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Design of Butterfly Valve Components

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***Abstract*— A Butterfly valve is a flow control device, typically used to regulate a fluid flowing through a section of a pipe. Our aim is to design a gating and risering system the components of a butterfly valve and to study and analyze various steps in casting. Here we increase the number of ingates by reducing its size and also increase the number of risers. Also the material selected is SG iron instead of Cast iron**

***Keywords*— Butterfly valve ; General Steps In Casting ; Design ; Conclusion ;Future work ;**

I. INTRODUCTION

Our aim is to design a gating and risering system for the components of a butterfly valve and to study and analyze various steps in casting. Design of gating and riser system assumes important stage in attaining quality of the product. Casting process is based on the property of a liquid to take up the shape of vessel containing it . Molten metal solidifies it takes the shape of mold but not exactly the same because solid being denser there is reduction of volume. In order to compensate for shrinkage of metal suitable provisions should be provided [4]. Casting is thus 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. Principles of casting consist of introducing the molten metal into a cavity and mold of the desired shape and allowing it to solidify. The molten metal passes through the four stages viz liquid stage, mushy stage, plastic stage and solid stage till the solidification takes place [1,3].

Fig 1. Butterfly Valve.

A Butterfly valve is a flow control device, typically used to regulate a fluid flowing through a section of a pipe [1]. The valve is similar in operation to a ball valve. A plate or disc is positioned in the center of the pipe. The disc has a rod through it connected to an actuator on the outside of the valve. A butterfly valve is from a family of valves called quarter-turn valves. Here we first discuss various steps in sand molding. Then the design calculation is done. Then concluded and future scope is discussed. Several figures of design is added

II. GENERAL STEPS IN SAND MOLDING

A. Pattern Making

Fig 2. Pattern of valve body

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Patterns are the foundry man's mold forming tool. The mold cavity and there for ultimately the casting are made from the impressions formed by the pattern. Manufacturing suitable pattern is thus the first step in casting .The selection of material of pattern depends up on the following factors.

1. Number of castings (quantity required)
2. Geometry of castings
3. Previous existence of items

Since valve castings are limited in order and has a relatively simpler geometry, Teak wood patterns are generally used.

B. Core Making

Cores are used to create the interior cavities of casting. The cores are made of core sand. Cores are actually sand shapes which form the contour of a casting that is molded with the pattern .Forming internal cavities thus depend on the cores which can be inserted in to a mold of casting exterior.

C. Molding

The term molding refers to making out a die in which the molten metal will be poured. Considering the easy availability, lower cost and refractory property, silica sand is used as base material for mold. In simplest terms a mold can be defined as the one which forms the gross outer shape if the casting [4]. It is a hollow cavity that receives the hot metal and helps in its solidification, through heat extraction molding process can be classified as follows

1. Sand molding
   (a) Green sand molding
   (b) Dry sand molding
   (c) Core sand molding
   (d) CO_2 molding
2. Investment or precision molding
3. Ceramic molding
4. Plaster molding
5. Graphite molding

Each of the process has a suitable and appropriate field of application depending on various factors including the technology available in the factory concerned, taking all the limited factors into account, the CO_2 molding process is the best suited for the designer under study that is make the cores [7].

D. Melting And Pouring

Generally molds having pouring weight larger than 50 Kgs need pouring basin [5]. The purpose of basin is to facilitate pouring and to avoid sand erosion, when the poured metal steam hits the mold continuously we can divide the pouring into time periods;

1. The first period start when the first liquid iron enters the pouring basin and last until the same is full of liquid iron from the parting line to the top of the pouring basin.

2. The second period starts at the end of first stage and lasts until pouring is completed.

E. Fettling And Finishing

The series of operations performed in the cleaning department may be classified as;

1. Removal of gates risers, rough cleaning.
2. Surface cleaning, exterior and interior of casting.
3. Finishing, final surface cleaning giving the casing outward appearance.

The finishing process includes chipping grinding shot blasting etc

F. Inspection

Inspection corresponds to those operations which check the quality of the casting and the result in their acceptance or rejection. Inspection procedures may be classified as

1. Visual inspection for foundry defects
2. Dimensional inspection
3. Non-destructive testing for soundness and quality of casting
4. Metallurgical inspections

III. DESIGN CALCULATION

Steps of design is calculated by using the values obtained from the drawing and various equations are used [8].

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A. Design of valve body

Approximate weight of casting = Volume × Density of casting (1)

The volume of butterfly valve body = 315733333 mm^3.

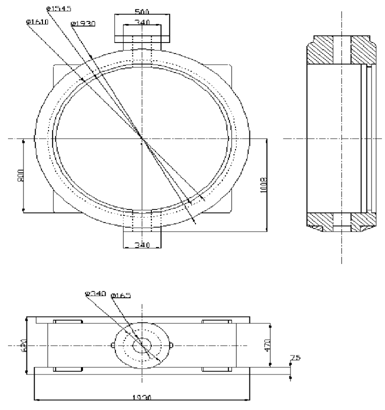

Fig 3. Drawing of valve body

Density of SG iron = 7.5×10^{-6} kg / mm^3

Therefore approximate weight of casting = 315733333 × (7.5×10^{-6}) = 2368 kg.

Actual weight of molten metal to be poured = 2368 / 0.65 = 3643.08 kg.

This value may be taken as 3650 Kg.

Therefore Pouring time, T = 0.97 √ (pouring weight) (2)

= 0.97 √(3650) =58.6 Seconds.

By considering human delay pouring time can be taken as 60 sec.

Gating Ratio for SG iron casting = 4: 8: 3

Once the pouring time in seconds is calculated, the next step would be to calculate the choke area which means the lowest cross sectional area anywhere in the gating system.

According to R.W. White's studies Choke area can be calculated as following

Choke Area = Pouring weight in kg / (1.1×Pouring time) (3)

= 3650 / (1.1× 60) = 55.30 cm^2

And from the gating ratio Sprue area = Choke area / 0.75 (4)

= 55.30 /0.75 = 73.74 cm^2

Minimum diameter of the Sprue = √ (4/π × Sprue area (5)

= √ (4/π ×73.74) = 9.69 cm

Therefore this diameter can be taken as 10 cm.

Thus the sprue area becomes = π/4 × (Sprue diameter)^2 (6)

= π/4 × 10^2 = 78.54 cm^2

Thus the Choke area become = 78.54 × 0.75

=58.91 cm^2

Runner area = Sprue area × 2 (7)

= 78.54 × 2 = 157.08 cm^2

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1. Ingate design

Normally the thickness to width ratio of ingates can be taken as 1:4 and the total number of ingates used in the gating system is fixed by the experience in the work.

Ingate should be thin and wide with a thickness to width ratio of 1:4
If 't' is the thickness, width = '4t'
Here we can calculate the dimensions of ingates by taking the number of ingates as 8.

Choke area = Total ingate area.
= No: of ingates ×Area of each ingate (8)
58.91 = 8 × 4t × t
Thickness of ingate, t = 1.36 cm.
We take thickness, t = 14 mm.
Width of ingate, w = 4 × 14 = 56 mm.

A minimum of 25 mm distance is to be maintained between the neighbouring gates [8]. The bottom runner and the bottom gate is kept at 100mm past the sprue or more. A neck should be provided at the entrance to mold cavity for the ease of cutting gating system from the required castings [6].

2. Runner

For the design of the runner system, it is to be noted that the height of runner should be twice its width.
If 'a' is the width, then the height will be '2a'.
Also the no: of runners can be 2.
Runner area = No. of runners x Sectional area of each runner. (9)
157.08 = 2 × (2a×a)
width of runner, a = √(157.08/(2×2))
= 6.26 cm.
= 63mm.

3. Riser

Riser 1
Modulus of section = Volume of casting design / Surface area of casting section (10)
For a flanged section,
Modulus of casting = (a × b) / (2(a+b))
= (163 × 78) / (2 (163+78)-45.5)
= 29.13 mm.
Modulus of riser = modulus of casting ×1.2 (11)
= 1.2 × 29.13 =34.95 mm
Riser diameter = 5 × Modulus of riser (12)
= 5 × 34.95 = 174.76 mm
Height of riser = 1.5 × Diameter of riser (13)
= 1.5 × 174.76 = 262.14 mm
Weight of riser = Area of riser × Height × density (14)
= $\pi/4 \times d^2 \times h \times \rho$; (ρ= 7.5×10^{-6} kg/mm^3)
= $\pi/4 \times 174.76^2 \times 262.14 \times 7.5\times10^{-6}$

= 47.16 kg

Riser 2
The section below this riser may be of cylindrical shape.
Modulus of casting = (a × b)/ (2(a+b)) (15)
= (88 × 305)/(2 (88+305))
= 34.14 mm.
Modulus of riser = modulus of casting ×1.2 (16)
= 1.2 × 34.14 = 40.96 mm
Riser diameter = 5 × Modulus of riser (17)
= 5 × 40.96 = 204.84 mm
Height of riser = 1.5 × Diameter of riser (18)
= 1.5 × 204.84 = 307.26 mm
Weight of riser = Area of riser × Height × density (19)
= $\pi/4 \times d^2 \times h \times \rho$; (ρ= 7.5×10^{-6} kg/mm^3)
= $\pi/4 \times 204.84^2 \times 307.26 \times 7.5\times10^{-6}$
= 75.90 kg

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B. Design of valve disc

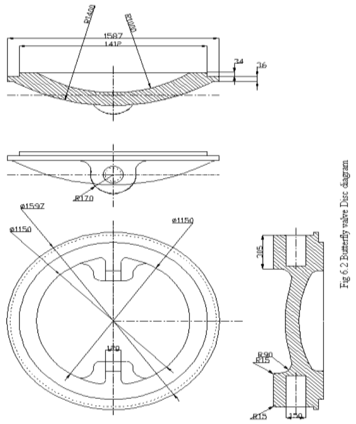

Fig 4. Drawing of valve disc.

Approximate weight of casting = Volume × Density of casting. (20)
The volume of butterfly valve body = 277066667 $mm^{3.}$
Density of SG iron =7.5×10^{-6} kg / mm^3
Therefore approximate weight of casting
= 277066667 × (7.5×10^{-6}) = 2078 kg.
Actual weight of molten metal to be poured
= 2078 / 0.65 = 3196.9 kg.
We take pouring weight as, W = 3200 kg
Therefore Pouring time, T = 0.97 √ (pouring weight) (21)
= 0.97 √ (3200)
=54.87Seconds.
By considering human delay pouring time can be taken as 55 sec.
Gating Ratio for SG iron casting = 4: 8: 3
According to R.W. White's studies Choke area can be calculated as following
Choke Area = (Pouring weight in kg)/ (1.1× Pouring Time) (22)
= 3200 / (1.1× 60)
= 52.89 cm^2
And from the gating ratio; Sprue area = Choke area/0.75 (23)
= 52.89 /0.75
= 70.52 cm^2
Minimum diameter of the Sprue = √ {(4/π) × Sprue area} (24)
= √ {(4/π) ×70.52}
= 9.48 cm
Therefore this diameter can be taken as 9.5 cm.

Thus the sprue area becomes = (π/4) × $(\text{Sprue diameter})^2$ (25)
= (π/4) × 9.5^2
= 70.88 cm^2
Thus the Choke area become = 70.88 × 0.75
=53.16 cm^2
Runner area = Sprue area × 2
= 70.88 × 2
= 141.76 cm^2

1. Ingate design

Ingate should be thin and wide with a thickness to width ratio of 1:4. Assuming the number of ingates as 8.
If 't' is the thickness, width = '4t'
Choke area = Total ingate area.
= No: of ingates × Sectional area of each ingate (26)

$52.89 = 8 \times 4t \times t$

Thickness of ingate, t = 1.29 cm.

We take thickness, t = 13mm.

Width of ingate, $w = 4 \times 13$

$= 52$mm.

A minimum of 25mm distance is to be maintained between the neighbouring gates [8]. The bottom runner and the bottom gate is kept at 100mm past the sprue or more. A neck should be provided at the entrance to mold cavity for the ease of cutting gating system from the required castings.

2. Runner

For the design of the runner system, it is to be noted that the height of runner should be twice its width. Assuming no: of runner as 1.

If ‘a’ is the width, then the height will be ‘2a’.

Runner area = No. of runners x Sectional area of each runner. (27)

$141.76 = 1 \times (2a\times a)$

width of runner, $a = \sqrt{(141.76/(2\times1))}$

$= 8.4$ cm.

$=84$ mm.

3. Riser

Modulus of section = (Volume of casting design) / (Surface area of casting section) (28)

For the flanged section,

Modulus of casting $= (a \times b) / (2(a+b))$

$= (96 \times 308)/(2(96+308))$

$= 36.59$ mm.

Modulus of riser $= 1.2 \times$ modulus of casting (29)

$= 1.2 \times 36.59 = 43.91$ mm

Riser diameter $= 5 \times$ Modulus of riser (30)

$= 5 \times 43.91 = 219.55$ mm

Diameter of the riser can be taken as 220 mm.

Height of riser $= 1.5 \times$ Diameter of riser (31)

$= 1.5 \times 220 = 330$ mm

Weight of riser = Area of riser × Height × density (32)

$= \pi/4 \times d^2 \times h \times \rho$; ($\rho = 7.5\times10^{-6}$ kg/mm^3)

$= \pi/4 \times 220^2 \times 330 \times 7.5\times10^{-6} = 94.08$ kg

If two risers are used in 2 hub side,

total weight of riser = 2 × 94.08 = 188.16 kg.

IV. CONCLUSION

The number of ingates is increased from six to eight .The ingate area is reduced thereby increase the number. Choke area, sprue area,runner area is redesigned. And the number of risers is increased from six to eight. The improved design is a very cost effective method and it has leaded a very innovative way in casting process. Also material is changed from cast iron to SG iron which has more ductility due to its spheroidical graphite structure which increases the yield.

V. FUTURE WORK

Since we use conventional methods for the design calculations, advanced softwares can be used which will reduce the time and also provide more accurate results

VI. FIGURES AND TABLES

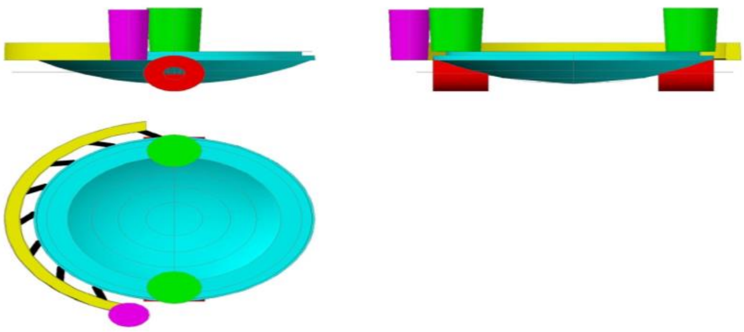

Fig 5.Valve disc gating and risering system.

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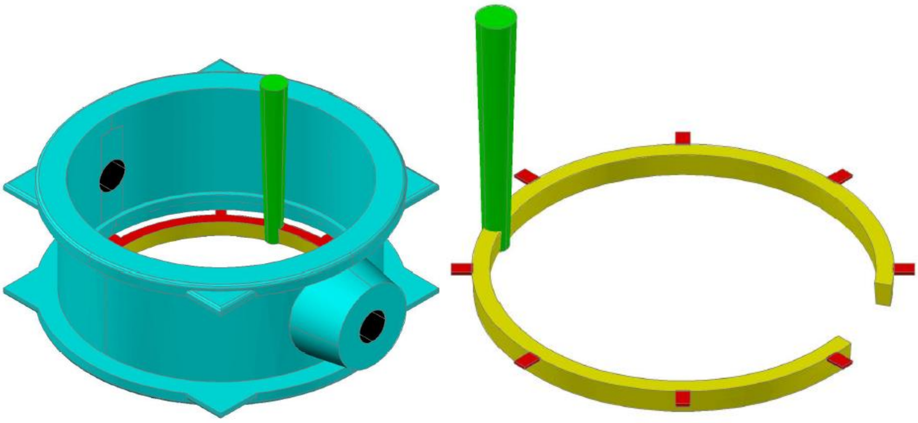

Fig 6.Valve body gating system.

TABLE 1 DESIGN RESULT

SL NO	DESIGN RESULT OF VALVE BODY		
	PROPERTIES	***Current Design***	***Improved Design***
1	Pouring Time	90s	60s
2	No of risers	6	8
3	No of gates	6	8
4	Slag formation	High	Low

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