Gating and Feeder Design of Aluminium Alloy (6061 T6) Casting for Circular Component

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Abstract: Sand casting is an oldest technique to achieve required shape, Every Foundry Industries Requires Minimum Rejection of Component, Rejection Is Caused by Undesired Uncertainty Found in Component's. Quality of casting is depends upon flow of molten metal through gating system. Improper gating design is mainly responsible for the turbulence and also responsible for shrinkage porosity. In other words, molten metal should enter into the mold cavity within solidification time of melt, so proper design of gating system is essential. Proper gating system design reduces the turbulence in the flow of molten metal, it also minimize air entrapment, sand inclusion, oxide film and dross. This paper describes the design of a gating system and feeder to produce Aluminium alloy casting of circular component having diameter 180mm, and height 60mm the gating system with ratio of 1:4:4 (non-pressurized) and silica sand moulding technique. It is essential to understand design of gating system and feeder for producing defect free casting. Objective of this research is to improve the quality of 6061T6 aluminium alloy casting by reducing defects produced in silica sand moulding process through proper gating system design and feeder design.

Keywords: Gating Design, Feeder Design, Sand casting, Aluminium Alloy

Introduction:

Gating system is one of the major component for producing good quality of component. Many attempts have been made to study the effect of gating system on the flow pattern of molten metal entering to the mould. The formation of various casting defects could be directly related to fluid flow phenomena involved in the stage of mould filling. For instance, vigorous streams could cause mould erosion; highly turbulent flows could result in air and inclusions entrapments; and relatively slower filling might generate cold shuts The manufacturing of a component consist several steps (i) Design of part itself (ii) material specification (iii) Design of gating system (iv) Design of feeder system Furthermore, porosity which is a common defect in every casting also caused from improper design of gating system The basic element of gating system are pouring basin, sprue, runners, ingate and, it is a series of passages in which the molten metal flows into the mould cavity to produce the castings for minimizing degradation in metal quality and for minimizing the occurrence of shrinkage porosity during the solidification. The proper feeding of the molten metal into the mould cavity has been very problematic especially when it involves castings with thin sections. In order to properly feed the molten metal into the mould cavities of these thin section castings, a proper design of gating system is required. The problem in this study is how to design a single optimize gating system that will be used to produce for aluminium alloy circular plate of different sizes and also minimize defects in the castings.

Literature review:

C.M.Chaudhari, B. E. Narkhede and S. K. Mahajan *et al.*[4] have discussed about the component (cover plate)which is suffered from shrinkage porosity defect which leads to premature failure. CAD software and AUTOCast-x software is used to carry out the entire modelling, simulation & optimization processs.it was observed that simulation of solidification enables the visualization of process of freezing inside and identifies the hot spots. location and size of the feeder were optimize so that the entire shrinkage porosity should get shifted inside the feeder, this improves the yield by 15%, which shows simulation can be great use in optimizing the feeder dimensions and should get shifted inside the feeder, this improves the yield by 15% which shows simulation can be great use in optimizing the feeder dimensions and increasing the feeding efficiency. He also suggested that proper designing of gating system helps to achieve directional solidification leading towards the feeder. **Dr. B. Ravi** [5] has presented an intelligent design environment to assist product engineers in assessing a part design for castability. He has mentioned design of sprue, runner, gate **S. Guleyupoglu** [3] explained a compilation of common rules of thumb used by foundry experts and guidelines suggested by researchers for better quality castings. He has given the guidelines about gating and rising practice for light alloy, ductile iron and steel castings. **JongCheon Park and Kunwoo Lee** [8] have been developed an interactive computer program to design a pattern and the risers. They included an automatic whole elimination, an automatic scaling for shrinkage allowance and an automatic draft addition for the pattern design and also included an automatic generation of risers and riser necks with their recommended locations. **B.H. Hu et al.** [9] has presented a numerical simulation technique used for optimization of the runner and gating systems for the hot chamber die casting of a thin-walled magnesium telecommunication part

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Gating Design Calculations:

For designing a wooden pattern for producing casting component. Design calculations of gating system for aluminium alloy (6061T6) is calculated Design of gating system will help to pour the charge into mold cavity before solidification. A Proper gating system always helps to avoid turbulence flow of molten metal into the mold cavity. For this study on 6061T6 aluminium alloy, we will use non- pressurized fating system with a gating ratio of:

As: Ar: Ag = 1: 4: 4 (1)

Where,

As = the cross sectional area of the Sprue Exit,

Ar = the cross sectional area of the Runner,

Ag = the cross sectional area of the Ingate

The choke (the smallest cross sectional area) is at the sprue base exit therefore.

As=Ac

Where, Ac = the cross sectional area of the Choke

Pattern Allowances:

Many types of pattern allowances like draft, machining, distortion, shrinkage allowance. Shrinkage allowance is necessary to avoid shrinkage defect in the casting. Shrinkage defect is the cavity remains inside the casting after solidification. To avoid shrinkage defect in the casting, shrinkage allowance is necessary. Shrinkage allowance for Aluminium alloys is 16 mm/m

Pattern Dimension = Actual Dimension + Shrinkage allowance (2)

Original dimensions of component and feeder on the basis of simulation software .

Length=180 mm,

Height=60mm.

Pattern length = 180+0.180×16 = 182.88 mm

Pattern height =60+0.060×16 = 60.96 mm

Step 1: Calculate the total weight of castings

$W = \rho \times V$ (3)

Where: W = total weight of casting,

ρ = density (2705 kg/m^3)

V = total volume of casting.

V = 980445 mm^3

$W = 2705 \times 980445 \times 10^{-9} = 2.66$ Kg

Step 2: Calculate the pouring rate and pouring time

Pouring rate formula for non-ferrous gating:

$R = b\sqrt{W}$ (4)

Where, R = pouring rate

b = constant, depends on wall thickness;

Typical values of b are shown on table-1

Casting thickness (mm)	Below 6 mm	6 mm to 12 mm	Above 12 mm
Constant b	0.99	0.87	0.47

Table – 1 Values of Constant (b) for Different Casting Thickness

$R = 0.47\sqrt{2.67} = 0.77$ kg/sec

$R_a = R / (k.f) = 0.8/1x0.875 = 0.88$ kg/s (5)

Where,

R_a = adjusted pouring rate,

K = metal fluidity,

C = the effect of friction with values of 0.85-0.90 for tapered sprue in the gating system.

$t = w/ R_a$ (6)

Where, t = pouring time.

$t = \frac{2.67}{0.88} = 2.92$ sec.

Step 3: Calculate the effective sprue height:

The design of the downsprue is critical in order to avoid start of turbulent flow in the 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. To avoid turbulence flow, oxides formed, erosion proper design of sprue is necessary.

- Sprue height (h) = 150 mm
- Height of casting in the cope H_1= 30 mm
- Total height of casting H_2=60 mm, then using equation
- $H_p = h - 0.5x\frac{H_1^2}{H_2}$ (7)

Where, Hp = effective sprue height. For parting plane gating system

- $H_p = 150 - 0.5\,\frac{30^2}{60} = 142.5$ mm

Step 4: Calculate the choke cross sectional

Area:

Choke cross sectional area is the smallest cross sectional area in the gating system which is sprue exit area used to calculate sprue height and also sprue inlet and exit radius.

The flow rate equation:

$$A_C = \frac{W}{\rho t C\sqrt{2g\mathrm{Hp}}} \quad (8)$$

Where, A_C = choke area (mm^2),
W = casting weight (Kg),
ρ = density of molten metal (kg/m^3)
Hp = effective sprue height (mm)
C = discharge coefficient (0.8)
g = acceleration due to gravity ($9.81 m/s^2$),
Ra = adjusted pouring rate (Kg/s)
t = pouring time (s).

$$A_c = \frac{2.67}{2705X3X0.8X\sqrt{2X9.81}X142.5} = 244 \text{ mm}^2$$

Step 5: calculation of the sprue inlet area, since sprue exit area A_{sprue_exit} = choke area A_c

- From continuity equation:

$$A_{sprue\text{-}inlet} = \frac{A_{sprue-exit}\sqrt{H_{sprue-exit}}}{\sqrt{H_{sprue-inlet}}}$$

Where,

- $A_{sprue\text{-}inlet}$ = sprue inlet cross-sectional area,
- $A_{sprue\text{-}exit}$ = sprue exit cross-sectional area,
- $H_{sprue\text{-}inlet}$ = distance between the ladle and sprue top,
- $H_{sprue\text{-}exit}$ = distance between ladle and sprue exit.
- $A_{sprue\text{-}exit}$ = 244 mm^2

Height between ladle & sprue-inlet or height of the sprue inlet = 25 mm

$H_{sprue\text{-}exit}$ = 150+25 = 175 mm
Pitting all these values in equation …. (9)

$$A_{sprue\text{-}inlet} = 112.985 \times \frac{\sqrt{175}}{\sqrt{25}} = 645.56 \text{ mm}^2$$

Diameter of the sprue inlet: 28.67 mm (cross sectional area of a circle = $\frac{\pi}{4}d^2$)
Diameter of sprue exit: 17.62 mm

Step 6: Calculation of the Ingate and Runner cross-sectional areas using a gating ratio of 1: 4: 4

Runners are the passages that carry the molten metal from the sprue well to the gates through which metal enters the mold cavity. Gates are the passages between the runners and the part.

Runner cross-sectional area = 4×244 = 976 mm^2
Area of a Square = L×B
Where, L = length, B = breath.
Since for a square,
Length = Breath,
Therefore, Area = $(Length)^2$
Length of Runner = 31.24 mm and Breath of Runner = 31.24 mm.
Ingate cross-sectional area = 4×244 = 976 mm^2
Number of ingate used is 2 means the total area of ingate

will be divided in to two equal areas.
Therefore area for each ingate is 488mm^2

Step 7: Design of Sprue well:

Sprue well is the passage of transferring molten metal from sprue exit to runner.

Sprue well cross-sectional area = 5×sprue exit area = 5×244 mm^2 = 1220 mm^2
Sprue well depth = 2×runner depth
= 2×31.24 = 62.68 mm

Design of feeder:

Feeders are designed to compensate the solidification shrinkage of a casting, and make it free of shrinkage porosity. Feeder design parameter includes shape, and dimensions of feeder, circular section requires higher gradient than flat rectangular sections. It also depends upon the quality improvement. The temperature and gradient at any point along the feed path influence the type of feeding at that location. If both temperature and gradient are high (near the feeder). Mass feeding takes place by movement of liquid. If temperature is high, but gradient is low, inter dendrite feeding takes place finally, if temperature is low, but gradient is high solid freezing takes place. Improper feeding in the above three zones usually leads to macro porosity, micro porosity and surface sink, respectively. The feeder location must facilitate fettling and grinding off the feeder mark, this implies connecting a feeder to flat surface rather than a curved face of the casting. The idle shape of feeder is spherical this has the lowest surface area for a given volume and therefore the longest solidification time compare to other shape. Feeders are also classified as open or blind depending upon whether the top of the feeder is open to atmosphere or not. In sand casting open feeder lose more heat than blind feeders once they are less efficient then the blind feeders. But in metal mould it is reverse open are more efficient then the blind feeders open feeders are also referred as riser since liquid metal can be seen rising in them, serving as useful indicator that mould has filled completely. The blind feeder also requires an opening to the atmosphere to enable feed metal flowing down to the hotspot. This is ensured by placing a special core above a blind feeder. For small casting, cylindrical, feeders are widely used. For larger casting, cylindrical feeders with spherical bottom (side location) or spherical (top position, blind type) are widely used. In this study. For the greatest efficiency, for small casting, riser should be cylindrical.

According to Chvirino's rule:

$\frac{V}{A}$ Riser > $\frac{V}{A}$ casting

Volume of riser = 0.47 × Volume of casting

Volume of riser= 0.47 × 980445 = 460809.15 mm^3

$\frac{\pi}{4}D^2H$ = 460809.15

For top riser: H = $\frac{D}{2}$

$\frac{\pi}{8}D^3$ = 460809.15

D = 105.47 mm, H = $\frac{D}{2}$ = 52.73 mm

Modulus of top riser: $\frac{V}{A} = \frac{D}{6} = 17.57$mm

For side riser: H = D

$\frac{\pi}{4}D^2H$ = 460809.15

$\frac{\pi}{4}D^3$ = 460809.15

D = 83.71 mm, H = 83.71 mm

Modulus of side riser: = $\frac{V}{A} = \frac{D}{6}$ = 13.95mm

Result and recommendations:

Table- Calculations of Gating System

Element	Height	Length	Width
Sprue	150mm	Exit diameter=18mm	Inlet diameter=29
Runner	31mm	100mm	31mm
Ingate (no. of ingate-2)	22mm	25mm	22mm
Sprue well	63mm	63mm	Daimeter39mm

Table-3 Parameters of Feeder

Feeder type	Height	Diameter	Modulus
Top feeder	52.73	105.47	17.57
Side feeder	83.71	83.71	13.95

After calculating the dimensions of gating system the pattern allowances values will be obtained to make the wooden pattern.The mould cavity is produced by placing the pattern in a wood frame, filling it with the silica sand proper ramming the sand mix with the pattern in it to give the mould strength. After that the pattern is removed, now 6061T6 Aluminium alloy is then charged into the furnace to get molten metal after melting up to required Temperature it is further heated because pouring temperature is always greater than melting temperature. After solidification and cooling casted component is taken out by breaking the mould. Design calculations of the gating system are shown in the Table-2 and design parameters of the feeder are shown in the Table-3. Proper design of gating calculations helps to avoid aspiration effect, turbulence, air entrapment, sand inclusion, oxide film and dross during pouring molten metal into the casting cavity. From the feeder design calculation it has been seen that the dimensions of height, diameter and modulus for top feeder are 52.73, 105.47 and 17.57 respectively and for side feeder 83.71, 83.71, 13.95

Conclusion:

To achieve good quality of a casting (circular component) . Deign calculations of gating system for 6061T6 aluminium alloy casting with a non-pressurized gating system of gating ratio 1:4:4 in a silica sand molding process are calculated along with feeder design parameters to avoid shrinkage defects in the casting. Proper feeder design parameters and its location are important because it will help to transfer shrinkage defect into the feeder and provide extra material when it is required. With the help of proper design of gating system & feeder, defect free casting can be achieve.

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