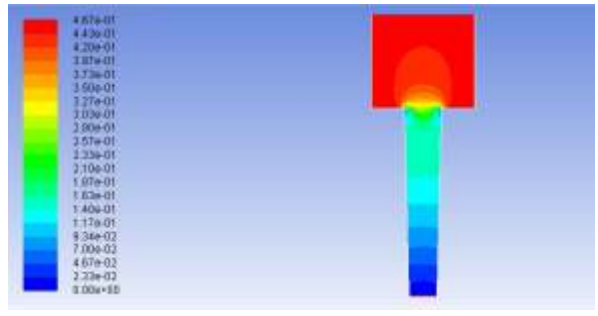


Figure 15: Variation of static pressure under Set2

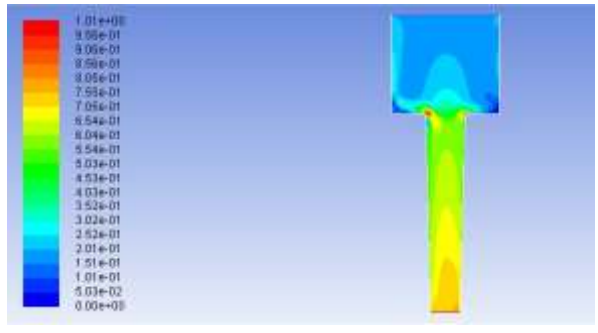


Figure 16: Variation of velocity magnitude under Set2

CONCLUSION

1. For straight sprue profile (when no taper is provided), pressure variations show that pressure become negative after certain distance in downward direction from the entrance of sprue and this negative pressure may create aspiration effect, which, in turn, produces casting defects.

2. The condition becomes worse when area of cross section increases in the direction of flow as shown in tapered sprue 1.

3. The best results are obtained in tapered sprue 2 in which cross section area decreases in the direction of flow.

Hence from the velocity and pressure profiles, we conclude that to prevent air aspiration effect, sprue should be designed with a taper.

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