Stress Analysis on Disc of a Butterfly Valve in Ansys

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***Abstract*: Industrial valves are major sector of business in now days. It has various applications in pipeline and power industries. They have a major role in regulating and on-off process of the fluid flows in various systems. This project is like a case study in tie up with an MNC to modify its butterfly valve disc component to be a competitive environment. Since the market is very competitive, the costing of the product must be very less to sustain in the market. Thus this project deals with modification of disc and its FEA analysis in ANSYS to iterate and figure out the best design for the disc. In the phase 1, concept models will be developed and the in the phase 2 will do the FEA analysis. The basic inputs will be provided by the company. The input details and the company name will not captured in this report due to security and intellectual property act reasons.**

***Keywords:* Butterfly Valve, ANSYS, Stress Analysis, Ribs, Casting.**

I.INTRODUCTION

By definition, valves are mechanical devices specifically designed to direct, start, stop, mix, or regulate the flow, pressure, or temperature of a process fluid. Valves can be designed to handle either liquid or gas applications. By nature of their design, function, and application, valves come in a wide variety of styles, sizes, and pressure classes. The smallest industrial valves can weigh as little as 1 lb (0.45 kg) and fit comfortably in the human hand, while the largest can weigh up to 10 tons (9070 kg) and extend in height to over 24 ft (6.1 m). Industrial process valves can be used in pipeline sizes from 0.5 in [nominal diameter (DN) 15] to beyond 48 in (DN 1200), although over 90 percent of the valves used in process systems are installed in piping that is 4 in (DN 100) and smaller in size. Valves can be used in pressures from vacuum to over 13,000 psi (897 bar). Today's spectrum of available valves extends from simple water faucets to control valves equipped with microprocessors, which provide single-loop control of the process. The most common types in use today are gate, plug, ball, butterfly, check, pressure-relief, and globe valves. Valves can be manufactured from a number of materials, with most valves made from steel, iron, plastic, brass, bronze, or a number of special alloys.

II. BUTTERFLY VALVES

A butterfly valve is a valve which can be used for isolating or regulating flow. The closing mechanism takes the form of a disk. Operation is similar to that of a ball valve, which allows for quick shut off. Butterfly valves are generally favored because they are lower in cost to other valve designs as well as being lighter in weight, meaning less support is required. The disc is positioned in the center of the pipe, passing through the disc is a rod connected to an actuator on the outside of the valve. Rotating the actuator turns the disc either parallel or perpendicular to the flow. Unlike a ball valve, the disc is always present within the flow; therefore a pressure drop is always induced in the flow, regardless of valve position.

A butterfly valve is from a family of valves called quarter-turn valves. In operation, the valve is fully open or closed when the disc is rotated a quarter turn. The "butterfly" is a metal disc mounted on a rod. When the valve is closed, the disc is turned so that it completely blocks off the passageway. When the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the fluid. The valve may also be opened incrementally to throttle flow.

There are different kinds of butterfly valves, each adapted for different pressures and different usage. The zero offset butterfly valve, which uses the flexibility of rubber, has the lowest pressure rating. The high performance double offset butterfly valve, used in slightly higher-pressure systems, is offset from the Centre line of the disc seat and body seal (offset one), and the Centre line of the bore (offset two). This creates a cam action during operation to lift the seat out of the seal resulting in less friction than is created in the zero offset design and decreases its tendency to wear. The valve best suited for high-pressure systems is the triple offset butterfly valve. In this valve the disc seat contact axis is offset, which acts to virtually eliminate sliding contact between disc and seat. In the case of triple offset valves the seat is made of metal so that it can be machined such as to achieve a bubble tight shut-off when in contact with the disc.

III. WORKING OF BUTTRFLY VALVE

A butterfly valve is a type of quarter turn valve. A quarter turn valve can open or close whenever the handle is turned 90 degrees (a quarter of a turn). The main function of these valves is to control the flow of liquids through a section of pipe. Butterfly valves are mainly used in waste treatment systems. They are extremely durable and need minimal maintenance. Butterfly valves operate like other quarter turn valves. Understanding the way a basic butterfly valve works is pretty simple. It can help you to learn more about the components of valves.

Butterfly valves are made of a number of components. The most important one is the metal disc. This metal disc is the one commonly referred to as the butterfly. The butterfly is mounted on a rod and when the valve is closed it blocks passage of fluid. When the valve is fully open, the metal disc or butterfly moves a quarter turn. The passageway is unrestricted allowing fluids or air to pass. In essence, the movement of the disc will depend on whether the valve is open or closed either partially or completely. If the valve is opened partially, it means that the disc will not be rotated a full one quarter turn, thus it cannot provide unrestricted passage. This means that, smaller amounts of fluid or air will pass through. However, if the valve is opened completely, the disc will be rotated 90 degrees then larger amounts of air or fluid will pass through. There are many other components that form the butterfly valve. They include the resilient seat, body, packing, a stem and an actuator. The resilient seat is mounted on the body of the butterfly valve in order to provide the proper seal. The packing provides an additional seal especially in case the resilient seat is damaged.

Butterfly valves are configured differently. There are some which operate manually whereas others operate electronically depending on the system. They also come in different styles. There are those which offer high performance in systems like large pump lines and front suctions.

Butterfly vales can also be used in automobile systems. For instance, you will find the butterfly valve inside the carburetor of a car. In this case, the valve is used to control the flow of air to the car's engine. It can partially open and close to regulate the amount of air passing through.

The normal disc of the present valve will have plane casting and no much ribs because the thickness of the disc is high enough and meets the casting requirements.

IV. DESIGN CONCEPTS AND STRESS ANALYSIS

Various concepts are derived to arrive the low weight model and which can sustain in the required operation condition without failing in the stress distribution on the disc.

The various concepts are made by adding some ribs modifies ribs and supports in front and behind of the disc. The outer profiles and the dimensions cannot be disclosed because of, this relates to intellectual properties of a MNC.

Some of the concepts of stress analysis in the various flat plates are described in various journals. There are different ways of determining the stress concentration factor in flat plates. Experimental, numerical and analytical methods are used to determine stress concentration factor [1].Normal stresses increase in absolute value with the hole size for all orthotropic materials [2]. The stresses generated in the vicinity of a circular hole of orthotropic plate when it is under hydrostatic stress in a plane, are strongly affected by the elastic properties of the plate material into consideration [3]. In a flat plate with two holes loaded at its ends, the interaction of the stress concentration depends on the distance and the size ratio between them [4]. The theoretical stress concentration factor for orthotropic material pieces is influenced significantly by the type of load applied, as known by parameters such as the relative size of the borehole; also the load that produces the greatest effect on the theoretical stress concentration factors is the biaxial tension-tension loading whose effects are inconspicuous [5]. The stress concentration factor in composite materials is closely dependent on the geometry of the part, plus the stress concentration factor is not worth enough, by itself, to predict failure in laminates [6]. It is difficult to establish parameters of the orthotropic material behavior, but there is a marked influence between the elastic constants and the stress concentration factors [7]. The maximum stress concentration to finite width plate with central hole under axial load always occurs at the periphery of the hole, also stress concentration factor is greatest at the tip of the hole, that is perpendicular to the loading [8].In [9] a detailed report on the stress concentration in composite materials with notched reinforced with unidirectional fibers is presented.

The authors comment that due to the formation of the longitudinal division at the tips notch along the fiber direction, the extremely high stress concentrations ahead of the tip of notch could be reduced drastically for composites under remote tension. In [10] away optimization approach is presented to minimize stress concentration and the peaks caused by the contact pressure. In [11] the stress concentration factor in holes on orthotropic laminated plates produced by countersunk rivets under uniaxial tension load is studied, the analysis is performed using the finite element software Ansys. For this part in [12] how to get the curves of stress concentration using the ANSYS ® software is shown, the stress concentration factors are plotted in dimensionless form, obtaining curves of stress concentration factor. The stress concentration on flat plates with circular, triangular and rectangular holes is studied in [13].The concentration of stresses in a plate of infinite length with two holes of equal radii is analyzed using finite element software for analyzing the distance between the centers of the two holes and the diameter of these is varied [14]. In [15] a review of research on stress analysis in infinite plates with cuts occurs. In [16] the stress concentration on a flat plate of constant thickness with stress at its ends is analyzed, making a comparison of the results obtained by the theory of elasticity, experimentally and the method of finite elements. Stress concentration is one of the factors contributing to reduce the life of a component subjected to mechanical fatigue [17]. Using modified elliptical notches because it causes less stress concentration in comparison with semicircular notches and grooves, the ratio of the minor and major axes of the ellipse should be between 0.3 and 0.4 is suggested [18]. The elliptical opening leads to a generalized analysis, when the ratio of the minor to major axis of the ellipse axis is large, the hole tends to be a very thin slot, so their stress concentrator increases [19]. The stress concentration factor for U notches which support mixed loads is studied in [20], the authors use the criterion based on the deformation of the average energy density concept. The maximum stress concentration factors in a small rectangular hole rounded edges of orthotropic plate is located on the main axis 1 which is at 67.5º angle about the x axis [21].In [22] a flat plate with a hole in the center under the influence of a gradient of linear load was studied, the authors establish an approximate computational model that reduces the required type of load and support the results obtained experimentally and numerically by photo elasticity using the ANSYS® software. Stress concentration in a round bar with a circular arc or V-shaped notch with bending load, tensile load and torsional load is analyzed in [23]. A study to optimize the shape of the fillets and reduce the stress concentration in flat and round bars subjected to axial load, bending load, torsion load or combined loads is performed in [24].

The designs for casting components are very critical because it should not create result in cracks and without forming ant stress concentrations. The flow of the molten also should not be interrupted during the pouring time. And the design and allocation of the ribs should give strength to the complete component

By considering the casting design features and pressure class ratings, various design concepts are modeled with additional rib structures on the disc in the Solid Works.

The various stress distribution plots carried out for the different design concepts are shown below along with their respective 3D models.

A. *Concept 1:*

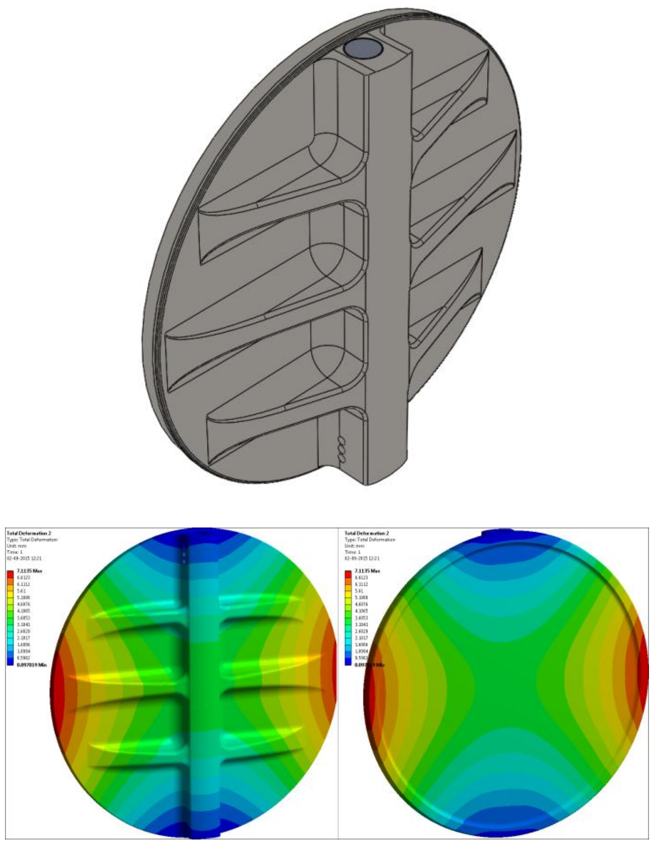


Figure 1: Concept 1

B. *Concept 2:*

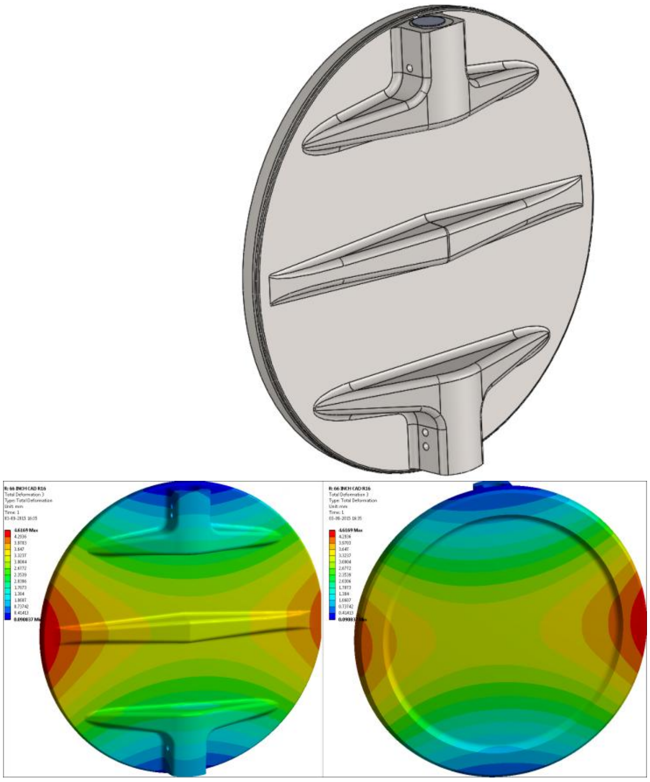


Figure 2: Concept 2

C. *Concept 3:*

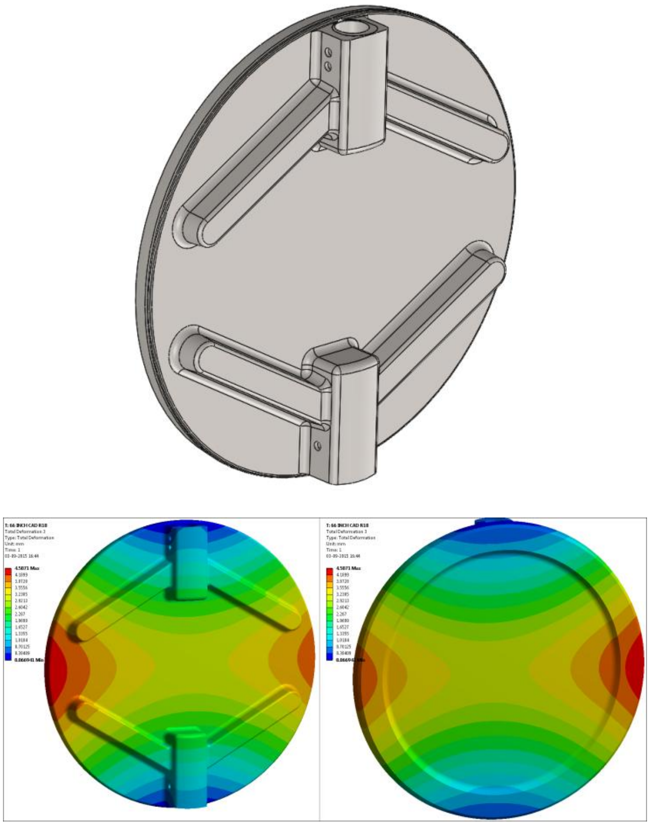


Figure 3: Concept 3

D. *Concept 4:*

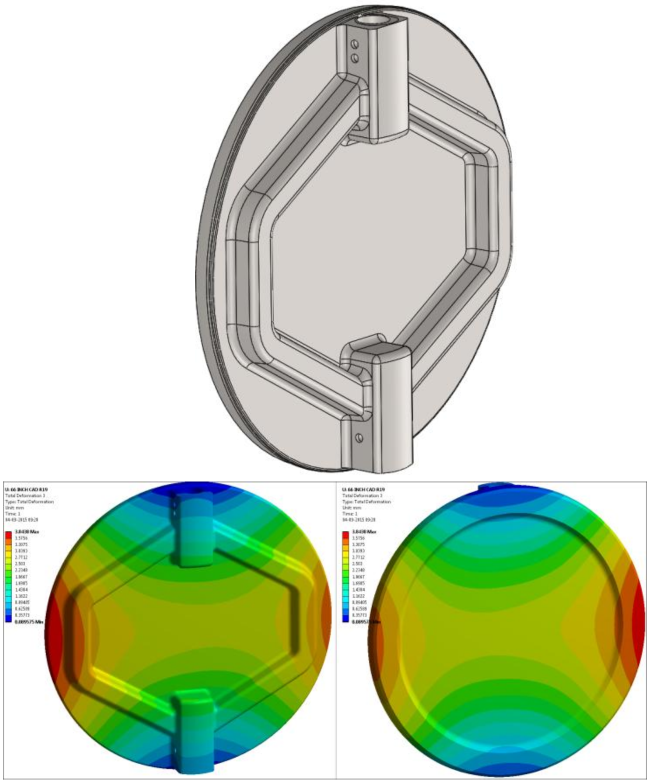
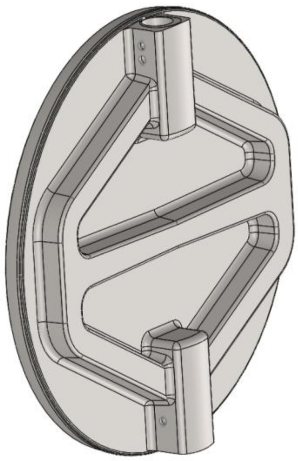


Figure 4: Concept 4

E. *Concept 5:*



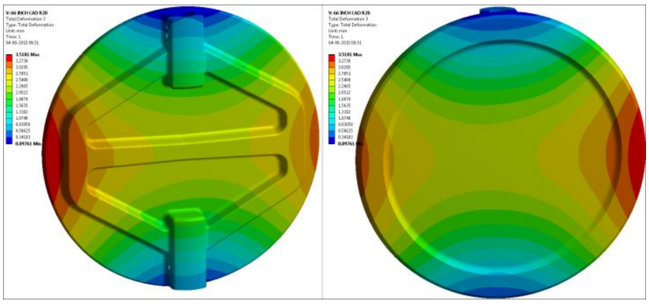


Figure 5: Concept 5

F. *Concept 6:*

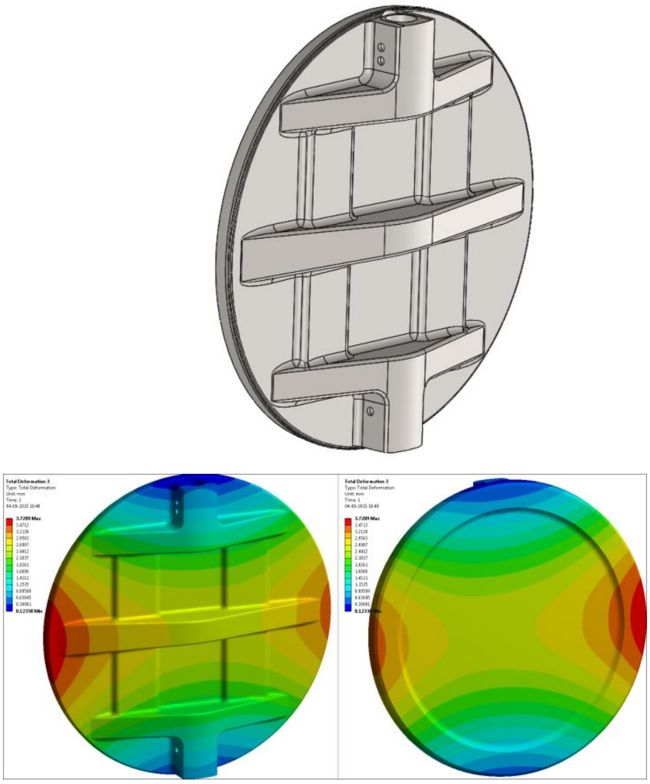


Figure 6: Concept 6

G. *Concept 7:*

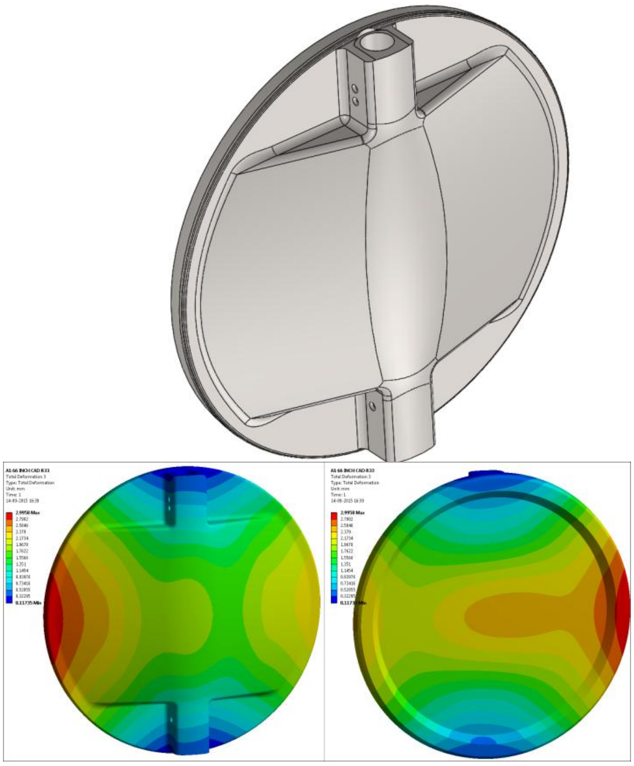


Figure 7: Concept 7

Table 1: Stress values & Weights of designed concepts

CONCEPT	STRESS VALUES MPa	WEIGHT Kg
1	7.1135	1440.2
2	6.4774	1465.7
3	4.5071	1571.2
4	3.8438	1634.9
5	3.5181	1855.6
6	3.7289	1687.4
7	2.9958	1443.1

X. CONCLUSION

The design concept 7 has lower stress concentration and lower weight. The centre portion of the disc is hollow and it has accommodated the wall thickness required for the flow of molten metal in casting. The weight reduction in each and every component in an assembly results in the overall cost reduction of the product.

X. REFFERENCE

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