METHODING DESIGN IN SAND CASTING, HEURISTIC RULES OF METHODING DESIGN IN SAND CASTING: A REVIEW

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Abstract

The design of gating and risering, or rigging systems as they are sometimes referred to, has been a very important task in producing good quality castings. This paper presents a compilation of common heuristic rules that are used for designing rigging systems in sand mould design. The heuristic rules are extracted from expertise of method engineers and compiled from well known published literature. The rules of thumb are divided into two sections: gating system components and riser configurations. These rules are organized and listed in a way to be easily used for producing sound and economical castings.

Keywords: rigging system, sand casting, methoding design, heuristic rules.

1. Introduction

The mould design requires prior experience [3]. The successful casting of a pre-designed casting is vitally depending upon the skill and experience of the foundry engineer, who performs a task known as the methoding design [4]. Methoding of intricate casting is still considered as an art and not very well documented in technical literature; while few empirical equations are available [5]. Heuristic rules of methoding design are becoming indispensable for producing sound casting.
2. Methoding design
This deals with decision related to tooling including gating system, feeding system, orientation of the casting in the mould, and location of parting line. The designs carried out are based on past experience or using empirical equations that vary with material, geometry and process combination [6, 7,8]. Sound castings heavily depend on the rigging system used.

Even after spending significant resource for casting development, one of the following situations may arise during regular production: Under. Over design: Borderline design: The three design conditions of feeders design are illustrated in Figure 1.3. Heuristic rules
One type of shallow knowledge is heuristic knowledge. George Polya defines heuristic as “the study of the methods and rules of discovery and invention” [9]. Instead of, heuristic is the rule of thumb or empirical knowledge that gained from experience. Heuristics employed in two basic situations: A problem that may not have an exact solution, a problem that may have an exact solution, but not practical [10, 11]. Heuristic rules are applied in many fields such as engineering medicine, and other fields, by using many techniques such as expert systems and fuzzy systems[12-18].

4. Rigging system design
In sand casting process the manufacture of a part involves several steps, the first of which is the design of the part itself, and specification of the material to be used. This information is passed to methods engineer, who will choose the casting process, and then design gating and risering system, necessary to get the molten metal into all regions of the part to produce a sound casting. Ravi identified seven elements associated with rigging system design as reported in [19].

The terms gating system referred to all passage or channels through which the metal enters a mould cavity [20]. Figure 2 shows the elements of gating system: basin or cup. sprue or downsprue, runners, gates or in-gates, and extension or blind ends. There are three types of gating system, top gate bottom gate and side gates. Nearly 40% of casting defects are attributed to faulty design of gating and poor pouring practice [21-23].

Riser (feeder) acts as a liquid reservoir provides liquid to the casting during solidification, serves as a heat reservoir, and creating a temperature gradient that induces directional solidification [24, 25]. Feeders appended to the casting at suitable locations are designed so that the shrinkage defects are contained within the feeders.

5. Heuristic rules of rigging system
The following common rules of thumb that aid the design of rigging system components are compiled from expertise and well known published literature.

![Figure 1](https://example.com/figure1.png)

**Figure 1:** (a) Over design, (b) borderline design (c) under design of feeder

![Figure 2](https://example.com/figure2.png)

**Figure 2:** (a) Cup and sprue (b) Runner, in-gates and well shape
5.1 Gating system rules
The rules of thumb of gating system elements are organized and listed as follows:

1. Part orientation rules:
Orientation of the part refers to the cavity in the mould in the shape of the part that is going to be casted. The rules are[26, 27]:
- Orient the part so that the large part of the casting is relatively low.
- Place open space down.
- Orient the part so that the thin part of the casting is low [28].

2. Parting line rules:
- Place the parting line at the cross-section of the largest area of the casting
- Place the parting line as low as possible relative to the casting [29].
- The internal angle of the mould walls at the parting line is less than 5°.
- It divides the part surface into separate regions, each produced by a different mould segment.

3. Cups rules:
- Pouring cups selection, whether external or cut in the moulding sand.
- Basin separates dross and slag from molten metal.
- Pouring of molten metal in the cup to be carried out at a point that is remote from the sprue hole
- Skimmer, filter or delay screen can be used in the cup to provide cleaner metal into the mould

4. Sprue rules:
- The sprue should be sized to limit the flow rate of molten metal.
- Rectangular cross-section sprue better than circular ones with same cross-section area.
- For non-ferrous, rectangular tapered is recommended.
- Generally, rectangular sprue is used to avoid vortex. Round sprue with small height and radius do not cause vortex.
- Choke area controls the sizing of gating component.
- Choke area can be calculated using the following formula [30].
\[
A = \frac{W_C + W_R}{Cpt\sqrt{2gS_L}}
\]
Where: \(W_C\) is weight of the casting, \(W_R\) is weight of the riser, \(t\) is pouring time, \(\rho\) is density of metal, \(S_L\) is sprue height, and \(C\) is constant
- Height of the sprue \(S_L\) is determined by the casting and the top riser height
\[
S_L = H_S + H_F
\]
For top gate \(H_S = 0\), for parting line gate \(H_S = \) half of casting height and for bottom gate \(H_S = \) the height of the casting. \(H_F\) is feeder height
- Sprue should be located as far from the gate as possible.
- The sprue should be located centrally on the runner with equal gates on each side.
- The sprue should be tapered by approximately 5% minimum to avoid aspiration and falling of metal.
- Unclean metal must be washed out in a well below the sprue.
- Well area for sprue box is 2-3 times the choke area.
• The well, is about 1.27 cm deeper than runners.

5. Runner rules:
• Standard sizes and shapes are used for runners.
• Rectangular cross-sections are preferred in sand mould.
• Runners run along the part for long part.
• Sharp edge must be fillet.
• Blind ends are 2.5 to 30.4 cm long.
• Runners are sized using gating ratio, for copper alloy range 1:2:2 - 1:4:4 and for aluminum 1:2:1 - 1:4:2 gating ratio is choke: in-gate area [19].
• The best thing is to keep part of the runner above and part of it below.

5.1. Gate rules:
Woldman asserts that a good gate design is independent of the alloy cast [31].
• Gate into thick regions.
• Rectangular gate are mostly used.
• Orient the gates in the direction of the natural flow path.
• Fillets between the gates and the casting are desirable.
• A slight flare between the castings is desirable.
• The number of gates is determined by casting base feature.
• The maximum gate thickness should be 0.64 - 0.95 cm.
• The first gate located at a minimum 3.81 cm distance away from sprue for small castings and 30-38 cm for large castings.

• Minimum gate length of 1.9 cm for small casting and 10.16 cm for large casting [20].

5.2. Feeder rules
The first six rules are general rules, suggested by Cambell [32].
• The feeder must solidify at the same time or later than the casting.
• The feeder must contain sufficient liquid to meet the volume -contraction requirements of the casting.
• The junction between the feeder and the casting should not create a hot spot.
• There must be path to allow feed to reach feeding point.
• There must be sufficient pressure differential requirement to cause the feed material to flow in the right direction.
• There must be sufficient pressure at all points in the casting to suppress the formation of cavities.
• Feeders are attached to heavy sections of castings and hot spot [33].
• Use the direction of the thermal gradient to detect the hot spot [20]
• Use of side risers is common for thin wall casting.
• Side feeders are usually located on top of the gates.
• Top feeders are used for thick casting.
• Top feeders are located on bosses, away from the gates.
• If the top feeder or side feeder is open to atmospheric pressure the height to diameter ratio is 1:1 to 2:1.
Feeders considered as a liquid and heat reservoir.

- Feeders are sized by the volume fed. In case of multiple risering, each riser is considered to be feeding a part of the casting.
- If it is necessary to use multiple feeders, they should be located at 10.16-12.7 cm apart.
- If two nearby thick sections are fed, thin section in between may contain porosities. The problem may be avoided by risering one thick section and chilling the other.
- The maximum feeding distance depends upon whether the alloy is of the short freezing range or long freezing range.
- The cross section of the feeder is slightly larger than the section it feeds.
- The design of feeder based on Chvorinov rules to ensure adequate feeding and have been widely investigated [34,35,36], which states that the total freezing time \(T_f\) in the casting of the volume \(V\) given by:

\[
T_f = B \left( \frac{V}{A} \right)^2
\]

Where \(B\) is a constant for given metal and mould condition, \(A\) is the surface area.

- Type of feeders and location of dimension as shown in Figure 3.
- For the design of feeder, N.R.L method may be used for thin section casting as shown in Figure 3

\[
SF = \frac{L + W}{T}
\]

by feeder

\[
Y = 2.51SF^{-0.74}
\]

\[
V_R = Y \cdot V_C
\]

Where: \(L\) is the length of the casting, \(W\) is the width of the casting, \(T\) is the thickness of the casting, \(SF\) is the shape factor, \(V_R\) and \(V_C\) is the weight of riser, and casting respectively.

6. Conclusion

A collection of gating system and feeders design common heuristic rules are presented in a way that is to be easily used. From the rules of gating system design, it can be observed that the geometric features of the casting such as casting boundaries, parting line, orientation of casting and flow path are essentially for the design of gating system. Also, from the feeders rules of thumb it can be observed that, beside the geometric feature of casting, solidification rate, directional solidification and location of gating system are important factors of feeders design.

![Figure 3 Riser volume to casting volume, plotted equation originally from [37] based on data from [38]](image-url)
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