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Designing and Modeling of Gating System and Feeder for Brass Flange Casting

Niyas M A[1], Akshay P[1], Asmilsha Rahman A.P[1], Pranav [1] Jibi.R[2]
[1]Graduate Students [2]Assistant Professor
Department of Mechanical Engineering, AWH Engineering College Calicut Kerala India

***Abstract*— Casting is one of the most versatile form of mechanical process for producing components, because there is no limit to the size, shape and intricacy of the articles that can be produced by casting. In metal industry sand casting is used to produce a wide variety of metal components with complex geometries. It offers one of the cheapest methods and gives high strength and rigidity even to intricate parts which are difficult to produce by other method of manufacturing. Casting can produce large number rapidly at low cost. Aim of this project is to design and modeling of gating system and feeder for brass flange casting. Design of gating system and riser is one of the major factors for improving the casting quality yield %. CAD model prepared using AUTOCAD and AUTO DESK INVENTOR.**

***Index Terms*—Gating system, Cad, Auto Desk Inventor, Yield.**

I. INTRODUCTION

Casting is one of the most versatile processes capable of being in mass production of items. Automotive industry is the sector which consumes most of casting products. More than 60% of the automotive components are made by casting process. One of the most attractive features of casting is its ability to form any shape in one operation. This results in saving labor costs and avoids any problem which might arise in joining sub assemblies together.

The function of a gating system is to permit the flow of molten metal to the mold cavity at the proper rate without excessive temperature loss free from turbulence entrapped gases and slags.One of the key elements to make a metal casting of high quality is the design of a good gating system. Main aim of this paper is to design a gating system and riser for a brass flange casting. Design of typical elements of gating system must be produced optimum weight of the gating system. Present competitive market always demands high quality defect free product and fast delivery. Green sand mold casting process is used for producing the brass flange casting.

Various solid modeling packages are available in order is to easy model the sand mold. Auto Desk inventor is a basic level software package available. 2D and 3D design of the sand mold make easy understand for various functions of each components of a fixture.

Green sand mold are expendable casting process widely used for producing various casting.

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II. METHODOLOGY

Methodology is the most important element to be considered to make sure the fluent of the project and get expected result. In other words methodology can be described as a frame work. Where it contains elements of work based on objectives and scope of the project. A good frame work can get overall view of the project and get the data easily. This includes literature survey 3D modeling of jig analysis and application of flow process chart.

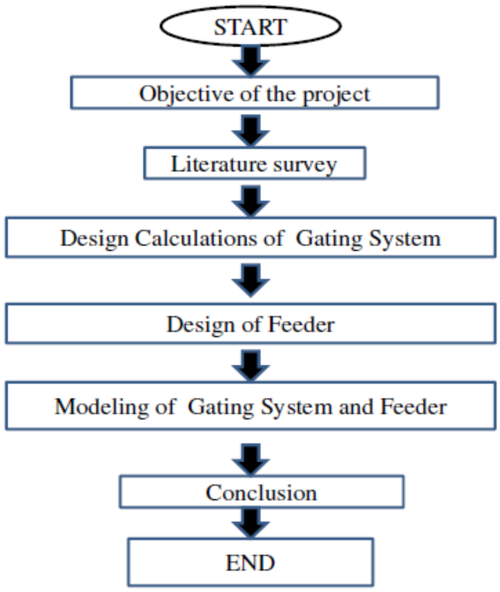

Fig 1: Methodology

III. LITERATURE REVIEW

Sand casting also known as sand molded casting is a metal casting process characterized by using sand as the mold material. Sand casting is relatively cheap and sufficiently refractory even for steel foundry. In addition to sand a suitable bonding agent is mixed or occurs with sand. Sand casting is basically a hot working process plastic deformation is of metal is carried out at temperature above recrystallization temperature .Casting process is classified in to two types expendable mold casting and permanent mold casting. In expendable mold casting the mold is destroyed to remove the casting and a new mold is required for each new casting .In permanent mold casting a single mold can produce large no of products.

- ***Main parts of sand mold***

The figure below shows main parts of sand mold.

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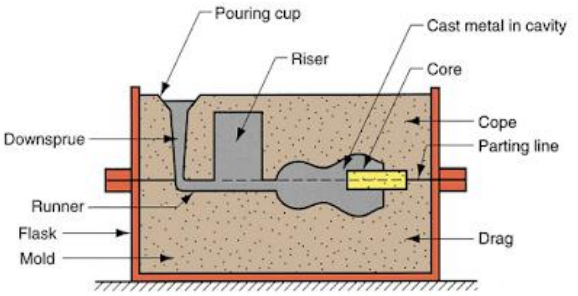

Fig 2: Different Parts of Sand Mold

Cope: It is the top half of sand mold consists of pouring basin, runner, riser, and half portion of mold cavity.

Drag: It is the bottom half of sand mold consist of half of the cavity. Cope and drag are aligned to each other.

Flask: It is generally rectangular boxes on which the moulding sand is filled .Flask are top flask and bottom flask.

Core: This is used to make hole in casting made up of core sand.

Cavity: Which gives outer parts of casting based on the shape of casting it is rectangular circular etc.

Pouring Basin: It is a reservoir at the top of the sprue that receives the stream of molten metal poured from the ladle.

Sprue: A sprue is a vertical channel that connect the pouring basin with runners molten metal is poured in to the pouring basin which is part of gating system that supplies the molten material to mold cavity through sprue and the horizontal portion is called runner and finally to the multiple points where it is introduced to the mold cavity is called the gate.

Riser: Riser is also known as feeder is the most common way of providing directional solidification. It supplies liquid metal to solidifying casting to compensate for solidification shrinkage. For a riser to work properly the riser must solidify after the casting otherwise it cannot supply liquid metal to shrinkage within the casting. Risers are classified in to open riser open to atmosphere and closed riser not open to atmosphere .Based on location if the riser is located on the casting it is known as top riser. If it is located next to casting it is known as side riser.

Chills: Chills are objects used to promote solidification in a specific portion of a metal casting mold. Chills are generally used to increase the cooling rate according to the thickness of casting. There are two types of chills internal chills and external chills. Internal chills are piece of metal that are placed inside the mold cavity, when the cavity is filled parts of the chill melts and ultimately become parts of the casting thus chills must be same material as the casting. The internal chills absorb heat capacity and heat of fusion energy.Ecternal chills are masses of material that have high heat capacity and thermal conductivity. They are placed on the edge of mold cavity and effectively become parts of mold cavity. Chills are made of many material including iron, copper, bronze, aluminum and silicon carbide other sand material with higher densities thermal conductivity or thermal capacity can also be used as a chill..Example chromite sand or zircon sand.

Alignment Pin: Which is use to align top and bottom half of mold.

➢ ***Sand Casting Process***

The figure below shows the different steps in sand casting process.

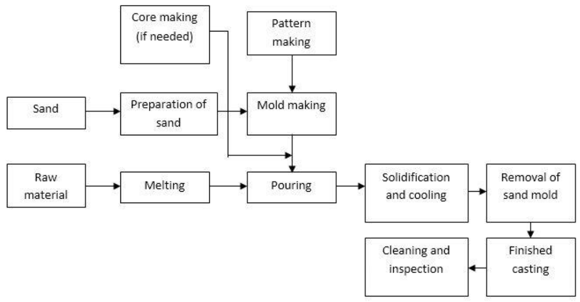

Fig 3: Sand Casting Process

Patterns are made for the top and bottom halfs feeds and risers are added to one of the pattern .Metal or wooden sand boxes are placed on the pattern. Casting sand is poured in to sand box. Then sand is compacted. The sand boxes are turned upside down then patterns are removed. The feed side box is placed on the top of bottom box. Molten metal is poured in to feed hole .The metal solidifies and cools. The top sand box is removed. The part with gating system and feeder is taken out side. Feeds are cut after cleaning and finishing casting moves to final inspection.

➢ ***Patterns***

Patterns are used forming impression in the mold .Pattern is defined as a model of a casting. The first step in the casting process is to making a model pattern. Patterns are generally made of wood or metal. Patterns are used to produce mold cavity. One major requirement is that pattern must be oversized to account for shrinkage in cooling and solidification and also to provide enough metal for the subsequence machining operation. Patterns classifications are given below.

Solid Pattern (Single Piece Pattern): A single piece pattern is the simplest of all forms. They are made in single piece. This type of pattern is used when the product is very simple and can be easily with drawn from the mold. This pattern is contained entirely in the drag. One of the surface usually flat which is parting line surface.


Fig 4: Single Piece Pattern

Split Pattern: In split pattern is split in to two half. One part is contained in the drag and the other part is contained in the cope. The split surface of the pattern is the parting line surface of the mold. Two half of the pattern should be aligned properly by making use of dowel pin which are fitted to the

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top half .This type of pattern is used when depth of casting is too high it is difficult to with draw casting from the mold.

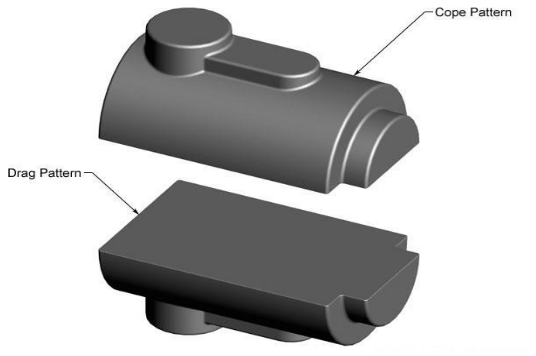

Fig 5: Split Piece Pattern

Multi Piece Pattern: Casting have more complicated design use multi-piece pattern. It is use inorde to facilitate an easy molding and with drawl of pattern. This pattern may consist of three or more number of parts.

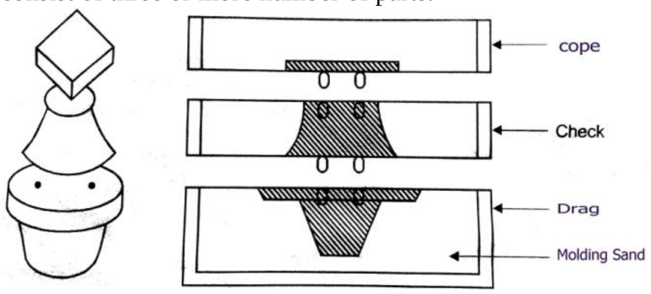

Fig 6: Multi Piece Pattern

Match Plate Pattern: These patterns are made in two pieces. One piece is mounted on one side and the other on other side of a plate called match plate. Gates and runners are also attached to the plate along with pattern. After molding when the match plate is removed a complete mold with gating is obtained by joining the cope and drag together. The complete pattern with match plate is entirely made of metal .Usually aluminum for its light weight and mach inability.

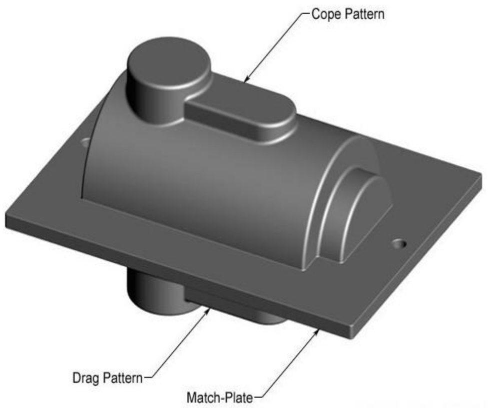

Fig 7: Match Plate Pattern

Gated Pattern: They are used for mass production of small casting. Patterns of casting s are connected to each other by means of gate formers. They form suitable channel or gates in sand casting for feeding the molten metal to these cavities. A single runner can be used for feeding all cavities. This is used where single sand mold carries number of cavities.

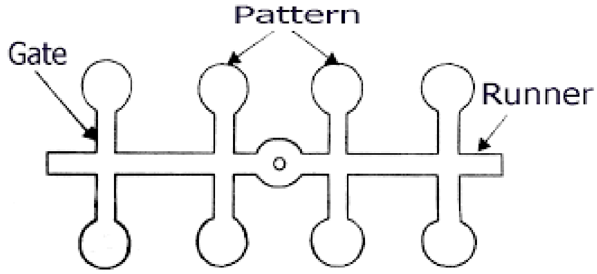

Fig 8: Gated Pattern

Sweep Pattern: Sweep pattern can be advantageously used for preparing moulds of large symmetrical castings. Particularly for circular crossection.The equipment consist of a vertical spindle and wooden template called sweep. The outer end of the sweep carries the contour corresponding to the shape of the desired casting. The sweep rotated is about the spindle to form the cavity. Then the sweep and spindle are removed leaving the base in the sand .The hole made by the removal of spindle is patched up by filling sand.

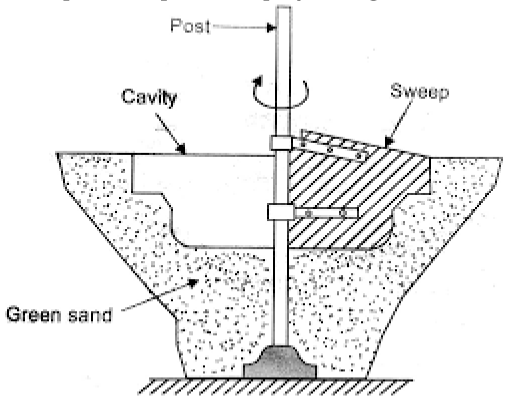

Fig 9: Sweep Pattern

Loose Piece Pattern: It is used to produce undercut. Certain Single piece patterns are made to have loose piece in order to enable their easy with drawal from the mold .These pieces from an integral part of the pattern during moulding. After the mold is completed the pattern is withdrawn leaving the pieces in the sand .These pieces are later withdrawn separately through the cavity formed by pattern.

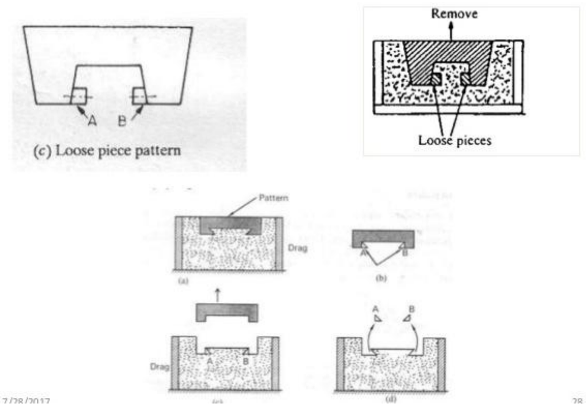

Fig 10: Loose Piece Pattern

Follow Board Pattern: Some casting have certain portions which are structurally weak.If this portion of pattern is not supported properly they are likely to break under the force of ramming. In this case a special pattern called follow board

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pattern is adopted. A follow board is wooden board used to support a pattern during molding.

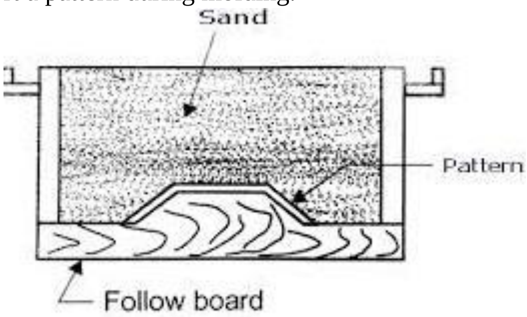

Fig 11: Follow Board Pattern

Segmental Pattern: Those patterns are used for preparing molds of large circular castings avoid the use of solid pattern of exact size. In principle they are similar to sweep patterns, but the difference is that while a sweep pattern is given a continuous revolving motion to generate the desired shape a segmental pattern is a portion of solid pattern itself and the mold is prepared in part by part .It is mounted on central pivot and after preparing the part mold in one position the segment is moved to next position. The operation is repeated till the complete mold is ready.

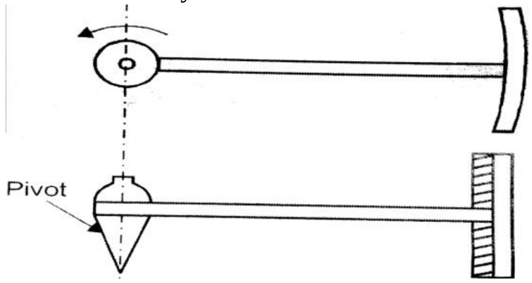

Fig 12: Segmental Pattern

- ***Pattern Allowance***

Pattern is not made exact size as the desired casting because such a pattern would produce under size casting. When a pattern is prepared certain allowances are given on the sizes specified in the drawing so that the finished and machined casting produced from the pattern will confirm to the specified size. Commonly using pattern allowance are given below.

Shrinkage allowance: Generally metal shrink in size during solidification and cooling in the mold. So casting becomes smaller than the pattern and the mold cavity. Therefore to compensate for this mold and pattern should be oversized than the casting. By an amount of shrinkage allowance. Shrinkage of casting varies with material used shape thickness casting temperature mold temperature and mold strength.

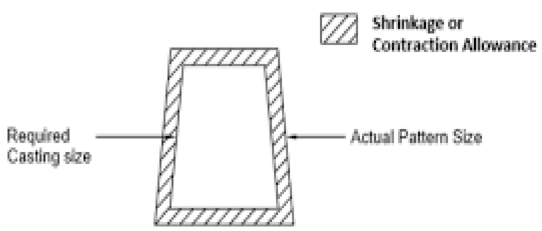

Fig 13: Shrinkage Allowance

Draft allowance: When pattern is drawn from mold there is always a possibility of damaging the edge of the mold. Draft is taper made on the vertical faces of a pattern to make easier withdrawing of pattern out of the mold. Draft is expressed in millimeters per meter on a side or degree. The amount of draft needed depends up on shape of the casting depth of casting molding method, molding material.

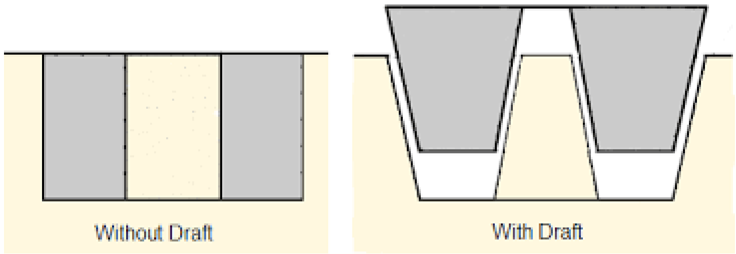

Fig 14: Draft Allowance

Machining or finishing allowance: Incase the casting designed to be machined they are cast over sized in those dimensions shown in the finished working drawing where machining is done the machined parts is made extra thick which is called machining allowance.

Distorton or camber allowance: .Sometimes casting because of their size shape and type of material tend to warp or distort during the cooling period depending on the cooling speed. This is due to uneven shrinkage of different parts of casting.

Expecting the amount of warpage a pattern may be made with Allowance of warpage is called camber allowance.

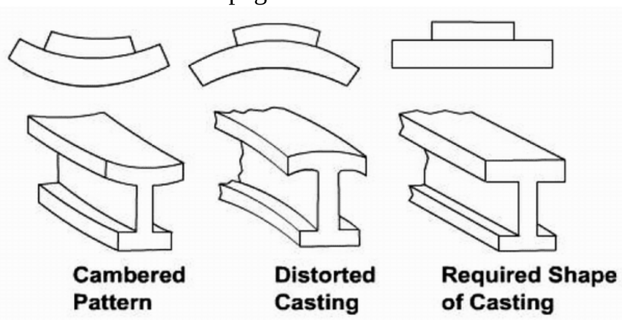

Fig 15: Camber Allowance

Rapping or shaking allowance: when the patter is shaken for easy withdrawal, the mold cavity hence the casting slightly increaseds, the pattern should be initially made slightly smaller. For small and medium casting this allowance can be ignored .But for large size and precision castings shaking allowance is to be considered.

- ***Types of Molding Sand***

The principle raw material used in molding is molding sand .The principle constituents of molding sand are silica alumina and iron oxide with smaller amount of the oxides of Ti Mn and Ca and some alkaline compounds.

Natural sand: It is also called green sand and is collected from natural resources .It contain water as the binder. It has advantage of moisture content as long time.

Synthetic sand: It is artificial sand obtained by mixing relatively clay and free sand binder (water +betonies).It is

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better molding sand as its properties can be easily controlled by varying the mixture.

Green Sand: When sand is in its natural more or less moist state, it is referred to as green sand. It is mixture of silica sand with 18 to 30% clay and 6to8% water. The clay and water give bonding strength to green sand.

Dry sand: Dry sand molding is employed for large casting. The mold prepared in green sand are dried or baked to remove almost all moisture of the sand.

Loam Sand: It is mixture of clay and sand powder with water to a thin plastic paste.

Facing Sand: It is used directly next to the surface of the pattern and it come in contact with molten metal. Since it is subjected to the most severe condition. It must possess high strength and refractoriness.

Backing Sand: The old and repeatedly used molding sand black in colour due to addition of coal dust and burning or coming in contact with molten metal is known as backing sand. It is used to fill the back of backing sand. It is weak in bonding strength because the sharp edge of the sand grains becomes rounded due to high temperature of molten material and burning of clay content.

System Sand: This is used in machine molding to fill the whole flask. Its strength permeability and refractoriness must be higher than those of backing sand.

Parting Sand: The molding boxes are separated from adhering to each other by spreading fine sharp dry sand called parting sand. Parting sand is also used to keep the green sand from sticking the pattern. It is clean clay-free silica sand.

Core sand: It is used for making cores. It is silica sand mixed with core oil.

➢ ***Core***

A core is a body made of refractory material which is set in to the prepared mold before closing .Core is a obstruction which when positioned in the mold naturally does not permit the molten poured metal to fill up the space occupied by the core, thus core is used to produce hollow castings. Cores are used for producing hollow casting; provide external undercut features etc.Core should have high refractory strength,highcollapsibility,smooth surface to ensure smooth casting. There are several types of cores are used in sand casting process depend up on application.

Cores may be green sand core or dry sand core. Green sand core have relatively low strength being made of green sand, where as dry sand cores are made of sand and special binders which develop strength when backed. Next classifications of cores are based on position.

Horizontal core: The core is placed horizontally in the mold and is very common in foundaries.It is usually positioned along the parting line of the mold.

Vertical core: These cores are positioned vertically in the mold. The two ends of the core rest on core seat in cope and drag. The maximum portion of the core is supported in the drag

Balanced core: These cores are used when blinds holes along horizontal axis are to be produced. Core is supported only at one end. The core seat should be sufficient length to prevent its falling in to the mold.

Hanging core: These cores are used when a cored casting to be completely molded in the drag with the help of single piece solid pattern. The core is supported above and hangs in to the mold. A hole in the upper part of the core is provided for the metal to reach the mold cavity.

Drop core: This core is used when a hole which is not in line with the parting surface is to be produced at lower level.

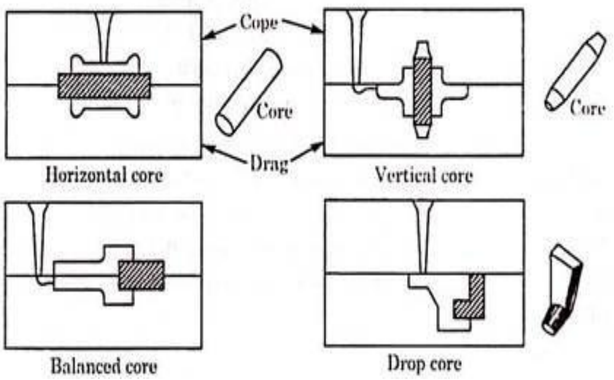

Fig 16: Types of Core

IV. IMPLEMENTATION

➢ ***Brass Flange Casting***

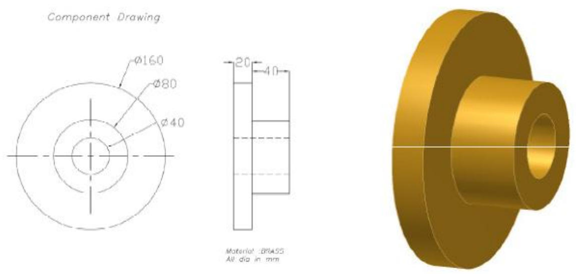

Fig 17: Component Drawing

Brass -Composition

Table1: Brass -Composition

Description	Cu%	Zn%	Pb%	Sn%	Fe%	Ni%	As%
Brass	68.5-72	28-31.5	0.02	0.03	0.03	0.1	0.01

Weight of Casting=4.69kg

Gross weight including casting +Gating system+ Feeder=5.0065Kg

➢ ***Gating System Design Calculations***

1. Selection of gating ratio-Non pressurized gating system.
2. Calculation of pattern allowance.
3. Calculation of total weight of casting.
4. Calculation of pouring rate and pouring time.
5. Calculation of effective sprue height.

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6. Calculation of choke cross sectional area.
7. Calculation of sprue inlet area.
8. Calculation of runner and gate cross sectional area using gating ratio
9. Design of sprue well.

1. ***Selection of gating ratio-Non pressurized gating system.***

Non pressurized gating system with gating ratio

As: Ar: Ag = 1:4:4

As=cross sectional area of sprue exit.
Ar=Cross sectional area of runner.
Ag=Cross sectional area of gate.

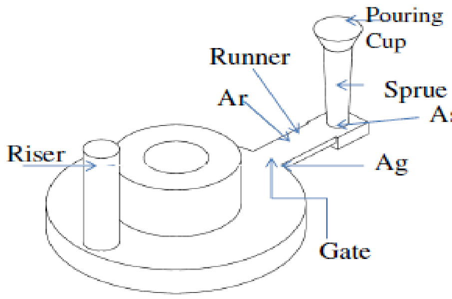

Fig 18: Gating Ratio

2. Calculation of Pattern Allowance.

Pattern Material: Wood. (White Pine).

Pattern Type: Split Type.

Shrinkage allowance for brass 14mm/meter.

Original dimensions of component.

Flange diameter=160mm

Hub diameter =80mm

Inside hole diameter=40mm

Flange length=20mm

Hub length=40mm

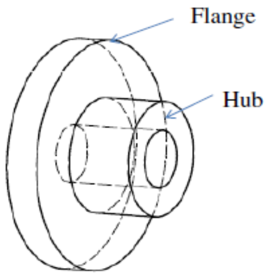

Fig 19: Wire Frame Model of Component

Pattern diameter of flange = 160+(.160x14)=162.24mm

Pattern diameter of hub =80+ (.08x14) =81.12mm

Pattern length of flange =20+ (.020x14) =20.28mm

Pattern length of hub =40+ (.040x14) =40.56mm

Core diameter =40+ (.040x14) =40.56mm

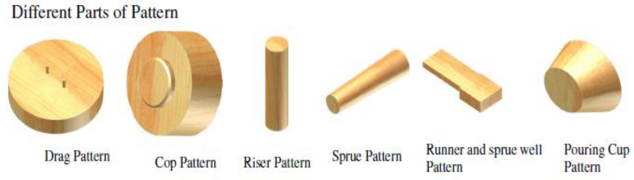

Fig 20: Different Parts of Pattern

Pattern Assembly

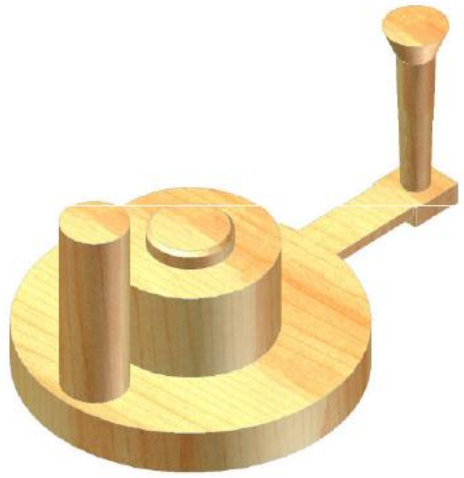

Fig 21: Entire Pattern Assembly

3. ***Calculation of Total Weight of Casting.***

Total weight of casting = ρ x v.

ρ =Density of casting.

v= Total volume of casting.

Density of brass=8500Kg/m^3

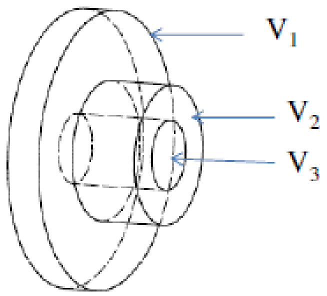

Fig 22: Volumes of Casting

Total Volume of Casting = $(V_1 + V_2) - V_3$

$V_1 = 4.02 \times 10^5 mm^3$

$V_2 = 2.01 \times 10^5 mm^3$

$V_3 = 50265.48 mm^3$

Total Volume of Casting = $(4.02 \times 10^5 + 2.01 \times 10^5) - 50265.48$

$= 552734.5 mm^3$

Total weight of casting = ρ x v.

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$=8500 \times 552734.5 = \underline{4.69 Kg/mm^3}$

4. Calculation of Pouring Rate and Pouring Time.

For Non-ferrous metal

Pouring rate $R = b\sqrt{W}$

Where R=Pouring Rate

b=Constant depend up on wall thickness

W=Weight of casting

Table 2: Value of Constant b

Casting Thickness	Below 6mm	6mm to 12mm	Above 12mm
Constant b	0.99	0.87	0.47

Pouring rate $R = 0.47 \times \sqrt{4.69}$

$= \underline{1.0178 Kg/sec}$

Adjusted Pouring Rate Ra=R/KxC

Where K=Metal Fluidity

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

$Ra = 1.0178/1 \times 0.85$

$= \underline{1.1974 Kg/sec.}$

Pouring Time t = W/Ra

$= 4.69/1.1974 = \underline{3.9168 sec}$

5. Calculation of Effective Sprue Height.

Effective sprue height $H = h - (a^2/2c)$

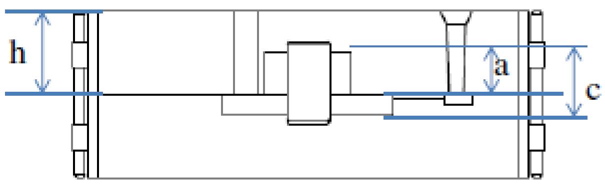

Fig 23: Effective Sprue Height

Where h= Cope box height.

a=Casting height in cope.

c=Total casting height.

Effective sprue height $H = 80 - (40^2/2 \times 60)$

$= \underline{66.66mm}$

6. Calculation of Choke Cross Sectional Area.

It is the minimum cross section area in the entire gating element. The flow rate equation

$Ac = W/\rho t c\sqrt{2gH}$

Ac=Choke area mm^2.

W=Casting Weight Kg.

ρ=Density of molten metal Kg/ mm^3.

H=Effective sprue height mm.

c=Discharge coefficient.

t=Pouring Time (sec).

$Ac = W/\rho t c\sqrt{2gH}$

$= 4.69/(0.0000085 \times 3.9168 \times 0.8 \times \sqrt{2 \times 9810 \times 66.66})$

$= 4.69/0.03046$

$= \underline{153.97 \; mm^2}$

7. Calculation of Sprue Inlet Area.

Sprue exit area Asprue-exit = Choke area Ac

From continuity equation

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

$= 153.97(\sqrt{105}/\sqrt{25})$

Asprue-inlet = Sprue inlet cross sectional area.

Asprue-exit = Sprue exit cross sectional area.

$= 153.97 \; mm^2$

H sprue-inlet= Distance between ladle and sprue top. =25mm

H sprue-exit= Distance between ladle and sprue exit. =105mm

Radius of sprue at inlet

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

$= \sqrt{(315.54/3.14)} \quad = \underline{10.02mm}$

Radius of sprue at exit

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

.

$= \sqrt{(153.97/3.14)} \quad = \underline{7mm}$

8. Calculation of Runner and Gate Cross Sectional Area Using Gating Ratio 1:4:4.

Runner cross sectional area=4xChoke area

$= 4 \times 153.97 = \underline{615.88mm^2}$

Runners have a square cross section

Length of runner cross section=Breath of runner cross section.

Length of runner=24.81mm

Breath of runner=24.81mm

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Gate cross section = 4xChoke area

=4x153.97=$\underline{615.88mm^2}$

9. Design of Sprue Well.

Sprue well cross section area =5xSprue exit area

=5x153.97

=$\underline{769.85mm^2}$

Sprue well depth = 2xRunner Depth

Runner depth = 5mm

=<u>10mm</u>

➢ ***Design of Feeder***

Top Riser, Cylindrical shape, Open type According to Chvirino's rule:

Solidification time of casting $=C_m (V/A)^2$

Mold constant brass material $C_m = 0.61 min/mm^2$

$= 0.61(552734.52/113040)^2$

=<u>14.58Minute</u>

Solidification time of riser=1.25xSolidification time of casting.

=1.25x14.58

=<u>18.225Minute</u>

Solidification time of riser = $C_m (V/A)^2$

V/A Ratio of cylindrical Riser is D/6 (Assumes that D=H)

$18.225 = 0.61(D/6)^2$

<u>D =33mm</u>

➢ ***Modulus of Riser***

Modulus is the ratio between volume to surface area.

(M) Riser> (M) Casting

Modulus of Riser =V/A =68389.2/9144.465=7.47mm

Modulus of Casting=Volume of casting/Surface area of casting

=552734.52/113040=4.88mm

(M) Riser =1.5 (M) Casting

(M) Riser >1.5 (M) Casting

➢ ***Yield or efficiency of Casting***

$$= \frac{\text{Volume of Casting}}{\text{(Volume of casting +Volume of gating system)}}$$

Volume of Casting =552734.52mm^3

Volume of casting +Volume of gating system= 628200mm^3

=552734.52/628200 =<u>87.98%</u>

➢ ***Modeling of Sand Casting Mold.***

Wire frame modeling.

Solid Modeling.

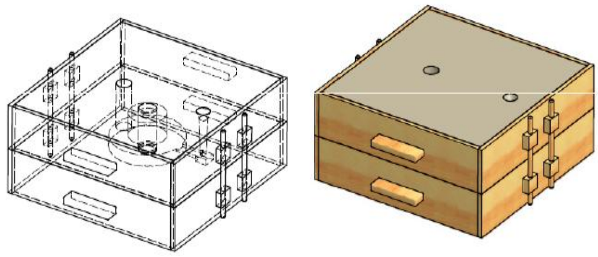

Fig 24: Wireframe and Solid Model of Sand Mold

Fig 25: Flask and Alignment Pin

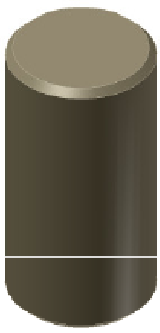

Fig 26: Sand Core

Size=ϕ40.56x76

Vertical Core

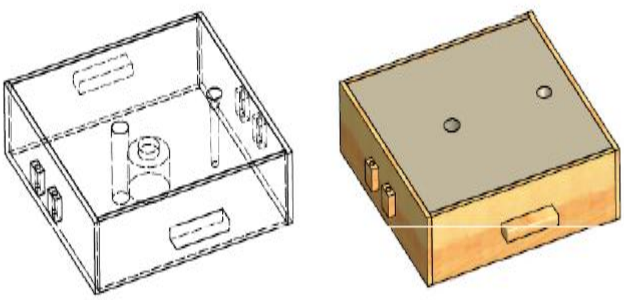

Fig 27: Wireframe and Solid Model of Cope

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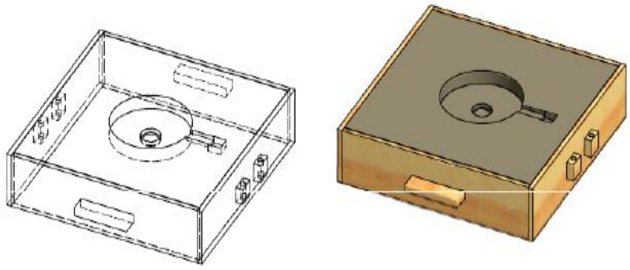

Fig 28: Wireframe and Solid Model of Drag

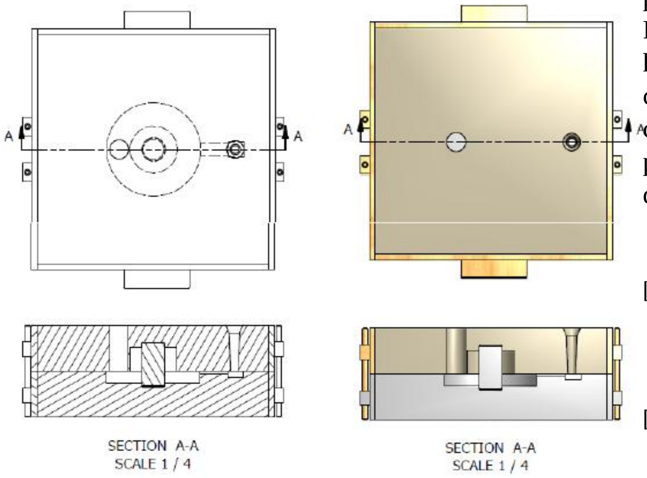

Fig 29: Half Sectional View

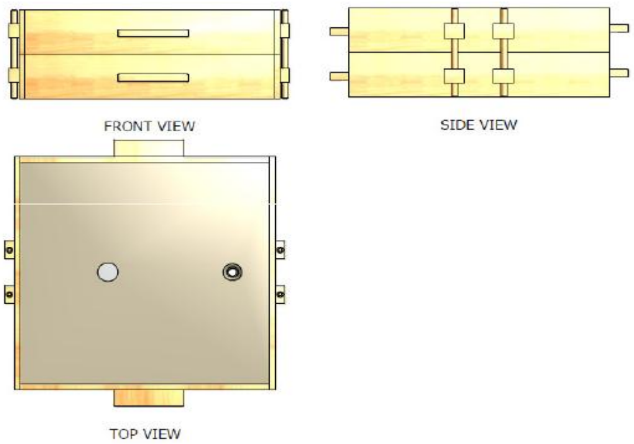

Fig 30: Orthographic View

Table 3: Details Regarding Sand Mold

Mold	Green Sand
Molding Process	Gravity Type
Box Size	400x400x80
Sand Binder	Bentonite
Sand Water Content	3.4-3.8%
Gas permeability	85-95%
Sand	Silica Sand Coating: water base coating

V.CONCLUSION

Design calculation of gating system for brass alloy casting with non-pressurized gating system of gating ratio1:4:4 in a green sand mold process are calculated. Yield or efficiency of casting is 87.98 %.(M) Riser =1.5 (M) Casting so riser will solidify after entire casting has get solidified.

VI.FUTURE WORK

Application of casting simulation is very powerful tool which is used to predict the growth of the process without physical perform process. By using simulation software like Pro Cast, Solid Cast, Auto Cast X, and MAGMA intelligently help foundries to reduce scrap rate even for defect which cannot be predicted. Simulation tools can also used to identify critical locations and filling pattern and solidification related problem areas in casting. Simulation also helps to identify defects like hotspots shrinkage defect porosity etc.

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AUTHOR BIOGRAPHY

Mr.Jibi.R Received M-tech in Production and Industrial Engineering from SCMS School of Engineering and Technology Ernakulum Kerala in 2013.Recieved B-tech Degree in Mechanical Engineering from CUIET Malappuram Kerala in 2011 and Diploma in Tool and Die Making from KELTRAC Alappuzha in 2008.He has published Seven International journals and presented two articles in International conference. He has more than seven years experience in teaching and one year Industrial experience in Press tool and Mold making. His interested area is computer aided design and analysis, Production Technology and Industrial Hydraulics. Currently he is working as an Assistant Professor in the mechanical engineering department at AWH Engineering College Calicut Kerala India

Mr. Niyas M A Final year B-tech student in the mechanical Engineering Department at AWH Engineering College Calicut Kerala India

Mr.Akshay P Final year B-tech student in the mechanical Engineering Department at AWH Engineering College Calicut Kerala India

Mr.Asmilsha Rahman A P Final year B-tech student in the mechanical Engineering Department at AWH Engineering College Calicut Kerala India

Mr.Pranav Final year B-tech student in the mechanical Engineering Department at AWH Engineering College Calicut Kerala India