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Gating System and Feeder Design of Aluminium Alloy (AA6063) Casting for Rectangular Component

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Abstract – In around 80% of components are manufactured by casting process. So there is a lot of scope for improvement in quality of casting. In today, many industries are struggling for good quality of casting. Quality of casting is dependent upon flow of liquid melt through gating system. In other words, liquid melt should enter into the mold cavity within solidification time of melt, so proper design of gating system is essential study of this project. Proper gating system design reduces the turbulence in the flow of molten metal, minimize air entrapment, sand inclusion, oxide film and dross. The problems caused by improper gating system design are aluminium oxide films, cuts and washes, low casting yield and entrapped gas. This study describes the design of a gating system and feeder to produce Aluminium alloy casting of rectangular component having length 55mm, breadth 30mm and height 30mm using the non-pressurized gating system with ratio of 1:4:4 and green sand moulding technique. Thus 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 aluminium alloy casting produced in green sand moulding process through proper gating system design and feeder design.

Keywords— Gating System Design, Feeder Design, Green Sand, Aluminium Alloy, Rectangular Component.

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INTRODUCTION

Casting processes are widely used to obtain complicated shapes of metal parts with little or no machining in a very economical way. The manufacture of a part involves several steps (a) Design of part itself (b) Specification of material (c) Design of gating system (d) Design of rigging system (feeder). Two major casting design considerations are the quality of the final product and the yield of the casting; both are dependent on the rigging system used.

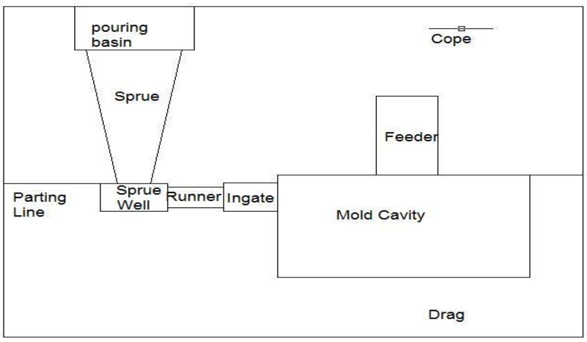

Fig. 1 Schematics of the Mold Cavities in Casting

The elements shown in the fig. 1 are actually cavities in the sand mold. The sand mold consists of two parts: the upper half, or cope and the lower half, or drag. The plane between the cope and the drag is called the parting plane. The parting plane is sometimes referred to as the parting line when the casting is viewed in two dimensions. The vertical passage through which the molten metal is poured into the casting is called the sprue or downsprue. The horizontal channels in the parting plane are called the runners. The connections between the runners and the cavity of the part to be cast are called the gates or the ingates. Those extra parts of the casting that feed metal to the casting as it solidifies and shrinks are called the risers or feeders.

S. Guleyupoglu [1] 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 risering practice for light alloy, ductile iron and steel castings. Victor ANJO and Reyaz Khan [2] has explained the gating system design calculations for casting thin aluminium alloy(Al-Si) plates using green sand mould and a non-pressurized gating system with a gating ratio of 1: 4: 4. A coal fired crucible furnace is used for the melting of aluminium alloy and an X-Ray machine is used to see internal defects in casting. C. M. Choudharia et al. [3] he has done study on casting design calculation of cover plate and numerical simulation using AutoCAST-X software. He has produced the casting with the help of silica sand and wooden pattern and finally radiographic test were performed on final casting to see internal defect. Jong Cheon Park and Kunwoo Lee [4] 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. [5] has presented a numerical simulation technique used for optimisation of the runner and gating systems for the hot chamber die casting of a thin-walled magnesium telecommunication part. Dr. B. Ravi [6] 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 and feeder on the basis of simulation software.

The aim of this research is design of gating system for rectangular component and also feeder design calculations for aluminium alloy material.

GATING DESIGN CALCULATIONS

Design calculations of gating system for aluminium alloy is calculated for designing wooden pattern for producing casting component. Design of gating system will help to pour molten metal into mold cavity before solidification temperature of aluminium alloy. Proper gating system will help to avoid turbulence flow of molten metal into the mold cavity.

For the study on aluminium alloys, we shall be using the non-pressurized gating system with a gating ratio of:

$A_s : A_r : A_g = 1 : 4 : 4$ (1)

(Non-pressurized gating ratio)

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.

$A_s = A_c$ (2)

Where, Ac = the cross sectional area of the Choke.

Pattern Allowances:

There are various types of pattern allowances which are named as draft, machining, distortion, shrinkage allowance. Mainly 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.

Turbulence in the metal flow may be caused by excessive velocity of the molten metal, free-falling of the stream while passing from one level to another, vortices formed, or abrupt changes in the flow direction. Sharp changes in the flow direction will form eddies at the corners, and these will cause aspiration of air and mold gases into the molten metal.

Shrinkage allowance for Aluminium alloys is 16mm/m. These allowances shall be added to the pattern parts in the mould cavity.

Pattern Dimension = Actual Dimension + Shrinkage allowance (3)

Original dimensions of component,

Length=55mm,

Breadth=30mm,

Height=30mm.

Pattern length = 55+0.055×16 = 55.88mm

Pattern breadth =30+0.030×16 = 30.48mm

Pattern height =30+0.030×16 = 30.48mm

Step 1: Calculate the total weight of castings

$W = \rho \times V$ (4)

Where: W = total weight of casting,

ρ = density,

V = total volume of casting.

$V = 55.88 \times 30.48 \times 30.48 (10^{-3})^3$

$V = 51914.21\ mm^3$

$W = 2500 \times 51914.21 = 0.1297$ Kg

- Step 2: Calculate the pouring rate and pouring time

Pouring rate formula for non-ferrous gating:

$$R = b\sqrt{W} \quad (5)$$

Where, R = pouring rate,

b = constant, depends on wall thickness; Typical values of b are shown on TABLE I.

TABLE I Values of Constant (b) for Different Casting Thickness

Casting thickness (mm)	Below 6 mm	6-12 mm	Above 12 mm
b -constant	0.99	0.87	0.47

$$R = 0.47 \times \sqrt{0.1297}$$

R = 0.16926 kg/s

$$R_a = \frac{R}{K.C} \quad (6)$$

Where,

R_a = adjusted pouring rate,

K = metal fluidity,

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

$$t = \frac{W}{R_a} \quad (7)$$

Where, t = pouring time.

$$R_a = \frac{0.16926}{1\times0.85} = 0.199129 \text{ kg/s}$$

$$t = \frac{0.1297}{0.199129} = 0.651336 \text{ sec}$$

- Step 3: Calculate the effective sprue height:

The sprue, or downsprue, is the part of the rigging into which the molten metal is poured. The design of the downsprue is crucial in order to avoid initiation of turbulent flow in the rigging 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_{sprue} = 40 mm
- Height of casting in the cope H_1=5 mm
- Total height of casting H_2=30mm, then using equation (8)
- $$H_p = H- 0.5\frac{H_1^2}{H_2} \quad (8)$$
- Where, Hp = effective sprue height.
- $$H_p = 40 - 0.5\frac{5^2}{30} = 39.58 \text{ mm}$$

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:
- $$A_c = \frac{W}{\rho t C\sqrt{2gH_p}} \quad (9)$$
- Where, Ac = 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 ($9.81m/s^2$),
- Ra = adjusted pouring rate (Kg/s)
- t = pouring time (s).
- $$A_c = \frac{0.1297}{2500\times0.65133\times0.8\sqrt{2\times9.81\times39.58\times0.001}}$$
- = 112.985 mm^2

- Step 5: calculation of the sprue inlet area, since sprue exit area A_{sprue_exit} = choke area A_c
- Continuity equation:
- $$A_{sprue-inlet} = \frac{A_{sprue-exit}\sqrt{H_{sprue-exit}}}{\sqrt{H_{sprue-inlet}}} \qquad (10)$$
- Where,
- $A_{sprue-inlet}$ = sprue inlet cross-sectional area,
- $A_{sprue-exit}$ = sprue exit cross-sectional area,
- $H_{sprue-inlet}$ = distance between the ladle and sprue top,
- $H_{sprue-exit}$ = distance between ladle and sprue exit.

$A_{sprue-exit}$ = 112.985 mm2

$H_{sprue-inlet}$ = 50 mm

$H_{sprue-exit}$ = 50+40 = 90 mm

$$A_{sprue-inlet} = 112.985 \times \frac{\sqrt{90}}{\sqrt{50}} = 151.58\ mm^2$$

Radius of the sprue inlet:

$$R_{inlet} = \sqrt{\frac{A_{sprue-inlet}}{\pi}} = \sqrt{\frac{151.58}{3.1416}}$$

= 6.946 mm

Radius of the sprue exit:

$$R_{exit} = \sqrt{\frac{A_{sprue-exit}}{\pi}} = \sqrt{\frac{112.985}{3.1416}}$$

= 5.997 mm

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

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

Runner cross-sectional area = 4×112.985

= 451.94 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 cross section = Breath of Runner cross section.
- Length of Runner = 21.25mm and Breath of Runner = 21.25mm.

Ingate cross-sectional area = 4×112.985

= 451.94 mm^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 = 5×112.985 mm^2 = 564.925 mm^2

Sprue well depth = 2×runner depth

= 2×21.25 = 42.5mm

DESIGN OF FEEDER

Risers are reservoirs of molten metal that are used to feed the casting during solidification. The shrinkage occurring during solidification causes voids unless more molten metal can be fed to the potential problem spots. Risers are designed to solidify last and to draw the shrinkage voids out of the casting. Risers also serve as exits for gases and dross entrapped in the metal and as pressure heads to feed thin sections.

For the greatest efficiency, for small casting, riser should be cylindrical.

According to Chvirinos rule:

$$\left(\frac{V}{A}\right)_{riser} > \left(\frac{V}{A}\right)_{casting}$$

Volume of riser = 0.47 × Volume of casting

= 0.47 × (55 × 30 × 30)

= 23265 mm^3

$$\frac{\pi \times D^2 H}{4} = 23265$$

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

$$\frac{\pi}{8} D^3 = 23265$$

$$D^3 = 59243.836$$

$$D = 38.98 \text{ mm}$$

$$H = \frac{D}{2} = 19.49 \text{ mm}$$

For side riser, H = D

$$\frac{\pi}{4} D^2 H = 23265$$

$$\frac{\pi}{4} D^3 = 23265$$

$$D = 30.94 \text{ mm}$$

$$H = D = 30.94 \text{ mm}$$

Modulus of riser:

For top riser, $M = \frac{D}{6} = \frac{38.98}{6} = 6.496$ mm

For side riser M = $= \frac{D}{6} = \frac{30.94}{6} = 5.156$ mm

RESULTS AND DISCUSSION

After the calculations of the gating system dimensions and the pattern allowances values obtained is transfer to the wooden pattern and gating in order to make the mould. The mould cavity is produced by placing the pattern in a wood frame, filling it with the green sand mix and properly ramming the sand mix with the pattern in it to give the mould strength. After the pattern is removed, the mould is assembled back together. Fig. 1 shows the schematics of the mould cavities and gating produced by the wood pattern and gating. Aluminium alloy is then charged into the melting furnace to get molten metal to pour into the mold cavity. After solidification and cooling casting is taken out of the mold and cleaned from sand particles.

Design calculations of the gating system are shown in the TABLE II and design parameters of the feeder are shown in the TABLE III.

Proper design of gating calculations helps to avoid aspiration effect, turbulence in the flow of molten metal, minimize air entrapment, sand inclusion, oxide film and dross while 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 19.48, 38.98 and 6.49 respectively and for side feeder 30.94, 30.94 and 5.15 respectively.

Table II Design Calculations of Gating System

Part	Height (mm)	Length (mm)	Width (mm)
Pouring basin	30	30	30
Sprue	40	Inlet Radius=7	Outlet Radius=6
Sprue Well	25	25	25
Runner	15	22	22
Ingate	10	15	10

Table III Design Parameters of Feeder

Feeder Type	Height (mm)	Diameter (mm)	Modulus (mm)
Top Feeder	19.49	38.98	6.496
Side Feeder	30.94	30.94	5.156

CONCLUSIONS

Deign calculations of gating system for aluminium alloy casting with a non-pressurized gating system of gating ratio 1:4:4 in a green sand molding process are calculated to get good quality of a casting. And also the feeder design parameters are calculated to avoid shrinkage defects in the casting. Proper feeder design parameters and its location will help to transfer shrinkage defect into the feeder. With the help of proper design parameter of gating system and feeder, defect free casting can be produced.

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