Analysis & Optimization of Pressure Equipment Swing Check Valve by using FEA Methods

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Abstract—**Valves are commonly used for safety, to control flow, to direct the flow, to allow only one directional flow in the pipe line (check). Among all the flow control valves. Check valve is the only valve which is very simple in construction and for this valve no actuation mechanism required. In this project we preform analysis and optimization of the check valve. In the optimization of the check valve the shape, weight & size parameters considered. Less thickness & less material in the valve and cap leads to failure of the valve and maximum thickness leads to cost implication. As per ASME standard's, check valve is categorized as a pressure vessel which contains only internal pressure. In the project, conducted structural analysis by using FEA method. Results are validated by using numerically calculated stresses. Also validate results by experimental set up. Which are matches with the FEA results. By using various tools in the FEA software reduced the weight and material of construction. The conclusion is that the for valve engineering project FEA is extremely powerful tool when it employed correctly.**

***Index Terms*—Check Valve, Optimization, Pressure Equipment etc.**

I. INTRODUCTION

Finite Element Method (FEM) is a calculated technique used to carry out the stress analysis. In this method the solid model of the component is split into smaller elements. Constraints and loads are applied to the model at specified surface or specified region. Various properties are assigned to the A pressure containing equipment is open & closed operating designed to control the flow of gases or liquids at a pressure different from the ambient pressure. The aim of this project is to carry out detailed analysis and optimization of Pressure equipment used in process industry for optimum thickness, temperature distribution and dynamic behavior using analysis

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software. The model will analyzed in FE solver. Then results will plot in the post processor. This project involves design, weight, Size & shape optimization of pressure equipment to sustain working pressure and shell pressure and determine the wall thickness, shape, material and weight required for the pressure to limit the maximum shear stress. Geometrical and finite element model of pressure equipment will create by using CAD and CAE tools. Geometrical model will created on PRO-E and for finite element modeling and post solver ANSYS will be used.

Check valve as a pressure vessel in fluid pipe line poses extreme potential danger due to the high pressure and variable operating temperature, hence there should be no complacency about the risks. Unfortunately, pressure vessels related accidents happen much more than they should.

Due to the differential operating pressure of pressure vessels, they are potentially risky and accidents relating pressure vessels can be deadly and poses lethal dangers when vessels contents are flammable, volatile, toxic or reactive.

Stress is the internal resistance or counterforce of a material to the distorting effects of an outside force or load which depends on the direction of applied load as well as on the plane it acts. And At a assumed plane, there are both normal and shear stresses. However, there are planes within a structural component applied to mechanical or thermal loads which contain no shear stress. Such planes are principal planes, the directions perpendicular to those planes and the stresses are principal stresses.

II. OBJECTIVES

The objective of this Project is to perform analysis and optimization of the critical components of Check Valve, its Body & Cap. Body and Cap is mainly prone to its internal fluid pressure which passes through it. Circumferential Shell thickness of the Check valve body and cap is an important factor which decides the life of the valve. Wall thickness maintained should be an optimized, otherwise more thickness will lead to cost implication and less wall thickness will lead to failure of the vessel. This project involves design, weight, Size & shape optimization of pressure equipment to sustain working pressure and shell pressure and determine the wall thickness, shape, material and weight required for the pressure to limit the maximum shear stress.

III. SCOPE

Valves are common components of Upstream and Downstream fields in the Process Industry, Oil and Gas Industries. They have been playing an important role in a variation of different industries as a hydraulic device for fluid flow control. Different types of valves have different applications. Valves are regularly used for safety reasons in flow control systems. When used for flow control, the dynamics and shape of the valve has to match the dynamics of the flow system and fluid Properties. The relation between valve position and the system of trough which fluid flow would make the pressure drop and flow highly non-linear. Most of the valves are in the category Thick Walled Pressure Vessels in which the internal line pressure acts as the main loading factor.

There are several types of fluid control valves, such as, globe valve, butterflyvalve, gate valve, check valves etc. Among all the flow control valves, check valve is the only valve which is simple in construction and does not require any actuation mechanism to operate.

Such valves we can optimise by using FEA method and we can save the cost required. Product will be cheaper without affecting stress and deflection of the valve.

IV. ANALYTICAL APPROACH

A. *Swing Check Valve*

A check valve is a typical valve from the family of valves non return control valves, commonly used in applications where the reversible flow of fluid restricted. The swing check valve works by leading flow forces to move the disc from the shut position to the open position. It travels in a sweeping arc motion against the hinge-stop inside of the valve body as shown in Figure A. Due to the weight and centre-of-gravity location of the disc and hinge-arm assembly, the valve return to the shut position when the flow is disturbed or reversed. External counter weights are mounted on the hinge pin.

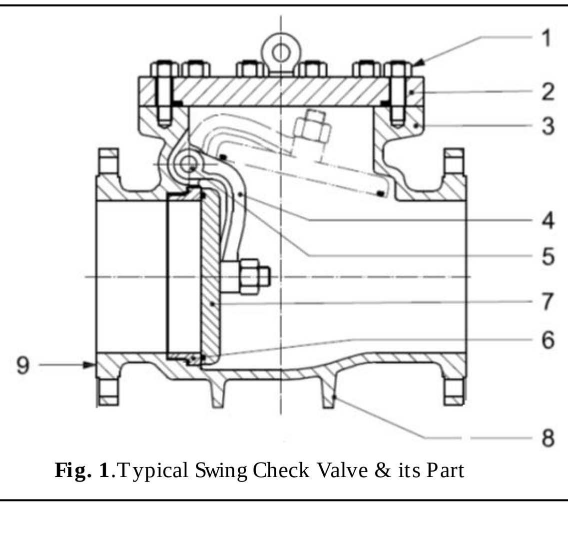

Fig. 1.Typical Swing Check Valve & its Part

1) *Cap / Cover Bolting*
2) *Cap / Cover*
3) *Body*
4) *Clapper disc arm*
5) *Shaft*
6) *Seat Ring*
7) *Clapper disc*
8) *Support ribs and legs*
9) *Raised face*

B. *Working principle of check valve*

The main function of check valves is to forward maximum flow and prevent or minimize the development of reverse flow. This purpose helps to protect pumps and systems from damage caused by generated reverse flow. Check valves are also used to separate areas of plants, such as nuclear power plants, from over-pressurizing or being polluted. Among several types of check valve designs, Swing Check Valves are the simplest in construction and working hence often used in industry.

Swing check valve discs are not continuously in same position unless they are in systems with steady and laminar flow and are in the fully open position when maximum possible fluid flow through it as shown in Figure 1. As the disc and clapper arm is hinge at pivot point, it take a relatively more time for swing check valves to shut when the flow is disturbed or reversed. During this period, forces reverse-flow fluid is experience a large increase in energy from revers fluid flow and pressure increased on disc. This situation may cause high-energy water hammer results disc slams onto the seat. Hence 2 to 3 times thickness should considered of calculation thickness.

C. *Modeling*

3D model is required for ANSYS simulation study. These 3D Model of DN50 size is created and assemble by using Creo Parametric 2.0 Software

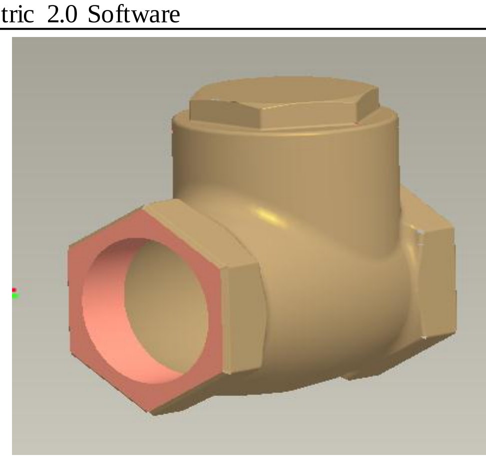

Fig. 2..Assembly Model of DN50 Swing Check Valve

D. Calculation For swing check Valve

I. Design Parameter Swing Check Valve

a. Size of the Valve: DN50

b. Pressure Rating: PN25

c. Maximum Allowable Working Pressure (MAWP)=2.5Mpa

d. Shell Testing Pressure = $= MPWP \times 1.5$

II. Material Properties of the Check Valve housing & Cap

a. Material of valve body - Bronze Grade BS EN 1982 CC491K

b. LCC Tensile Yield Strength (S) - 117 MPa

c. The tensile ultimate strength - 225 MPa

d. Young 's Modulus - 80000 MPa

e. Poisson 's Ratio - 0.34

III. Calculation

As per UG 27 of ASME Section VIII Division 1 formula thickness of the shell under internal pressure using the below formula.

$$\geq (P \times R) \div (S \times E - 0.6 \times P) + CA$$

a. Shell thickness of the Body (T1)

$$= (3.75 \times 36.3) \div (117 \times 1 - 0.6 \times 3.75) + 1$$

$$= 3.19mm$$

b. Shell Thickness of Cap (T2)

$$= (3.75 \times 24.32) \div (117 \times 1 - 0.6 \times 3.75) + 1$$

$$= 1.79mm$$

TABLE I
UNITS FOR SHELL THICKNESS CALCULATION PARAMETER

Symbol	Quantity	SI Unit
P	Shell testing pressure	Mpa
S	Allowable Pressure	Mpa
R	Maximum Radius of Pressure containing device	mm
E	Efficiency of cylinder	
CA	Corrosion Allowances	mm

E. FEA Analysis

For FEA Study we have only consider half model as it is totally symmetric about center vertical plane. So reduce the time of simulation, and to reduce the no of nodes and elements, applied symmetry on the surface. Liner as well as non-linear material is created for conduct the simulation. In this simulation constraints and load applied correctly. Initially simulation is carried out with coarse mesh. Fine meshed is created by using ANSYS meshing tools and results are plotted & studied. Results observed within the yield limit.

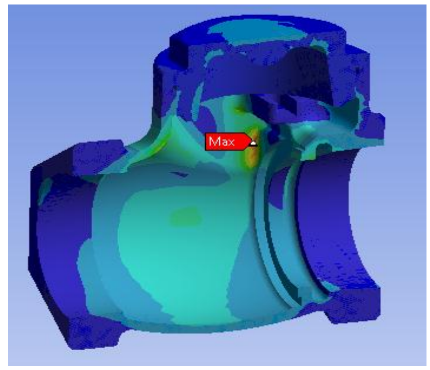

Fig. 3.Stress Pattern of Swing check Valve

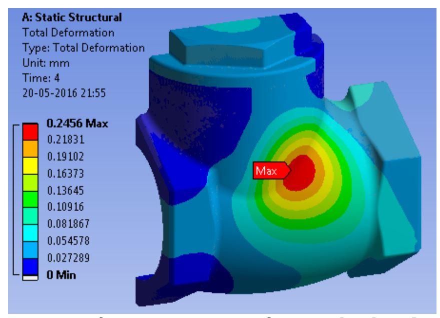

Fig. 4.Deformation Pattern of Swing check Valve

Shape optimization tool is applied to get where to save material how to optimize the shape of the valve.

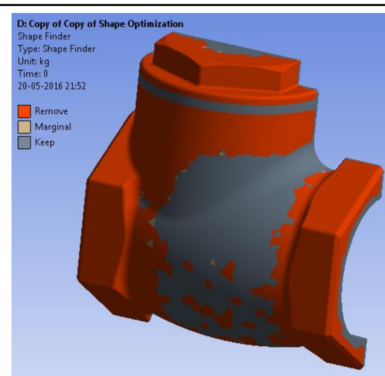

Fig. 5.Shape optimization of Swing check Valve

F. Testing

Testing done on pressure testing equipment with the help of stress and deflection measurement devices. Testing results are near to FEA results within 8% range.

V. RESULTS

By using stress and deflection FEA results and shape optimization results, created new CAD model on Creo software. Which is also test by using FEA analysis and confirmed that it is also safe with existing loads and boundary conditions. Existing model have weight 1.993 kg and new optimized model have 1.588 kg. New optimized model saved 20.3% material. This saved material cost directly improved the product profit.

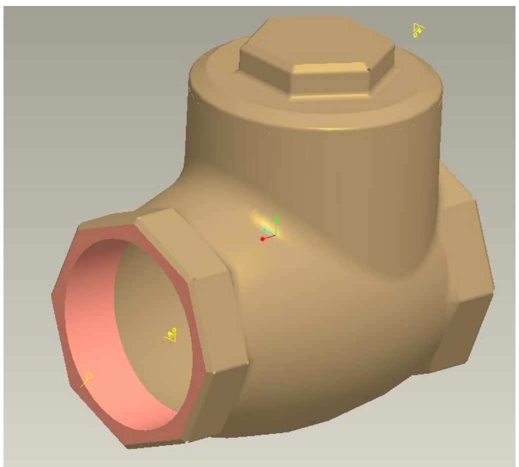

Fig. 6. New Optimized Model of Swing Check Valve

VI. CONCLUSION

FEA is powerful tool for optimization. In the recent days it is important not only in the development projects but also in the value engineering projects. As per above results in small valve size we are able to save the 0.405 kg of bronze material so for big assembly more material and material cost can be saved. The saved cost is directly considered as profit per unit of product. In mass production items small material and cost saving results in to big cost saving. Indirectly product become cheaper. In the market more customer attracts toward the product. Hence latest FEA techniques powerful tool when it used correctly.

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