Flow Analysis of Molten Metal through Various Ingates using Water Models

[1]N. Chandran, [2] J. Gunasekaran, [3] D. Nithyanand, [4] C. Vinoth kumar
[1,2,3,4] Student, Department of Mechanical Engineering
Panimalar Engineering College, Chennai, Tamilnadu, India

***Abstract*— A foundry must continuously improve the quality of castings produced to thrive in the global competitive environment, minimize cycle time, reduce costs, as well as meet out its delivery times. So, from the viewpoint of customer satisfaction and operational economy, foundries cannot afford production runs on a series of trial castings with routine changes in the gating system and choose the most economical option amongst all by testing the quality of castings obtained from each trial. This is because of the intrinsic cost and time implications which would adversely affect the survival of the organization. All these factors indicate the necessity of a scientific approach to the design of gating systems to increase the quality and yield in a foundry. Hence, this paper deals with the flow analysis through the various gating systems [1].**

I. OBJECTIVE

In this work, attention is focused on the study of gating systems to understand its hydraulics using acrylic water models. Similitude between water and liquid metal was invoked through the application of the principles of similarity from the fluid mechanics by choosing the most relevant non-dimensional numbers. On the basis of gating ratio commonly adopted in foundries for producing aluminium castings, a un-pressurized gating system, was chosen for analysis.

II. EXPERIMENT

A typical gating system with a specific gating ratio, consisting of four gates was designed and fabricated in acrylic plastic (polymethyl-methacrylate). Polymethyl-methacrylate, being a highly transparent material, permits direct visualization of the mold filling process. A modularized set comprising of runners of three different aspect ratios and three different Ingate geometries, leading to nine possible combinations of runner-ingate pairs was designed. The design is modelled in 3D using Pro/ENGINEER Wildfire 5.0 and a CAD Drawing was developed.

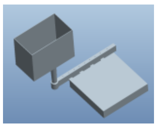

Figure 1. 3D Model of the Gating System designed using Pro/ENGINEER Wildfire 5.0

This was followed by the fabrication of acrylic models at M/s M.K. Engineering Works, Vellore.

Figure 2. Fabricated pouring basin with sprue and runner models signifying three different aspect ratios

W - Width Of The Runner
H - Height Of The Runner

Figure 3. Various Ingate modules

ISSN: 2278-0181
PECTEAM - 2K18 Conference Proceedings

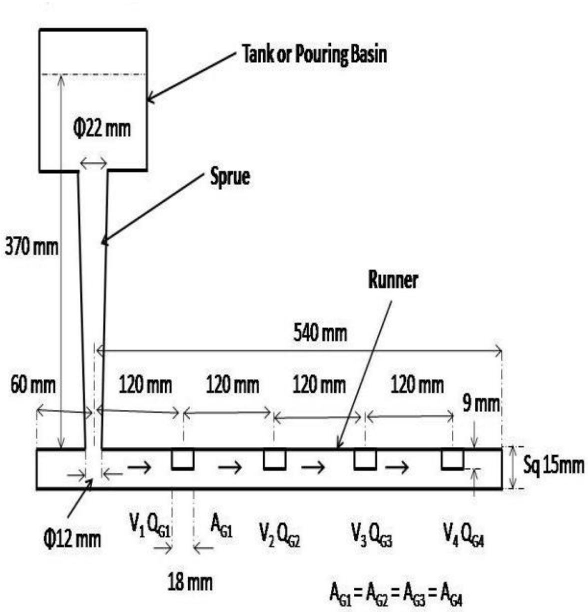

Figure 4. Two dimensional view of the overall Setup

Most suited manufacturing methods, tools and specially made wooden dies were employed as the fabrication of acrylic model posed a challenge due to the fragile nature of the material and its tendency to crack during manufacture.

Tests of the acrylic models were conducted with water, due to its cost efficiency when compared to the cost of liquid metal in both experiments. The tests involved filling of the pouring basins to required level heads and allowing water to flow through the gating system, simulating that of metal flow in a real casting process physically.

Experimentation was carried out in two different phases. The first one was flow measurement phase, in which the flow parameters like discharge through the ingates, flow rate and flow velocity of water exiting through each gate was physically measured for varying levels of head and runner-ingate combinations followed by analysis with the help of graphical plots.

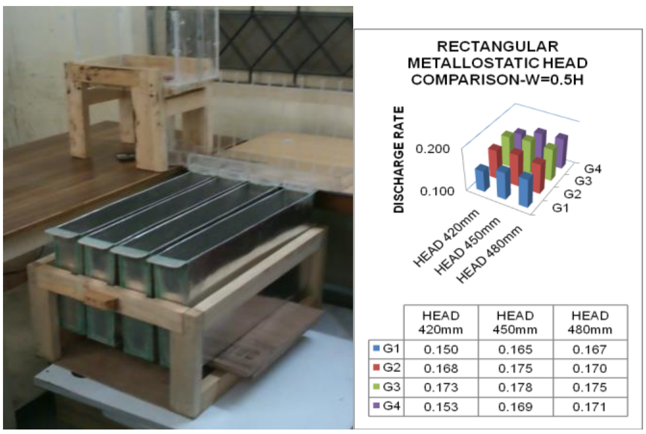

Figure 5. A typical experimental setup for flow measurement with a sample 3D plot for discharge rate

III. ANALYSIS

The second phase of experimentation was the flow visualization phase, wherein, the patterns of flow through the gating system was recorded with a high speed camera capable of capturing images up to 10,000 frames per second. The variation in filling profiles, splashing and turbulence phenomena for different ingate geometries were recorded and interpreted.

Figure 6. A typical experimental setup for flow visualization and the camera used

Videos recorded during experimentation are split into frames and analysed in both cases

Figure 7. Picture frames of a particular video recording

IV. RESULTS

This was followed by a computer simulation through FLOWCast software. By applying the conditions for similitude, linear dimensions in the model were scaled by a suitable scaling factor and drawings were generated. The drawings were imported to the software and the simulation was run for all runner-ingate pairs.

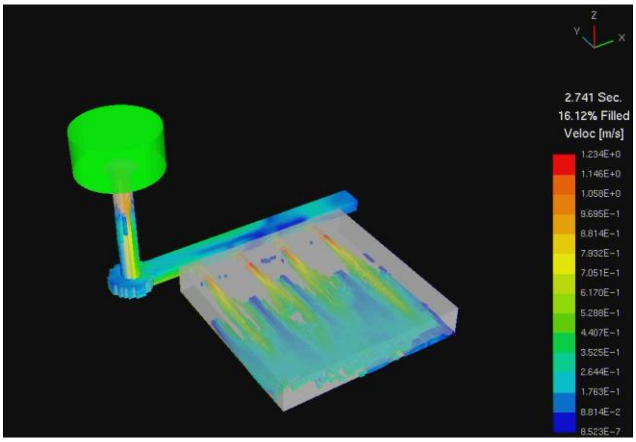

Figure 8. A screenshot of a FLOWCast simulation showing a 3D velocity plot

The results of the simulation did coincide with the practical experiment which was done earlier. The results are for your viewing.

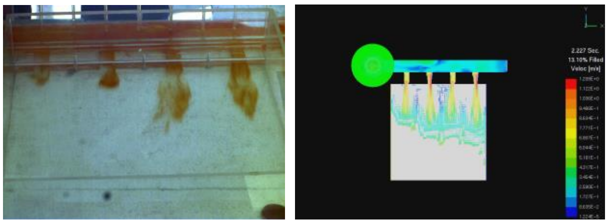

Figure 9. Experimental flow pattern and flow patterns in actual video grab in simulation

The filling profiles obtained from the camera and simulation were compared. The range of velocities indicated by the software was in good consistency with the measured values. Similarly, the filling profiles observed in the runner system was concurrent with the images captured with the high speed camera. It wasfound that the combination consisting of runner aspect ratio of 0.5 with convergent ingates showed uniform filling patterns, which is desired in the real-time casting scenario.

REFERENCES

[1] P.Sivaraman "Experimental studies on flow of molten metal through gating systems using water models" ISSN 2249-1619 (May 2015), Vol 5 Issue 5

[2] K.S. Anastasion "Optimization of the aluminium die casting process based on the Taguchi method" J. Eng. Manuf., 216 (2002), pp. 969–977

[3] P.B. Barua, P. Kumar, J.L. Gaindhar "Surface roughness optimization of V process castings through Taguchi's method" AFS Trans., 45 (1997), pp. 763–768.

[4] F. Bradley, S. Heinemann "A hydraulics-based optimization methodology for gating design" Appl. Math. Model., 17 (1993), pp. 406–414

[5] D.M. Byrne, S. Taguchi "The Taguchi approach to parameter design" Qual. Progr. (1987), pp. 19–26.

[6] J. Campbell "The ten castings rules guidelines for the reliable production of reliable castings: a draft process specification" Materials Solutions conference on Aluminum Casting Technology, Chicago (1998), pp. 3–19

[7] J. Campbell "Castings" Elsevier Butterworth-Heinemann (2003)

[8] C.E. Esparza, M.P. Guerrero-Mata, R.Z. Rios-Mercado "Optimal design of gating systems by gradient search methods" Comput. Mater. Sci., 36 (2006), pp. 457–467

[9] J. Ha, P. Cleary, V. Ahuja, Comparison of SPH simulation of high speed die filling with experiment, in: Proceedings of the 13th Australasian Fluid Mechanics Conference, Melbourne, Australia, December 1998, pp. 901–904.

[10] R.W. Hockney, J.W. Eastwood, Computer Simulation Using Particles, Institute of Physics Publishing Ltd, 1988.

[11] C.W. Hirt, B.D. Nichols, Volume of fluid method for the dynamics of free boundaries, J. Comp. Phys. 39 (1981) 201–225.

[12] W-S. Hwang, R.A. Stoehr, Modelling fluid flow, Metals Handbook, Casting, ASM Int. 15 (1988) 867–876.

[13] L.R. Jai, S.M. Xiong, B.C. Lui, Mold filling and heat transfer simulation of die casting process, in: P.R. Sahm, P.N. Hansen, J.G. Conley (Eds.), Modeling of Casting, Welding and Advanced Solidification Processes IX, Aachen, Germany, 1998, pp. 303–310.

[14] M.R. Jolly, H.S.H. Lo, M. Turan, X. Yang, J. Campbell, Development of practical quiescent running systems without foam filters for use in aluminium castings using computer modelling, in: P.R. Sahm, P.N. Hansen, J.G. Conley (Eds.), Modeling of Casting, Welding and Advanced Solidification Processes IX, Aachen, Germany, 2000, pp. 311–318.

[15] D. Kothe, D. Juric, K. Lam, B. Lally, Numerical recipes for mold filling simulation, in: B.G. Thomas, C. Beckermann (Eds.), Modeling of Casting, Welding and Advanced Solidification Processes VIII, San Diego, CA, 1998, pp. 17–28.

[16] Y.C. Lee, H.Y. Hwang, J.K. Choi, A study on the application of solidification and fluid flow simulation to die design in gravity die casting, in: P.R. Sahm, P.N. Hansen, J.G. Conley (Eds.), Modeling of Casting, Welding and Advanced Solidification Processes IX, Aachen, Germany, 2000, pp. 349–356.

[17] MAGMAsoft User Manual MAGMA GmbH, Kackertstrasse 11, D-52072, Aachen, Germany, 1996.

[18] J.J. Monaghan, Smoothed particle hydrodynamics, Ann. Rev. Astron. Astrophys. 30 (1992) 543–574.

[19] J.J. Monaghan, Simulating free surface flows with SPH, J. Comp. Phys. 110 (1994) 399–406.

[20] J.J. Monaghan, Improved modelling of boundaries, SPH Technical Note #2, CSIRO Division of Mathematics and Statistics, Technical Report DMS – C 95/86, 1995.

[21] J.P. Morris, P.J. Fox, Y. Zhu, Modeling low Reynolds number incompressible flows using SPH, J. Comput. Phys. 136 (1997) 214–226.

[22] D. Kornack and P. Rakic, "Cell Proliferation without Neurogenesis in Adult Primate Neocortex," Science, vol. 294, Dec. 2001, pp. 2127-2130, doi:10.1126/science.1065467.