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Multi-spiral flow benchmark for small thin-wall castings supported by computer simulation

Himanshu Khandelwal, PhD Research Scholar
K. H. Renukananda, PhD Research Scholar
Dr. B. Ravi, Institute Chair Professor
Mechanical Engineering Department,
Indian Institute of Technology Bombay, Mumbai

Fluidity of molten metal is an important measure of castability, and is useful for optimizing the gating and pouring parameters to ensure fully filled castings. In this work, an improved benchmark is proposed to measure metal fluidity in thin wall castings. It has three spirals of 1 mm, 2 mm and 3 mm thickness; all originating from a central sprue. The fluidity pattern was fabricated in stainless steel, and was used to create sand molds by alkyd urethane no-bake binder system, common in foundry industry today. To demonstrate the use of the proposed benchmark, Al-Si12 alloy was melted and poured at various superheat temperatures to obtain test castings with different extent of filling. The effect of thickness and superheat on metal fluidity are presented, which can be used to determine the optimal pouring temperature for a given range of casting thickness. The same geometry was also used to visualize the flow of molten metal inside the mold using casting simulation software; and the results were compared with experimental values.

Keywords: *Fluidity, thin-wall, simulation, benchmark*

1. Introduction

The increasing need for weight reduction is leading to research in thin wall castings. The main challenge is to ensure molten metal flows in thin sections, avoiding misrun and cold-shut defects [1,2]. The distance of flow of molten metal before it stops by solidification, is called fluidity [3]. Several tests have been proposed to measure fluidity, including: (i) Spiral (ii) Vacuum fluidity (iii) Strip fluidity, and (iv) Various other multi-channel fluidity tests [1,3–6]. Since all these tests are based on a single stream of metal flowing through a single section of constant thickness, they are not very useful to predict flow behavior in industrial parts with branched flow and varying section thickness. Thus there is a need to device a standard test for fluidity to overcome the above limitation, which has been taken up in the present work.

2. Multi-Spiral Fluidity Test

The proposed benchmark is shown in Fig. 1(a). It has three spiral channels of thickness 1 mm, 2 mm and 3 mm. A central common sprue (lower Φ=6 mm, upper Φ=7.5 mm, height=22 mm, pouring basin=15 mm) lets molten metal flow simultaneously through the three channels. Thus branching of flow and fluidity in sections of different thickness can be studied. This benchmark is especially suited to thin wall castings.

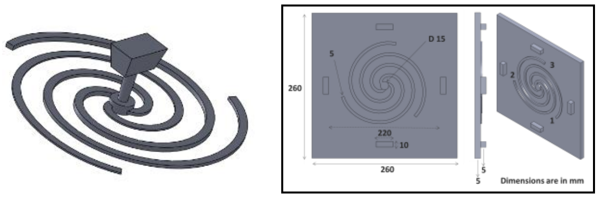

Fig. 1: CAD model of multi-spiral fluidity benchmark, and its match-plate pattern

3. Casting Experiments

To demonstrate the multi-spiral benchmark, a match-plate pattern was designed and fabricated in stainless steel by micro milling (Fig. 1). Silica sand molds (AFS 75 mesh size) were prepared using the pattern and three part no-bake alkyd urethane binder system. AlSi12 (LM6) alloy was melted and poured using a tabletop furnace with bottom opening, minimizing air contact and fall in temperature. Three castings were poured at temperature of 620℃, 660℃ and 700℃, shown in Fig. 2. The experiments were repeated and the average flow length measured for each section of each casting is given in Table 1.

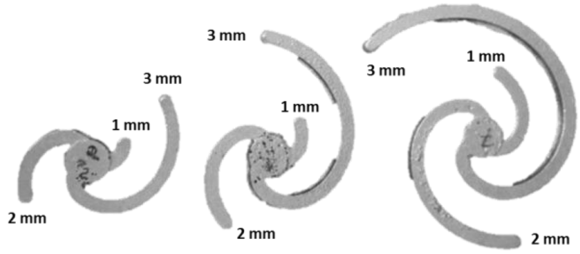

Fig. 2: Multi-spiral castings for fluidity study

Table 1: Results of fluidity experiments

Expt. No.	Pouring temperature (℃)	Flow length (mm) for Section thickness		
		1 mm	2 mm	3 mm
1	620	11	36	61
2	660	26	67	121
3	700	55	116	187

The results clearly show that flow length increases with thickness as well as the pouring temperature. Fig 3 represents the plot of flow length with respect to the pouring temperature for different values of thickness. Fig 4 represents the plot of flow length with respect to thickness for different values of pouring temperature. These plots are useful for two purposes: (i) casting design for manufacturability, in which the section thickness can be optimized for a given set of process parameters (mainly, gating layout and pouring temperature), and (ii) optimizing casting process parameters (gating and pouring) for a given section thickness of cast part.

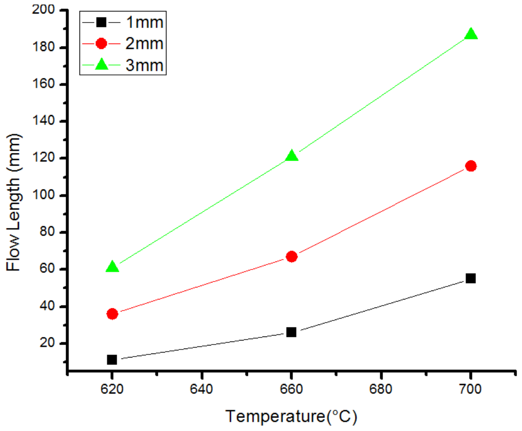

Fig. 3: Effect of pouring temperature on flow distance

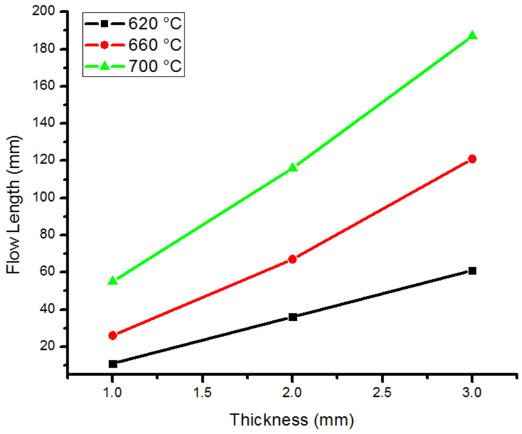

Fig. 4: Effect of section thickness on flow distance

4. Computer Simulation

Numerical simulation of mold filling and casting solidification was performed using FLOW^{+} module of AutoCAST-X1 software [7]. A mesh size of 0.54 mm was selected, giving 18.79 million cells for the total volume of casting and mold. The simulations were performed for all three pouring temperatures and the results are shown in Fig. 5. The sequence and extent of flow stoppage in simulation matches fairly well with experimental results, thus establishing the usefulness of multi-spiral as benchmark for simulation software.

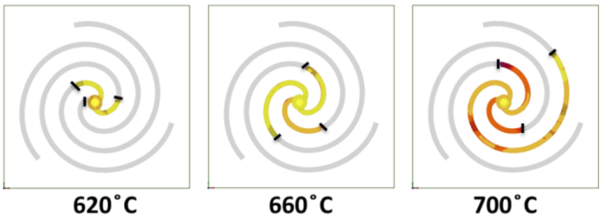

Fig. 5: Effect of section thickness on flow distance

5. Conclusion

The paper presented a multi-spiral benchmark for determining and understanding metal fluidity in thin wall castings, with branching of sections with varying thickness. The flow-length was found to increase with section thickness and pouring temperature; the values of fluidity for a given combination of thickness and temperature are useful for casting design (optimal wall thickness) as well as process optimization (gating and pouring parameters). Further, the benchmark results are also useful for verifying and comparing different software programs for metal casting simulation. The proposed fluidity benchmark can be used to produce castings with different combinations of casting alloy and process parameters, to develop a fluidity database that will be very useful in practice.

References

[1] A.H. Zadeh and J. Campbell: Trans. Foundry Soc. 022 (2003) 115–124.

[2] K.R. Ravi et al.: J. Alloys Compd. 456 (2008) 201–210.

[3] M. Di Sabatino et al.: Int. J. Cast Met. Res. 18 (2005) 59–62.

[4] A.H. Zadeh and J. Campbell: Int. J. Cast Met. Res. 17 (2004) 201–205.

[5] H. Khandelwal and B. Ravi, Indian Foundry J. 7 (2014) 23–29.

[6] M. Górny: J. Iron Steel Res. Int. 19 (2012) 52–59.

[7] AutoCAST, http://www.autocast.co.in, 2015.