Gating System Measuring of Sandcasting

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Abstract. Sandcasting is the oldest casting method and valuable however it has still some problems. This study discussed a mathematical approach in the gating system design. A gating system of a Connecting Road from cast iron was used as an object this study. This study measured fluid flow, a gating position in a mold, pouring, spur basin, pouring time, and riser. Solidification time affect volume and surface area, so in this study we adjusted the height of riser based of 1.2 up to 2 as riser diameter. Results of mathematic analysis show that pouring time was 3 sec, dimension of runner as 1.2 cm as High, 1.2 cm of Large, 2.06 of Pressure. The other dimensions were 2.9 cm of High spur, 5.5 cm of Pouring basin, 3.15 cm² of large of spur with 7.56 cm³ as volume total, and weight total of gating system and riser 0.285 kg. The metal fluid was poured in a molding at 2.83 sec. Dimensions of gating were gotten the 0.42 cm² from the first in gate and 0.63 cm² for second in gate.

Keywords: Gating System, Measuring, Sandcasting

1. Introduction

The oldest casting method is sandcasting and this method is also valuable[1]. Santosh Reddy Sama et al developed a Sprue design for metal casting using 3D sand-Printing[2]. On the other hand design and control from greensand mold press casting based on estimation of estimation of metal filling behavior[3]. San molding can used to produce a component with complex shape, various size required or specification need. The getting system is still problem in this method[4]. Sandcasting method still has problem and many researchers have developed this method.

Optimization of Sand Casting Process for aluminum has studied by Mekonnen Liben Nekere and Ajit Pal Singh. They used Taguchi’s Robust Design method to optimize the seven of casting parameter that affect to quality of product feature[5]. Optimization of characteristic of 3D sand printing processing was studied by Philip Hackney, Richard Wooldridge for producing a traditional Fouran mold tool[6]. Optimization of Design from Gating and feeding system based on Simulation technique had been studied by Sachin L. Nimbulkara and Rajendra S. Dalu[7]. Process parameters of sand casting affected to quality of casting result.

Core shifts was monitored when was processing of metal casted by a wireless sensing[8, 9]. Datau S.G. et al studied the effect of sand casting process parameter to mechanical properties of casting results. They stated that casting parameters significantly influence to casting result such as an effect of runner size to mold cavity[10]. Mohammed Viquar Mohiuddin et al has experimental studied the sand mold process parameter of aluminum alloy sand casting. The sand mold parameters were used grand size, clay content, molding hardness. They had used sand size, clay content, moisture content, and number of ramming[4]. K.K.Pathak et al studied the influence of gating geometry on casting based
computer simulation. They state that shrinkage porosity, filling time, solidification time and velocity were critically parameters in experiment[11]. Hodbe and Shinde stated that in the traditional casting process redesign of the feeder, getting system, etc to improve the quality of casting product and prevent the defect casting[12]. This study discussed measuring of gating system of Sandcasting.

2. Material and Method

Each metal has difference mechanical properties[13, 14], not only mechanical properties but also difference thermal and physic properties. Thermal and Physic properties were sound in table 1.

| Property                        | Value               |
|---------------------------------|---------------------|
| Melting Temperature             | 1150 - 1250 ºC      |
| Service Temperature             | -100 - 400 ºC       |
| Density                         | 7.1 - 7.3 g/cm³     |
| Young's Modulus, E              | 167 - 170 GPa       |
| Compressive Strength, σc        | -                   |
| Yield Strength, σy               | 250 MPa             |
| Tensile Strength, σt             | 400 MPa             |
| Poisson's Ratio                 | 0.21 - 0.26         |
| Vickers Hardness                |                     |
| Shear Modulus, G                |                     |
| Fracture Toughness, K_{fc}      | 22 - 54 MPa/√m      |
| Thermal Conductivity, λ         | 25 - 42 W/m.K       |
| Thermal Expansion, α            | 10 - 11.5 E-6/C     |
| Production Energy               | 16.4 - 18.2 MJ/kg   |
| CO₂ Emission                    | 1 - 1.1 kg/kg       |

2.1. Fluid Flow

The metal fluid flows in the gating system or rising, the metal fluid through each cavity and in the casting. When metals liquid flew in the casting affected some energy such as potential energy, kinetics energy, pressure and friction. The energy rises because of gravitation and friction to wall of casting[15]. Effected from every energy could be represented with formulation

\[ WZ + WPv + \frac{W^2}{2g} + WF = k \]

\( W = \) Sum of flow fluid weight (kg)
\( Z = \) High of fluid metal flow (mm)
\( P = \) Pressure of fluid statics (kg/mm²)
\( v = \) Specific volume (mm³/kg)
\( V = \) flow fluid speed (mm/s)
\( g = \) gravitation (mm/s²)
\( F = \) Friction loss

2.2. Gating System

The Gating system mathematic analysis used Bernoulli Law. Value or Number of flow speed from fluid when come in and come out in a vertical gat which has difference height, based on the Continuities law that debit of fluid volume in 1 region same with 2 region. This illustration of this law was represented by figure. 1.

\[ Q = A_{1}V_{1} = A_{2}V_{2} \]
Figure 1. Fluid flow

\[ A_1 = \text{Cross-sectional area 1 (mm}^2\text{)} \]
\[ V_1 = \text{Fluid speed on cross-sectional 1 (mm/s)} \]
\[ A_2 = \text{Cross-sectional area 2 (mm}^2\text{)} \]
\[ V_2 = \text{Fluid speed on cross-sectional 2 (mm/s)} \]

A gating position in a mold has three types

Top Gating was shown in figure 2.

\[ h_m = a - \frac{c}{2} \]

Middle Gating was shown in figure 3.

\[ h_m = \frac{2ac}{2c} b^2 \]

Bottom gating was shown in figure 4.
2.3. Pouring

Pouring is a place where metals fluid was put in a cast molding. Effect pouring from the metal fluid rise a turbulence flow so to reduce effect of turbulence of the metal fluid, a pouring place was shaped cup or basin. Pouring cup and basin were presented by figure 5.

2.4. Sprue

Sprue is a part of a gating system which is to reduce a turbulence effect when the metal fluid is falling down before an in gate part. The shape of spur was presented by figure 6.

2.5. Total of In Gate area large

Debit of Fluid flow through in the mold based on total of in gate area large. The gate area large total could be counted with:
\[
A_1 = \frac{22.6 \times W_t}{\rho \times t_p \times f \times \sqrt{hm}}
\]

\(A_1\) = Total of In gate area large  
\(W_t\) = Pouring Weight Total  
\(t_p\) = Pouring time  
\(hm\) = Effective High  
\(f\) = velocity Factor  
\(\rho\) = density

### 2.6. Pouring Time

Pouring time is the need of time to pour the metal liquid or fluid to mold up to completely. The mathematic model to calculate pouring time presented by

\[
(t_p) = K \left[1.4 + \frac{T_c}{1.5}\right] \sqrt{W_t}
\]

\(t_p\) = Pouring time (Sec)  
\(T_c\) = Casting Thickness (cm)  
\(W_t\) = Casting Weight (kg)  
\(K\) = Fluidities Factor (based on Factor composition of Chemist composition)

### 2.7. Riser

Metal casting process has effected to reducing volume when solidification so riser was need to add liquid or metal fluid at around riser. The height of riser can be adjusted based on diameter such as 1.2 up to 2 from diameter of riser.

### 3. Result and discussion

Solidification time of the casting process was also effected volume and surface area.

Given :

\[
\begin{align*}
W_c &= 0.172 \times 2 = 0.344 \text{ kg} \\
W_g &= 0.16 \text{ kg (planned)} \\
W_t &= W_c + W_g \\
&= 0.344 + 0.16 \\
&= 0.504 \\
T_c &= 1.6 \text{ cm} \\
k &= 2.5
\end{align*}
\]

Pouring time

\[
T_p = k \left(1.4 + \frac{T_c}{1.5}\right) \sqrt{W_t}
\]

\[
= 2.5 \left(1.4 + \frac{1.6}{1.5}\right) \sqrt{0.504}
\]

\[
= 2.5 \times (1.49) \times 0.71
\]

\[
= 2.645 \text{ s}
\]

- In gate → Bottom Getting
\( H_m = a \)
\( H_m : 55 \text{ mm} = 5.5 \text{ cm} \)
\( A_1 = \frac{22.6 \omega f}{\rho \cdot \text{tp} \cdot f \cdot \sqrt{h_m}} \)
\( = \frac{22.6 \cdot 0.504}{7.250 \cdot 2.645 \cdot 0.6 \cdot \sqrt{5.5}} \)
\( = \frac{11.4}{27} \)
\( = 0.42 \text{ cm}^2 \)

\( A_{11} = \frac{1}{2} A_1 \)
\( = \frac{1}{2} \cdot 0.42 \)
\( = 0.21 \text{ cm}^2 \)

- Dimensi in gate
  \( h_1 : 0.6 \text{ cm} \)
  \( l_1 : 1.2 \text{ cm} \)
  \( pr : 2.061 \text{ cm} \)

- Runner
  \( Ar = 3 A_1 \)
  \( = 3 \cdot 0.42 \text{ cm}^2 \)
  \( = 1.26 \text{ cm}^2 \)
  \( Ar_{11} = \frac{1}{2} Ar \)
  \( = \frac{1}{2} \cdot 1.26 \)
  \( = 0.63 \text{ cm} \)

- Dimensi runner
  \( H_r : 1.2 \text{ cm} \)
  \( L_r : 1.2 \text{ cm} \)
  \( Pr : 2.061 \text{ cm} \)

- Sprue
  \( A_s = 1.5 A_1 \)
  \( = 1.5 \cdot 0.42 \text{ cm}^2 \)
  \( = 0.63 \text{ cm}^2 \)
  \( D_s = \frac{\sqrt{A_s \cdot 0.63}}{3.14} \)
  \( = 0.89 \text{ cm} \)
  \( H_s = 29 \text{ mm} \rightarrow 2.9 \text{ cm} \)

- Pouring Basin
  \( X = 2.31 \)
  \( D_p = (2 \cdot 2.31) + D_s \)
  \( = 4.62 + 0.89 \)
  \( = 5.51 \text{ cm} \)

- Sprue Basin
  - Large of sprue basin\((\text{Asb})\) \(= 5 \cdot A_s\)
    \(= 5 \cdot 0.63\)
    \(= 3.15 \text{ cm}^2\)
  - Diameter \((d)\) \(= \frac{\sqrt[4]{A_s \cdot \text{Asb}}}{\pi} \)
\[ \sqrt{4 \times 3.15} = \frac{3.14}{3.14} = 2.0 \text{ cm} \]

- Height of sprue basin = 2.0 cm

**Weight gating system**

- Volume in gate \( = A_{r1} \cdot p_i \)
  \[ = 0.21 \times 2.061 \]
  \[ = 0.43281 \text{ cm}^3 \]

- Volume runner \( = A_{r1} \cdot Pr \)
  \[ = 0.63 \times 2.061 \]
  \[ = 1.3 \text{ cm}^3 \]

- Volume sprue basin \( = A_s \cdot hs \)
  \[ = 0.63 \times 2.9 \]
  \[ = 1.827 \text{ cm}^3 \]

- Volume pouring basin = 23.9 cm\(^3\)

- Volume sprue basin \( = A_{sb} \cdot hsb \)
  \[ = 3.15 \times 2.4 \]
  \[ = 7.56 \text{ cm}^3 \]

- Weight gating system
  \[ = \frac{(2V1) + (2Vr) + Vs + Vps + Vsb) \cdot \rho}{1000} \]
  \[ = \frac{(2 \times 0.21) + 2 \times (0.63) + 4.441 + 23.9 + 7.56) \times 7.20}{1000} \]
  \[ = 0.27 \text{ kg} \]

- Weight total gating system and riser
  \[ = \text{weight riser} + \text{weight gating system} \]
  \[ = 0.015 + 0.27 \]
  \[ = 0.285 \]

Calculation based on CAD represented with figure 7.
8

Figure 7. The results of calculation based on software

4. Conclusion
Some mathematic models could be used to calculate a gating system in a sand casting mold. This study counted the size of some gating system elements. The metal fluid was poured in a molding at 2.83 sec. Dimensions of gating were gotten the 0.42 cm$^2$ from the first in gate and 0.63 cm$^2$ for second in gate.

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References
[1] S. Pal, A. Gupta, and R. Kapoor, "Analysis and Validation of Sand Casting Process Using Procast," Journal of Basic and Applied Engineering Research, vol. 4, pp. 278-281, 2015.
[2] S. R. Sama, T. Badamo, P. Lynch, and G. Manogharan, "Novel sprue designs in metal casting via 3D sand-printing," Additive Manufacturing, vol. 25, pp. 563-578, 2019.
[3] R. Tasaki, H. Seno, and K. Terashima, "Process design and control of greensand mold press casting using estimation of metal filling behavior," Procedia Manufacturing, vol. 15, pp. 443-450, 2018.
[4] M. V. Mohiuddin, S. F. Hussainah, A. Krishnaiah, P. Laxminarayana, and S. Sundarrajan, "Experimental Study of Sand Mold Process Parameters on Al-Alloy Sand Castings Using DoE," IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), vol. 11, pp. 01-06, 2014.
[5] M. L. Nekere and A. P. Singh, "Optimization of Aluminium Blank Sand Casting Process by Using Taguchi’s Robust Design Method," International Journal for Quality research, vol. 6, pp. 81-92, 2012.
[6] P. Hackney and R. Wooldridge, "Optimisation of Additive Manufactured Sand Printed Mould Material for Aluminium Castings," Procedia Manufacturing, vol. 11, pp. 457 - 465, 2017.
[7] S. L. Nimbulkar and R. S. Dalu, "Design optimization of gating and feeding system through simulation technique for sand casting of wear plate," Perspectives in Science, vol. 8, pp. 39-42, 2016.
[8] J. M. Walker, A. Prokop, C. Lynagh, B. Vuksanovich, B. Conner, K. Rogers, et al., "Real-time process monitoring of core shifts during metal casting with wireless sensing and 3D sand printing," Additive Manufacturing, vol. 27, pp. 54-60, 2019.
[9] H. G.A and S. B.R, "Design And Simulation Of LM 25 Sand Casting For Defect Minimization," Materials Today: Proceedings, vol. 5, pp. 4489-4497, 2018.
[10] D. S. G, O. J, and E. I. R. D. N, "The effect of sand casting process parameters on mechanical properties of aluminum alloy casting," International Journal of Metallurgical in Materials Science and Engineering, vol. 2, pp. 32 - 41, 2012.
[11] K.K.Pathak, V. Verma, P. Pawar, and G. Agnihotri, "Effects of gating geometry on casting solidification using computer simulation tools," Materials Science an Indian Journal vol. 11, pp. 135-141, 2014.
[12] Y. Motoyama, S. Sekiguchi, T. Okane, and M. Yoshida, "Thermo-elasto-plastic finite element analysis of warping deformation during casting of gray cast iron," Journal of Materials Processing Tech, vol. 277, p. 116454, 2020.
[13] H. Muzakki, A. S. Baskoro, G. Kiswanto, and Winarto, "Mechanical Properties of the Micro Resistance Spot Welding of Aluminum Alloy to Stainless Steel With A Zinc Interlayer," International Journal of Technology, pp. 686-694, 2018.
[14] A. S. Baskoro, H. Muzakki, G. Kiswanto, and W. Winarto, "Mechanical Properties and Microstructures on Dissimilar Metal Joints of Stainless Steel 301 and Aluminum Alloy 1100 by Micro-Resistance Spot Welding," Trans Indian Inst Met, vol. 72, pp. 487-500, 2019.
[15] H. Muzakki, "Perancangan Ulang Gating System dan Riser untuk Satu Cetakan Dua Produk pada Pengecoran Sapu Roda," Proceeding Call For Paper-SNFT UMSIDA, pp. C-17 - C-25, 2012.