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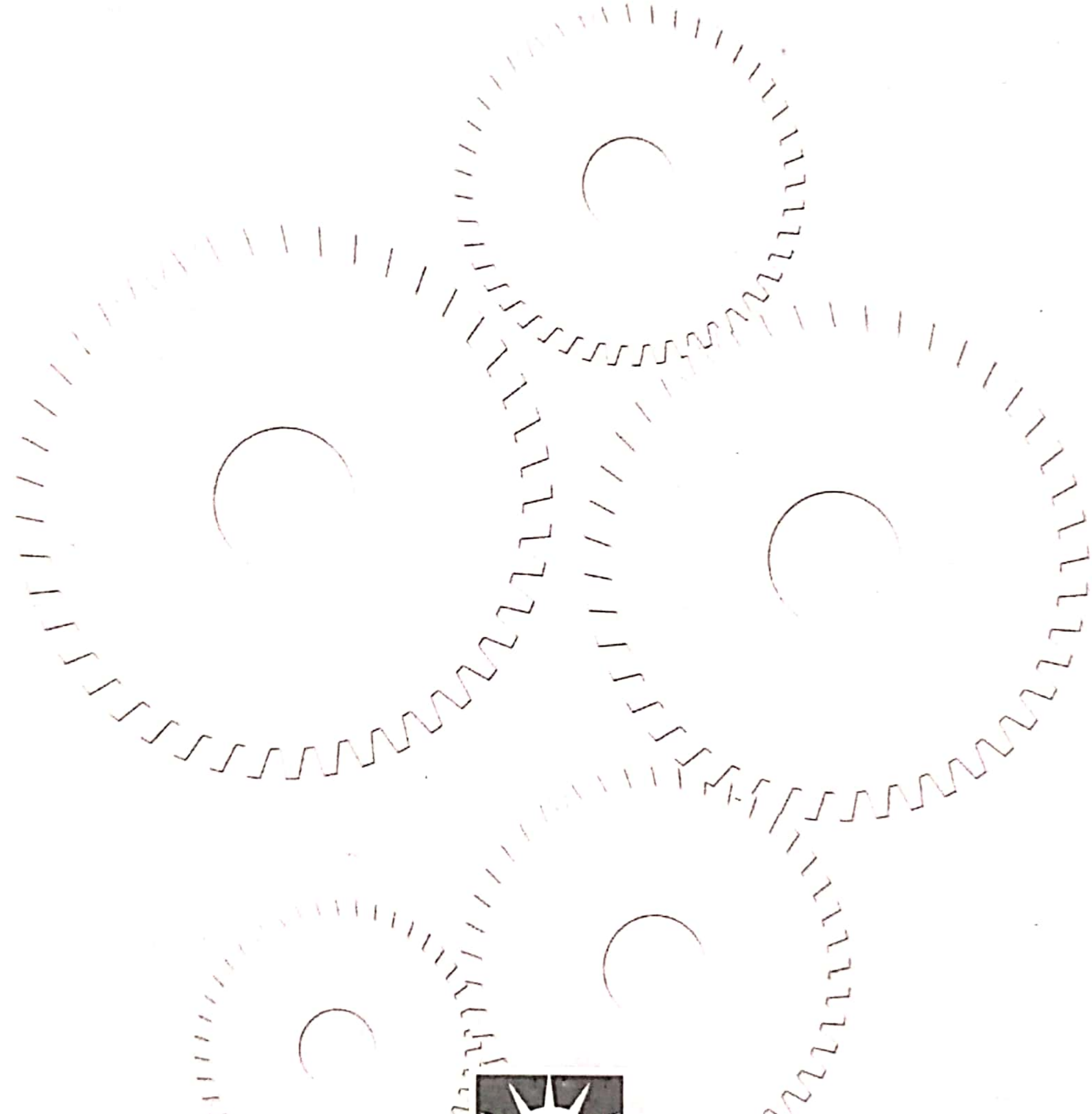

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IUP Publications
(A Division of ICFAI)
52, Nagarjuna Hills, Panjagutta
Hyderabad 500082, Andhra Pradesh, India
Tel: +91(40)23430448
E-mail: jms@iupindia.in; info@iupindia.in
Website: www.iupindia.in

Send your feedback to

The Editor, IUP Publications
(A Division of ICFAI)
52, Nagarjuna Hills, Panjagutta
Hyderabad 500082, Andhra Pradesh, India
Tel: +91(40)23430448
E-mail: info@iupindia.in

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Focus

Hydrodynamic journal bearing has varied industrial applications. As it has a significant role, its design should be quite accurate. Conventionally, it is designed using various charts and tables relating to its performance, because of which it is observed to consume more time. Of late, it is also felt that conventional designing is not accurate enough. That is how designers have switched over to CAD. Normally, design of hydrodynamic journal bearing takes two parameters—operating parameters and performance parameters—into consideration. Operating temperature of the bearing is considered to be one of the significant performance parameters that needs to be ascertained for a safe operation of the bearing. Against this backdrop, the authors, K Tripathi, S Rajput and S Gadakh of the first paper, "Effect of Various Bearing Design Parameters on the Operating Temperature of Hydrodynamic Journal Bearing", have attempted to design a bearing based on heat balance adapting CAD process since it is believed that bearing designing being an iterative process CAD will provide more accurate, optimum, easy and fast calculation. They have also assessed the effect of various other parameters such as oil grade, lubrication system, bearing housing geometry, R/C and L/D on the operating temperature of the bearing. Their study revealed that CAD gives more precise results and fast design—many iterations of the design can be tried and compared to get the optimum design pretty fast.

In the next paper, "Pattern and Feeder Design for the Production of Gray Cast Iron Brackets", the authors, Mary Adebola Ajiboye, Matthew Sunday Abolarin and Johnson Adegbenga Ajiboye, have reported their efforts to design and develop the manufacturing process of pattern and riser systems for sand casting operation of gray cast iron bracket with least casting defects such as porosity and incomplete filling. They have used a riser to feed metal to the casting as it solidifies. The riser was designed to be large enough so that it solidifies only after casting and also to contain a sufficient volume of metal capable of supplying to compensate the shrinkage contraction that occurs on cooling and completion of solidification. Using the feeder design so evolved in the study, the authors have produced two bracket castings.

Moving away from designing to Total Productive Maintenance (TPM) that originated in Japan in 1971 as a critical adjunct to lean manufacturing, essentially by improving machine availability through better utilization of maintenance and production resources, we have the next paper, "Implementation of Kaizen Techniques in TPM", the authors, M S Prabhuswamy, K P Ravi Kumar and P Nagesh, have presented their findings of implementing Kaizen to eliminate problems of the shop floor in an automobile industry. They have concluded that implementation of TPM using Kaizen improved the machine utilization, operator's morale and productivity. Its implementation reduced breakdown hours while simultaneously improving the availability, performance efficiency and also the rate of quality of output. Implementation of Kaizen was found to reduce breakdowns in boring machine to two hours and its OEE had gone up from 59% to 73.6% resulting in increased profits for the company.

The last paper, "Investigation of Mechanical and Tribological Properties of Polymer Composite Material: A Review", by Abhay Kakirde, Kartikey Tripathi, Vishal Achwal and Shilpa Tripathi, presents a review of the current research status of mechanical and tribological properties of polymer composite material. It reviews the current approach in designing various mechanical and tribological testing of polymeric composites in order to operate under low friction and low wear. The authors claim to have focused more on reinforced polymers with special pillars including nanoparticles. The review however, sounds incomplete for there is hardly any coverage of research carried out after 2006. Nonetheless, the review is comprehensive.

GRK Murty
Consulting Editor

Pattern and Feeder Design for the Production of Gray Cast Iron Brackets

Mary Adebola Ajiboye*, Matthew Sunday Abolarin**
and Johnson Adegbenga Ajiboye***

In this paper, the design and production of sand casting for a gray cast iron bracket was carried out. The bracket was divided into different sections called Appendages A, B, C and D, and Ribs E and F. Efficient feeder design is important so as to minimize casting defects such as porosity and incomplete filling to the barest minimum. The feeder or riser is used to feed metal to the casting as it solidifies; therefore they are designed and positioned such as to ensure filling the cavity during solidification. The implication of this is that the riser must be designed to be large enough so that it solidifies only after the casting and it should contain a sufficient volume of metal capable of supplying the shrinkage contraction which occurs on cooling from the casting temperature to the completion of solidification. Based on the feeder design in this work, two bracket castings were produced.

Keywords: CAD, Appendages, Ribs, Modulus

Introduction

Casting is known to have existed for well over 6000 years. The major applications are in statutes for idols used for worship, lamps, doors, frames and agricultural implements. Earliest castings include the 11 cm high bronze dancing girl dated 3000-3500 BC. Casting is a process of forming metallic products by melting the metal and then pouring it into a cavity known as the mold and then allowing it to solidify. The molten metal takes the shape of the mold cavity and the product is cleaned and machined to the desired dimension.

Casting has marked advantages in the production of complex shapes, parts having hollow sections or internal cavities, parts that contain irregular curved surfaces and of parts made from metals that are difficult to machine. Because of these obvious advantages, proper consideration must be given in order to reduce casting rejects.

In all manufacturing techniques, the best results and economy are achieved if the designer understands the various options and tailors the design to use the most

* Research Scholar, Department of Computer Engineering, Federal University of Technology, Minna, Nigeria. E-mail: ajiboyemary@gmail.com

** Professor, Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria. E-mail: abolarinmatthew@yahoo.com

*** Lecturer, Department of Electrical and Electronics Engineering, Federal University of Technology, Minna, Nigeria; and is the corresponding author. E-mail: ajiboye2003@yahoo.com

appropriate process in the most efficient manner. The various processes differ primarily in the mold material (whether sand, metal or other materials) and the pouring method (whether gravity, vacuum or high pressure).

Virtually any metal or alloy that can be melted can be casted. The most common ferrous metals include gray iron, ductile iron, malleable iron and steel. Alloys of iron and steel (alloy content of over 4%) are used for high performance application. The most common non-ferrous metals are aluminium, copper, zinc and magnesium-based alloys. Sand casting is the most widely used process for both ferrous and non-ferrous metals and it accounts for approximately 90% of all castings produced. The type of binders used may be inorganic (as in green and dry sand molds) or organic (as in shell molding). A typical green sand foundry involves mainly three groups of activities: pre-casting, casting and post-casting. Pre-casting includes sand preparation, core making, molding and mold assembly. The casting stage involves furnace charging, melting, holding, melt treatment (such as inoculation) and pouring into molds which is then left to cool. Post-casting involves shakeout, cleaning, fettling, shot-blasting and inspection. There could also be heat treatment and machining.

During molding, paths or channels are created. The preparation of molds entirely by hand is slow and costly. In most modern foundries, molds of small and medium sizes are prepared by machines, for mass production, match-plate patterns are normally used (Lindberg, 1990). The path of molten metal during casting process comprises mainly four parts:

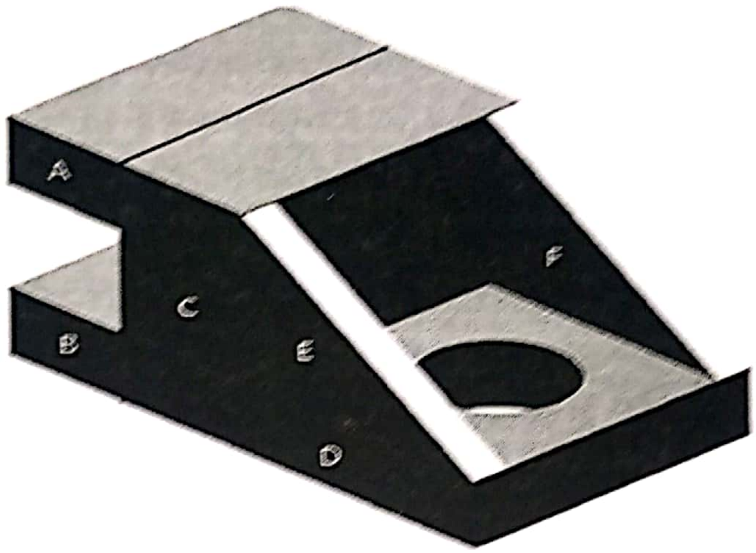
1. Pouring of molten metal from ladle to the cup in the mold.
2. Flow within the gating channels, from pouring basin to ingate through the sprue and runner.
3. Jet molten metal emerging from ingate and entering the mold cavity.
4. Filling of mold cavity by liquid movements in the bulk as well as near the surface.

In general, the entire path of molten metal, within the gating systems as well as the mold cavity, is turbulent in most castings. The major aim of the gating system is to reduce the turbulence (although it cannot be completely eliminated) by ensuring that liquid metal is not poured directly into the mold cavity. As the metal in the casting solidifies, it shrinks. The riser or feeder provides extra liquid material that will seep into these areas so as to prevent shrinkage cavity. The riser is also a heat source, so that they freeze last and promote gradients from a remote chilled area to the riser (Niebel *et al.*, 1989). Researchers and foundry engineers have done so many investigations on the correlation between gating/riser parameters with casting quality (Yang *et al.*, 2000; and Campbell, 2003). There has been an attempt to propose general guidelines for gating/riser system design, however, the variations in casting parameters selected by different researchers have led to considerable difference in empirical guidelines (Rumyoro et al., 1992; and Campbell, 1998).

2. Objective

The purpose of this research is to design and develop the manufacturing process of pattern and risering systems for sand casting operation of gray cast iron bracket. Based on this design, two bracket castings will be produced. The orthographic view of the bracket whose pattern and gating system is to be designed is shown in Figure 1.

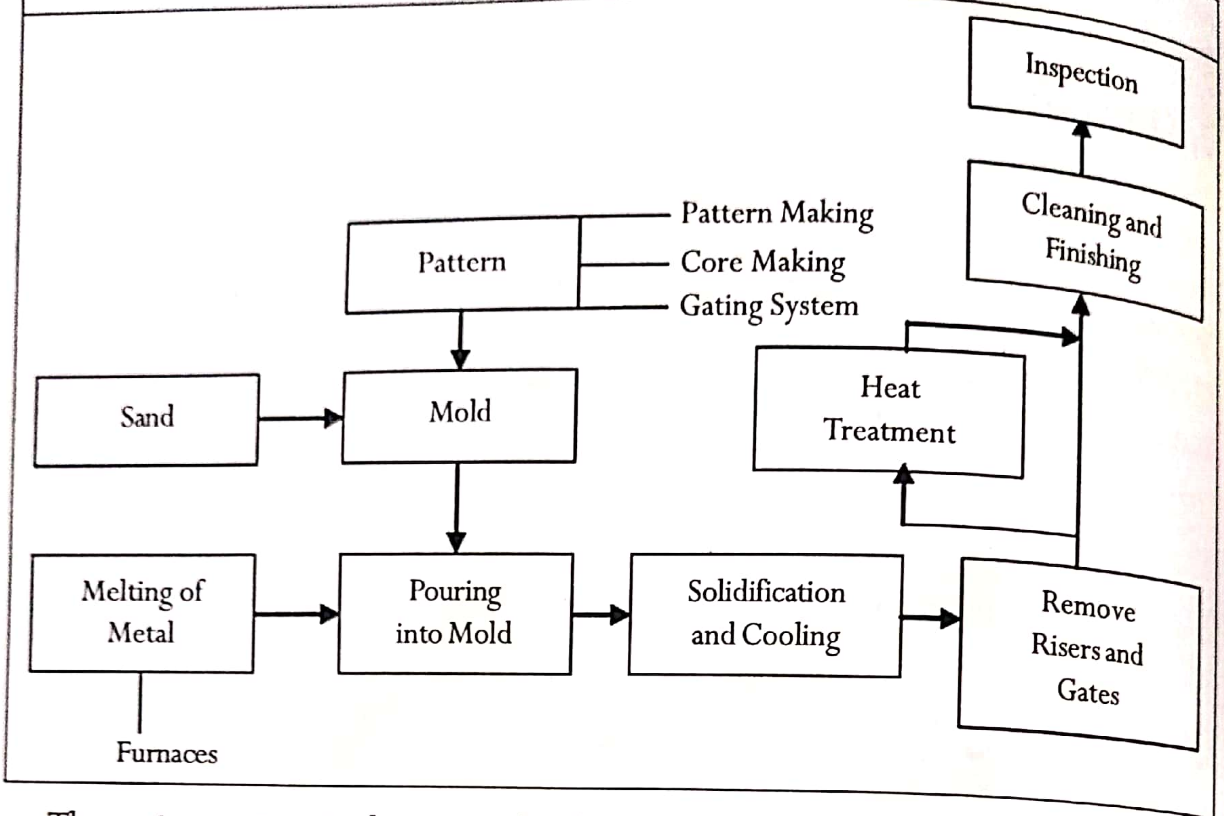
Figure 1: Solid Modeling of the Gray Cast Iron Bracket



3. Sand Casting Process

The casting starts with the construction of a pattern, an approximate duplicate of the final casting (Wikipedia, 2008). The molding material (refractory and binding materials) is then packed around the pattern and the pattern is removed to produce a mold cavity. The flask is the box that contains the molding aggregate. In a two-part mold, the cope is the top half of the pattern, flask, mold or core. The drag is the bottom half of any of these features. A core is a sand shape that is inserted into the mold to produce internal cavity recess on a casting, such as holes or passages for water cooling. A core print is the region added to the pattern, core or mold that is used to locate and support the core within the mold. The mold material and the core then combine to form the mold cavity, the void into which the molten metal will be poured to solidify and produce the desired casting. A riser is an extra void created in the mold that will be filled with molten metal. It provides a reservoir of molten metal that can flow into the mold cavity to compensate for any material shrinkage that occurs during solidification. Any shrinkage voids should then be in the riser and not in the final casting. Figure 2 shows the various processes involved in sand casting (Kalpakjian and Schmid, 2006).

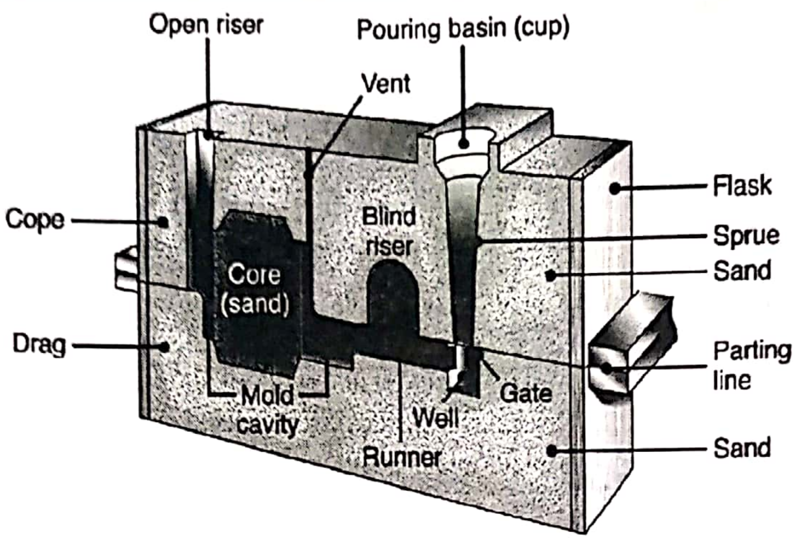
Figure 2: Sand Casting Operation



The gating system is the network of channels used to deliver the molten metal from outside the mold into the mold cavity. The pouring cup is the portion of the gating system that initially receives the molten metal from the pouring vessel and controls its delivery to the rest of the mold. From the pouring cup, the metal travels down the sprue (the vertical portion of the gating system), then along horizontal channels (called runners), and finally through controlled entrances or gates into the mold cavity. As soon as the mold is ready, molten metal is poured into the mold cavity through the pouring basin. The metal is allowed to solidify after which the mold sand is knocked off to bring out the cast for fettling operation. Fettling is the process of removing excess part that does not constitute the required part of the casting such as the sprue, risers and in-gates. It is from here that the casting goes to the machine shop where it is given accurate surface finish (Asuquo and Bobo-Jama, 1991).

Casting has a lot of advantages over other manufacturing processes. Casting can be used to produce complex shapes which may not be possible with other processes. The pattern cost for castings is lower than any other method and the tolerances are usually wider. These factors combine to have a significant effect on making sand casting the least expensive and most commonly used process for the casting of varieties of metals. In sand casting operation, sand free from clay is mulled properly with binder in order to coat the sand grain to produce a mix. Figure 3 shows the cross-section of a typical two-part sand mold and incorporates many features of the casting process.

Figure 3: Schematic of a Sand Mold



4. Pattern Design for the Gray Cast Iron Bracket

To design the pattern for the gray cast iron bracket, shrinkage allowance and machine allowance are considered.

4.1 Shrinkage Allowance

According to Rao (1998), most of the foundry alloys shrink during solidification. The shrinkage or contraction must be considered by making the pattern proportionately larger in every dimension. This is due to the fact that during cooling, the casting is subjected to various effects and therefore to compensate for these effects, corresponding allowances are given in the pattern. The part dimensions are increased by certain amount, depending on the cast metal and type of mold. Also, there must be provision for a feeder that will provide liquid metal to prevent void during solidification (Mikhailov, 1989). The volume of metal in the riser should be sufficient to retain heat long enough to feed the shrinkage cavity and to equalize the temperature in the mold, avoiding casting strains (Little, 1997). It is important to note that the casting shrinks away from the mold wall; this implies that while external dimensions are to be increased, internal dimensions such as diameter of hole are to be decreased. The shrinkage allowances for various metals are shown in Table 1.

Table 1: Shrinkage Allowance for Various Metals

Material	Pattern Dimension (mm)	Section Thickness (mm)	Shrinkage Allowance (mm/m)
Gray Cast Iron	Up to 600	–	10.5
	600 to 1,200	–	8.5
	Over 1,200	–	7
White Cast Iron	–	–	16.0 to 23.0

Table 1 (Cont.)

Material	Pattern Dimension (mm)	Section Thickness (mm)	Shrinkage Allowance (mm/m)
Ductile Iron	–	–	8.3 to 10.4
Malleable Iron	–	6	11.8
	–	9	10.5
	–	12	9.2
	–	15	7.9
	–	18	6.6
	–	22	4
	–	25	2.6
Plain Carbon Steel	Up to 600	–	21
	600 to 1,800	–	16
	Over 1,800	–	13
Chromium Steel	–	–	20
Manganese Steel	–	–	25 to 38
Aluminium	–	–	13
Aluminium Bronze	–	–	20 to 23
Copper	–	–	16
Brass	–	–	15.5
Bronze	–	–	15.5 to 22
Gun Metal	–	–	10 to 16
Manganese Bronze	–	–	15.6
Silicon Bronze	–	–	10.4
Tin Bronze	–	–	10.4
Chromium Copper	–	–	20.8
Lead	–	–	26
Monel	–	–	20
Magnesium	–	–	13
Magnesium Alloys	–	–	16
White Metal	–	–	6
Zinc	–	–	10 to 15

Source: Rao (1998)

Using the value for the gray cast iron from Table 1, and since all dimensions for the bracket are below 600 mm, the shrinkage allowance forthe height, length and breadth of the brackets is calculated thus:

The shrinkage allowance for the height of the brackets is given as:

$$SHR_H = H_{Bracket} \times \left(\frac{10.5}{1000} \right) \quad ...(1)$$

Therefore,

$$SHR_H = 86 \times \left(\frac{10.5}{1000} \right) = 0.90 \cong 1 \text{ mm}$$

The shrinkage allowance for the length of the brackets is given as:

$$SHR_L = H_{Bracket} \times \left(\frac{10.5}{1000} \right) \quad ...(2)$$

Therefore,

$$SHR_L = 143 \times \left(\frac{10.5}{1000} \right) = 1.5 \text{ mm}$$

The shrinkage allowance for the breadth of the brackets is given as:

$$SHR_B = H_{Bracket} \times \left(\frac{10.5}{1000} \right) \quad ...(3)$$

Therefore,

$$SHR_B = 84 \times \left(\frac{10.5}{1000} \right) = 0.88 \text{ mm} \cong 1 \text{ mm}$$

The shrinkage allowance for the core of the brackets is given as:

$$SHR_D = D_D \times \left(\frac{10.5}{1000} \right) \quad ...(4)$$

Therefore,

$$SHR_B = 40.4 \times \left(\frac{10.5}{1000} \right) = 0.42 \text{ mm}$$

4.2 Machine Allowance

Machine allowance is only provided on the surface to be machined. It involves adding material to part surface along the direction of its normal. According to Khanna (1996), allowances for plain machining surfaces are necessary because of the following reasons:

1. Castings get oxidized in the mold during heat treatment and scales, etc.
2. It is intended to remove surface roughness and other imperfections from the castings.
3. It is required to achieve exact casting dimension.
4. Surface finish is required on the casting.

Table 2 shows the various machine allowances on patterns for sand casting.

Table 2: Machine Allowances on Patterns for Sand Casting

Dimension (mm)	Allowances (mm)		
	Bore	Surface	Cope Side
Cast Iron			
Up to 300	3	3	5.5
301 to 500	5	4	6
501 to 900	6	5	6
Cast Steel			
Up to 150	3	3	6
151 to 500	6	5.5	7
501 to 900	7	5	9
Non-Ferrous			
Up to 200	2	1.5	2
201 to 300	2.5	1.5	3
301 to 900	3	2.5	3

Source: Rao (1998)

For the bracket, all the faces are to be machines and therefore the appropriate machine allowance as seen from Table 2 is 3 mm. Therefore, 3 mm will be added to the height, length and breadth. The orthographic view showing the dimensions for the pattern of the bracket is shown in Figure 4, while the actual pattern produced is shown in Figure 5.

Figure 4: Orthographic View of the Pattern for the Gray Cast Iron Bracket

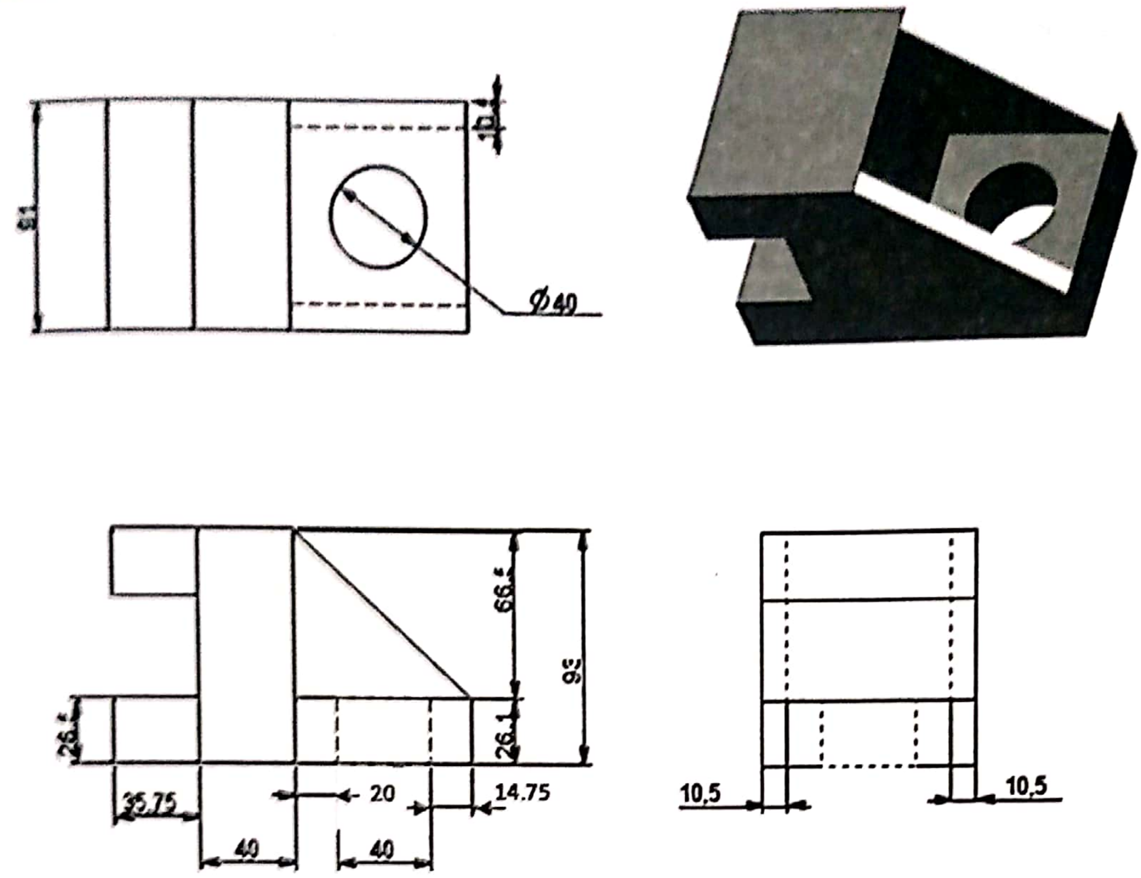
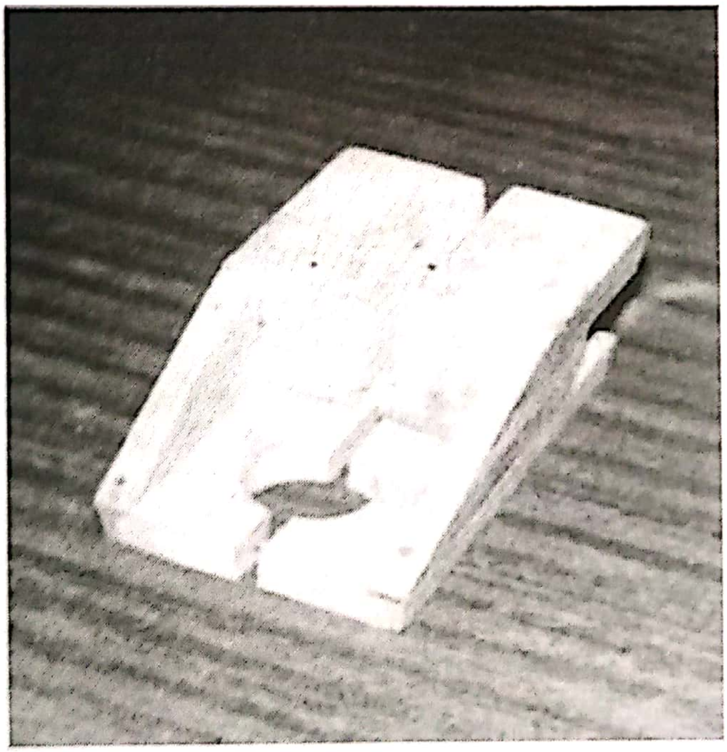


Figure 5: Picture of the Pattern for the Gray Cast Iron Bracket



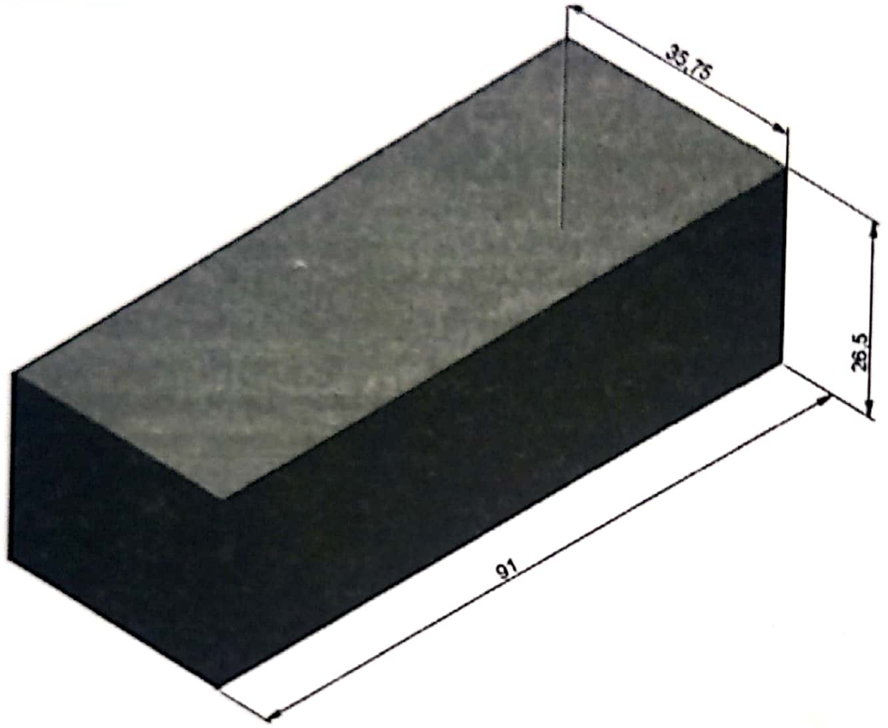
4.3 Determination of the Location of Feeder on the Bracket

The part of the bracket with the largest modulus will be the appropriate portion where the feeder is to be located. We therefore determine the last freezing region.

4.3.1 Calculation of Modulus for Appendages A and B

Appendages A and B have the same dimension, therefore their modulus will be the same. Figure 6 shows the dimensions of both appendages A and B.

Figure 6: Dimensions of Appendages A and B



Therefore, modulus of appendage A or B is given as:

$$MOD_A = MOD_B = \left(\frac{VOLUME_A}{SURFACE_A}\right) = \left(\frac{VOLUME_B}{SURFACE_B}\right) \quad \ldots(5)$$

$$VOLUME_A = VOLUME_B = L \times B \times H = 91 \times 35.75 \times 26.5 = 86211.125 \text{ mm}^3$$

$$SURFACE_A = SURFACE_B = 2(L \times B + B \times H) + (H \times L)$$

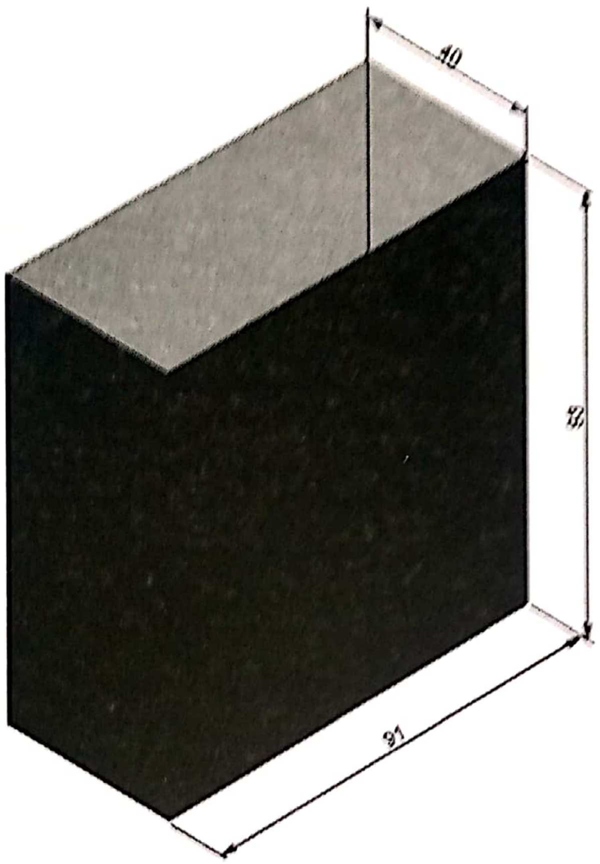
$$SURFACE_A = SURFACE_B = 2(91 \times 35.75 + 35.75 \times 26.5) + (26.5 \times 91) = 10812.75 \text{ mm}^2$$

$$MOD_A = MOD_B = \left(\frac{86211.125}{10812.75}\right) = 7.97 \text{ mm}$$

4.3.2 Calculation of Modulus for Block C

Figure 7 shows the dimensions for both block C. For this region, we assume that the appendages A, B and D, and ribs E and F essentially act like cooling areas owing to their small thickness. Therefore, the cooling surface area is the surface area of the entire block.

Figure 7: Dimensions for Block C



Therefore, modulus of block C is given as:

$$MOD_C = \left(\frac{VOLUME_C}{SURFACE_C} \right) \quad \text{...(6)}$$

$$VOLUME_C = L \times B \times H = 91 \times 40 \times 93 = 338520 \text{ mm}^3$$

$$SURFACE_C = 2(L \times B) + 2(B \times H) + 2(H \times L)$$

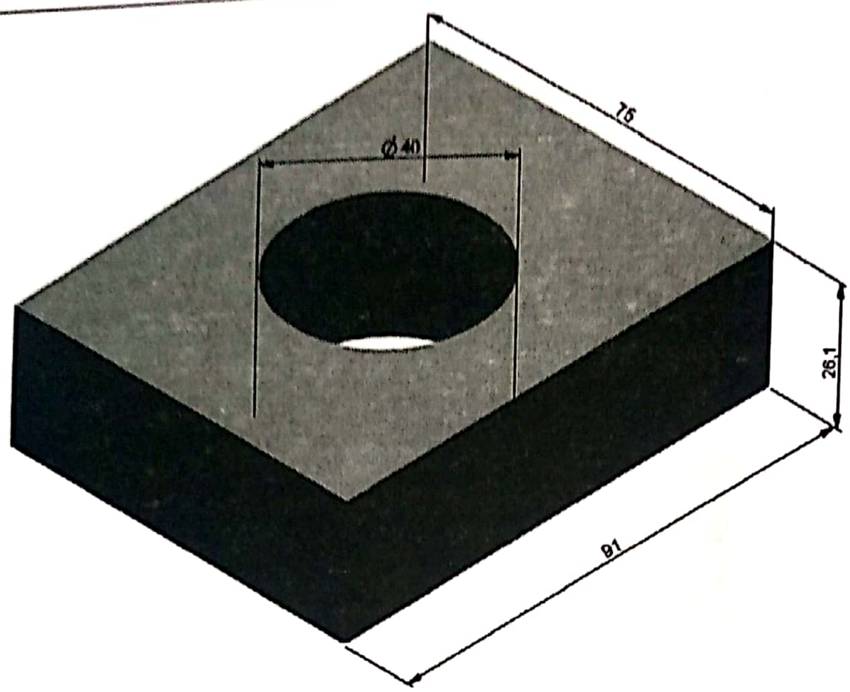
$$SURFACE_C = 2(91 \times 40) + 2(40 \times 93) + 2(93 \times 91) = 31646 \text{ mm}^2$$

$$MOD_C = \left(\frac{338520}{31646} \right) = 10.70 \text{ mm}$$

4.3.3 Calculation of Modulus for Appendage D

Figure 8 shows the dimensions for appendage D

Figure 8: Dimensions for Appendage D



Therefore, modulus of appendage D is given as:

$$MOD_D = \left(\frac{VOLUME_D}{SURFACE_D}\right) \qquad ...(7)$$

$$VOLUME_D = (L \times B \times H) - \left(\pi \times D^2\!/_4 \times H\right) = (91 \times 75 \times 26.5) - \left(3.142 \times 40^2\!/_4 \times 26.5\right)$$

$$= 147557.3 \text{ mm}^2$$

$$SURFACE_D = 2(L \times H) + 2(B \times H) + 2\left(L \times B - \pi \times D^2\!/_4\right) + (\pi \times D \times H)$$

$$SURFACE_D = 2(91 \times 26.5) + 2(75 \times 26.5) + 2\left(91 \times 75 - \pi \times 40^2\!/_4\right) + (\pi \times 40 \times 26.5)$$

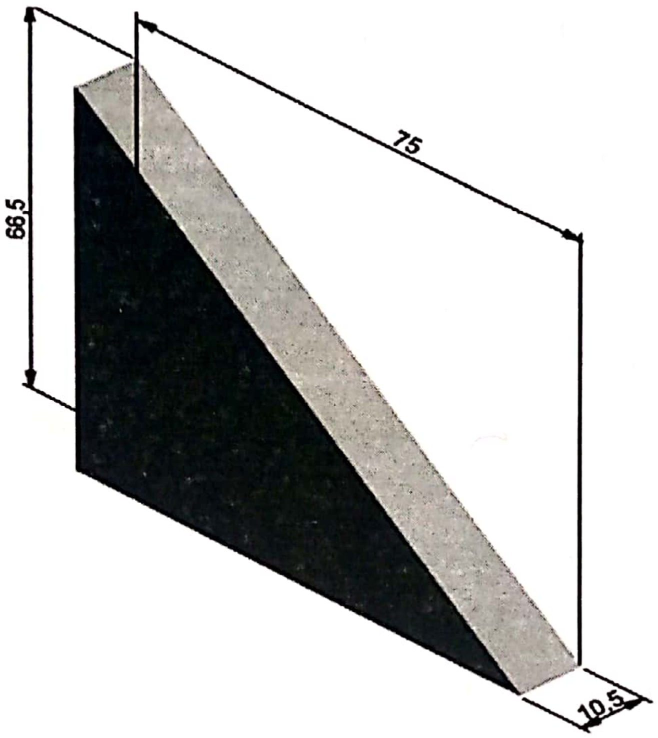
$$= 23264.92 \text{ mm}^2$$

$$MOD_D = \left(\frac{147557.3}{23264.92}\right) = 6.34 \text{ mm}$$

4.3.4 Calculation of Modulus for Rib E

Figure 9 shows the dimensions for Rib E

Figure 9: Dimensions for Rib E



Therefore, modulus of rib E and rib F is given as:

$$MOD_E = MOD_F = \left(\frac{VOLUME_E}{SURFACE_E}\right) = \left(\frac{VOLUME_F}{SURFACE_F}\right) \qquad ...(8)$$

$$VOLUME_E = VOLUME_F = \tfrac{1}{2}(B \times H \times t) = \tfrac{1}{2}(75 \times H66.5 \times 10.5) = 26184.375 \text{ mm}^3$$

$$SURFACE_E = SURFACE_F = 2\left(\tfrac{1}{2} B \times H\right) + \left(\sqrt{B^2 + H^2}\right) \times t$$

$$SURFACE_E = SURFACE_F = 2\left(\tfrac{1}{2} 75 \times 66.5\right) + \left(\sqrt{75^2 + 66.5^2}\right) \times 10.5 = 6040 \text{ mm}^2$$

$$MOD_E = MOD_F = \left(\frac{26184.375}{6040}\right) = 4.34 \text{ mm}$$

In summary, the modulus of each section is as follows:

Appendage A = Appendage B = 7.97 mm

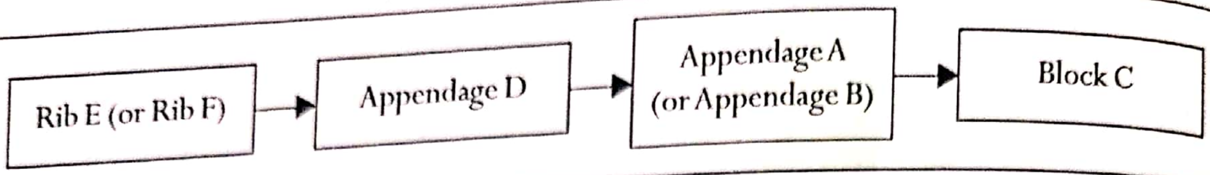
Block C = 10.70 mm

Appendage D = 6.34 mm

Rib E = Rib F = 4.34 mm

Therefore, the order of solidification is given in Figure 10.

Figure 10: Order of Solidification



It implies that block C is the last freezing region with the highest modulus and hence feeder location is most suitable on this region.

The total surface area of the bracket is 88616.42 mm^2 and the total volume is 710868.29 mm^3.

4.3.5 Geometric Properties of Pattern

The total surface area of the pattern is given as:

$$SURFACE_P = SURFACE_A + SURFACE_B + SURFACE_C + SURFACE_D + SURFACE_E + SURFACE_F$$

$$SURFACE_P = 10812.75 + 10812.75 + 31646 + 23264.92 + 6040 + 6040 = 88616.42 \text{ mm}^2$$

The total volume of the pattern is given as:

$$VOLUME_P = VOLUME_A + VOLUME_B + VOLUME_C + VOLUME_D + VOLUME_E + VOLUME_F$$

$$VOLUME_P = 86211.125 + 86211.125 + 338520 + 147557.3 + 26184.375 + 26184.375 = 710868.29 \text{ mm}^3$$

$$VOLUME_P = 710868.29 \times 10^{-9} \text{ m}^3$$

The density of iron is given as:

$$\rho_{Cast} = 7870 \text{ kg/m}^3$$

4.3.6 Determination of Metal-to-Sand Weight Ratio

The dimension for the mold size to be used is 300 mm × 150 mm × (102.5 mm + 102.5 mm).

Therefore, volume of mold is given as:

$$VOLUME_{MOLD} = 300 \times 150 \times 205 = 9225000\ mm^3$$

We are assuming a casting yield of 60%.

$$Casting\,Yield = \frac{VOLUME_F}{VOLUME_M}$$

where $VOLUME_M$ is given as Volume of metal poured and is given as:

$$VOLUME_M = \frac{VOLUME_F}{Casting\,Yield} = \frac{710868.29}{0.6} = 1184780.4\ mm^3 \cong 1184780\ mm^3$$

Therefore, the weight of metal poured is given as:

$$WEIGHT_M = \rho_{Cast} \times VOLUME_M = 1184780 \times 7870 \times 10^{-9}\ kg = 9.32kg$$

The mold sand volume is given as:

$$VOLUME_{MS} = VOLUME_{MOLD} - VOLUME_M = 9225000 - 1184780 = 8040220\ mm^3$$

The mold sand density is given as:

$$\rho_{MOLD} = 1600\ kg/m^3$$

Therefore, the mold sand weight is given as:

$$WEIGHT_{MS} = \rho_{MOLD} \times VOLUME_{MS} = 1600 \times 8040220 \times 10^{-9} = 12.86\ kg$$

Metal-to-sand weight ratio is therefore given as:

$$WEIGHT_M : WEIGHT_{MS} = 9.32 : 12.86 = 1 : 1.38$$

4.3.7 Feeder Design Based on Modulus Principle

For the feeder, the choice of a cylindrical feeder with height to diameter ratio of 1.5 was made. Assuming there is no heat transfer from the entire bottom face of the feeder, we recalculate the modulus of the last freezing region and correct the feeder dimensions through a second iteration.

$$H_F = 1.5D_F \quad \text{...(9)}$$

where H_F is the height of feeder, and D_F the diameter of feeder.

Therefore, the volume of the feeder is given as:

$$V_F = \frac{\pi \times D_F^2 \times H_F}{4} = \frac{\pi \times D_F^2 \times 1.5 D_F}{4} = 0.375 \pi D_F^3 \quad ...(10)$$

The surface area of the feeder is given as:

$$A_F = \frac{\pi \times D_F \times 1.5 D_F}{4} + \frac{\pi \times D_F^2}{4} = 1.75 \pi D_F^2 \quad ...(11)$$

The modulus of the feeder is given as:

$$M_F = \frac{V_F}{A_F} = \frac{0.375 \pi \times D_F^3}{1.75 \pi \times D_F^2} = 0.214 \pi D_F \quad ...(12)$$

$$M_F = 1.2 \times \textit{Modulus of Region around Hot Spot} = 1.2 \times MOD_C \quad ...(13)$$

Since MOD_C is 10.70 mm, we equate Equation (12) and Equation (13)

$$M_F = 1.2 \times 10.70 = 0.214 \times D_F \quad ...(14)$$

$$D_F = \frac{12.84}{0.214} = 60 \text{ mm} \quad ...(15)$$

Since $H_F = 1.5 D_F$,

$$H_F = 1.5 \times 60 = 90 \text{ mm}$$

The modified surface area of last freezing region is therefore given as:

$$SURFACE_{MODIFIED} = SURFACE_C - AREA_{FB}$$

where $AREA_{FB}$ is the area of feeder bottom

$$SURFACE_{MODIFIED} = 31646 - \left(\frac{\pi \times 60^2}{4}\right) = 28818.2 \text{ mm}^2$$

The modified modulus of last freezing region is given as:

$$MOD_{MODIFIED} = \frac{VOLUME_C}{SURFACE_{MODIFIED}} = \frac{338520}{28818.2} = 11.75 \text{ mm}$$

The modulus of feeder is again modified as shown below:

$$M_{SF} = 1.2 \times MOD_{MODIFIED} \qquad \ldots(16)$$

$$M_{SF} = 1.2 \times 11.75 = 14.10 \text{ mm}$$

Again,

$$M_{SF} = 0.214 D_F$$

Therefore $14.10 = 0.214 D_F$

$$D_F = \frac{14.10}{0.214} = 65.89 \text{ mm}$$

This is the new modified diameter of feeder. The new modified height of the feeder is calculated thus:

$$H_F = 1.5 D_F = 1.5 \times 65.89 = 98.83 \text{ mm}$$

For a top position feeder, the height of neck is given as:

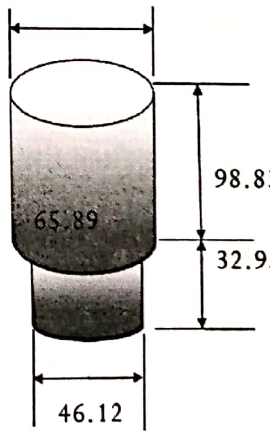
$$H_N = \frac{D_F}{2} = \frac{65.89}{2} = 32.95 \text{ mm}$$

The diameter of neck can be obtained thus:

$$D_N = 0.7 \times D_F = 0.7 \times 65.89 = 46.12 = 46.12 \text{ mm}$$

The dimension for the feeder and the neck is shown in Figure 11.

Figure 11: Feeder Dimension for the Gray Cast Iron Bracket



4.3.8 Feeder Yield

The feeder yield is given as:

$$Y_F = \frac{VOLUME_P}{VOLUME_P + VOL_{FEEDER}}$$

where VOL_{FEEDER} is the volume of the feeder including the neck

$$VOL_{FEEDER} = \frac{\pi \times 65.89^2 \times 98.83}{4} + \frac{\pi \times 46.12^2 \times 32.95}{4} = 337034.22 + 55052.90$$

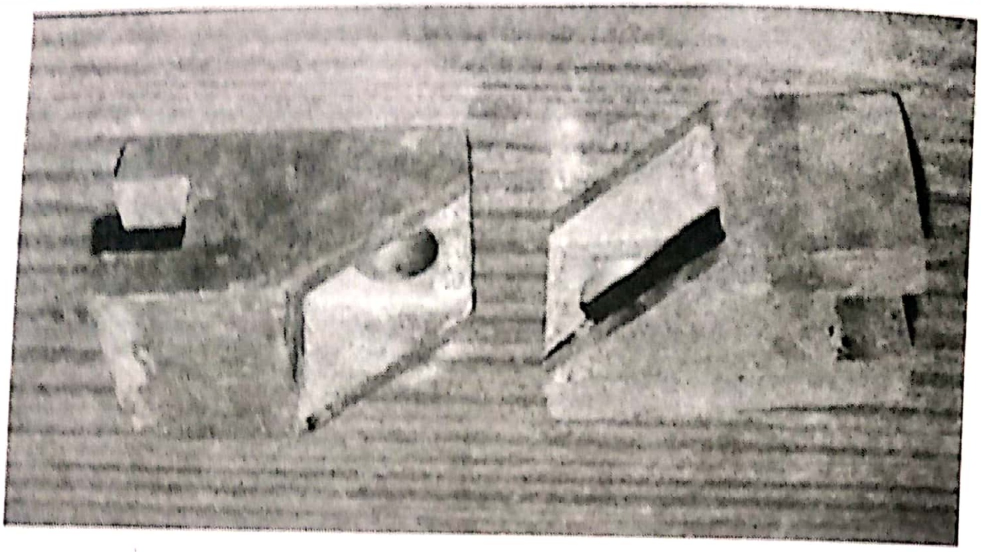
$$= 392087.12 \text{ mm}^3$$

Therefore, the feeder yield is given as:

$$Y_f = \frac{710868.29}{710868.29 + 392087.12} = 0.65 = 65\%$$

Based on the design of the feeder, Figure 12 shows the picture of the two brackets produced.

Figure 12: Gray Cast Iron Brackets Produced



Conclusion

A riser or feeder is a reservoir built into a metal casting mold with the aim of preventing formation of cavities due to shrinkage. Because metals are less dense as liquids than as solids (with some exceptions), castings typically shrink as they cool. This can leave a void, generally at the last point of solidification. Feeders prevent this by ensuring adequate provision of molten metal at the point of likely shrinkage, so that the cavity formation moves into the riser and not in the casting. Proper design of the feeders is therefore necessary. In this work, the feeder was carefully designed and so it cools only after the rest of the casting.

References

1. Asuquo L O and Bobo-Jama S A (1991), *Foundry Technology*, pp. 115-120, ABIC Publishers, Enugu.
2. Campbell J (1998), "The Ten Castings Rules Guidelines for the Reliable Production of Reliable Castings: A Draft Process Specification", in *Materials Solutions Conference on Aluminum Casting Technology*, pp. 3-19, Chicago.
3. Campbell J (2003), *Castings*, Elsevier Butterworth-Heinemann.

4. Wikipedia (2008), http://en.wikipedia.org/wiki, 2013.

5. Kalpakjian S and Schmid S (2006), *Manufacturing Engineering and Technology*, Fifth Edition, Prentice Hall, NJ.

6. Khanna O P (1996), *Foundry Technology (For Engineering Students)*, pp. 256-257, Dhanpat Rai Publications (P) Ltd., New Delhi.

7. Lindberg R A (1990), *Processes and Materials of Manufacture*, pp. 81-94, 428-440, Prentice Englewood, Cliffs, New Jersey.

8. Little R L (1997), *MetalWorking Technology*, pp. 115-182, McGraw-Hill Company, New York.

9. Mikhailov A M (1989), *Metal Casting*, pp. 112, 119-122, MIR Publisher, Moscow.

10. Niebel W B, Draper A B and Wysk R A (1989), "Modern Manufacturing Process Engineering", *McGraw Hill Series Industrial Engineering and Management*, pp. 265, 282, 323, 333, 356.

11. Rao P N (1998), *Manufacturing Technology, Foundry Forming and Welding*, Second Edition, p. 131, Tata McGraw Hill Publishing Company Limited.

12. Runyoro J, Boutorabi S M A and Campbell J (1992), *Critical Gate Velocities for Film-Forming Castings Alloy: A Basis For Process Specification, Trans, AFS*, pp. 225-234.

13. Yang X, Jolly M and Campbell J (2000), "Reduction of Surface Turbulence During Filling of Sand Castings Using a Vortex-flow Runner", in *Modeling of Casting, Welding and Advanced Solidification Processes* (MCWASP), Vol. IX, pp. 420-427, Aachen, Germany.

Reference # 60J-2013-08-02-01