International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Issue. 2, Vol. 2, June 2015.
e-ISSN: 2394-5141, p-ISSN: 2394-5133, pp 60-63

Analysis of Failure of Torispherical Head while Bending

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Abstract—**Pressure vessels are the containers that are used in number of industries for the purpose of storage of fluids. Pressure vessels are used mostly in storage of gas (compressed or uncompressed), oils, pressurized liquids, molten metals, etc. and are utilized in nuclear,chemical and thermal plants too. For such multipurpose and tiresome work environment, it is of utmost importance to have a good quality boiler. Boiler plates are very popular for such conditions and environments. The advantages ofimplying a Boiler Quality steel is that life of the machine components and indirectly of the plant can be increased considerably, which in turn results in the increase in the safety and durability of structures, thus making them more reliable. It also helps in reducing the costs of repairing linked to the quality of Boilerand plant failure. The pressure vessel ends are regarded as the most important part as most pressure of the boiler is exerted on the ends. The weakening of such chief part may lead to very hazardous after-effects. So as to avoid the failure of the dish ends, precise steps to analyze are to be carried out as it will aid in defining the problems associated, and according solutions could be generated. The processes used for the proper bending of the plates are also to be optimized.**

Index Terms—Pressure Vessels,TorisphericalDished End, Shearing, Bending, Rupture, Optimization.

I. INTRODUCTION

Vessel dish heads are designedfor using as ends of pressure vessels. These heads use less space than the hemispherical heads at an expense of slight increase in thickness of the heads.

The pressure heads are usually made up of boiler quality steel plates as they are better in terms of toughness and durability. The advantages of implying a Boiler Quality steel is that life of the machine components and indirectly the plant can be increased considerably, which in turn results in the increase in the safety and durability of structures, thus making them more reliable

Pressure vessels are the important parts of plants nd industries as they carry the materials that are of much prominence. The quality of the pressure vessels should be high as they may carry hazardous or toxic materials, which may be under pressure, and if not properly maintained can risk the life of the people working around it. To prevent such circumstances, the pressure vessels are needed to be designed with the highest precision possible and it should also be safe for maintainance purpose. The designated factor of safety is an important factor for deciding the reliability of the pressure vessel as is prescribed in pressure vessel design codes. But as there are number of different vessels designed according to their purpose, it is quite not possible to apply the same rules to all the designs. It may reduce the total load bearing capacity of the vessel. Furthermore, although some data are available for residual stress distributions in common pressure vessel and piping geometries, generalization and comparison for geometry and process effects are difficult to make due to the non-uniformity in the materials and the methods used to determine the residual stresses. Furthermore, even if there are number of ways to calculate the residual stresses, it is not easy to find out the stress distribution because of non-uniformity of materials.Calculating the loads in practical conditions can be very cumbersome and time consuming. To minimize them, the calculations and analysis are done with the aid of design and analysis software on computers. The software are more precise and consume very less time. The generated stresses can be easily estimated with the help of these softwares.

II. LITERATURE SURVEY

A. *Bending pressure vessel heads*

a) Material used for the Head plate:

The materials generally used for pressure vessels are steel and its alloys due to toughness, corrosion resistance, mechanical strength and tolerable elastic limit. Some other materials like carbon fibres, ceramic, polymers etc. are also used in the vessel heads which depends upon the purpose.

The pressure vessel is used for high capacity and pressure storage, and hence steel alloys are used. The material used for the industrial pressure vessel here is EN 10028-2 p265GH. The steel is widely used for the pressure vessel components because of its resistance to pressure.

The material used in the vessel heads has been tested at lab for chemical properties and composition, and the results are as under:

Table 1. Chemical composition of the material tested in laboratory

Sr. no.	Sample Identity	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Al %
1	BQ plate 36mm	0.161	0.211	0.914	0.025	0.020	0.025	<0.001	0.007

Mechanical properties of the material form the testing lab:
Density: 7700 kgm^{-3}
Yield strength: 265 MPa
Ultimate tensile strength: 580 MPa
Elongation(%): 27

B. Methods to manufacture and process the dished ends

a) Spinning and flanging process:

Fig 1. Spinning and flanging

The heads of the pressure vessel are bend by using the combination of processes-

1. Spinning
2. Flanging

By spinning, the require radius of the bend is attained, while by using the flanging process, the knuckle is produced.

b) Petal Welding

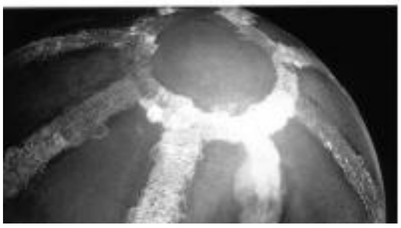

Fig 2. Petal welded dish end

The process of breaking a circular plate in parts, bending them separately and welding them together to get the final shape of the circular plate is called Petal welding. As the name suggests, the portions that are bend looks like petals while joining. In this process, the residual stresses due to welding gets induced thus affecting the strength of the dished end. These heads cannot sustain high pressure and so are generally prevented from use in areas with high temperature and pressure fluids[3].

c) Hydraulic press

The vessel dished ends can be manufactures with the aid of hydraulic press. The hydraulic press has a punch that can be used with different fixtures according to the bending required. The load is acted on a small area of the plate and the process of bending requires 5-6 cycles to completely bend the plate. The load is equal at all portions, just the dies are changed for attaining the proper shape. The stresses generated in the bending are more on the side of the edges and the problem of rupture can be seen in some conditions. The cracking may be because of various factors- load applied, nature of loading, impact, material properties, etc.

Fig 3. Bending of vessel head using a hydraulic press

Petal welding is the process of bending of triangular plates separately and then welding them together to make a dome shaped dish end. In petal welded hemispheres, the residual stresses due to welding emerges and the areas of stress concentration develops at the welds. When the pressure vessel is in working condition, the dish ends bear the maximum pressure and so if the pressure in the vessel increases the risk of bursting of the vessel along the welded region of dish end increases. The various residual stresses that get induced in the dome are explained in detail in reference [3].

C. Analytical calculation applicable for findind out the maximum stress :

For the manufacturing/bending of the plate, the forces acting on the plate are to be calculated analytically at first. The calculations can be done by referring the ASME Boiler and Pressure vessel codes. The applicable formula for the designing of a torispherical head is as under:

Equation:

$$S = \frac{(0.885L + .01t)P}{tE}$$

where,

S= Stress
L= Diameter of the bend
t= thickness of the plate
E= Young's modulus

It is to be noted that if the stress generated exceeds the value of ultimate tensile strength, the risk of rupture comes to exist.

Modelling and analysis of the pressure vessel head:

The modelling and analysis of the pressure vessel dished end was carried out using 2 different softwares:

- Solid Edge(modelling)
- Ansys(analysis)

The design of the circular plate was used as an input in the Modelling software and the model was generated.

- Initial diameter of plate: 4m
- Thickness: 36mm
- Knuckle radius: 10m
- Bend radius: 150mm

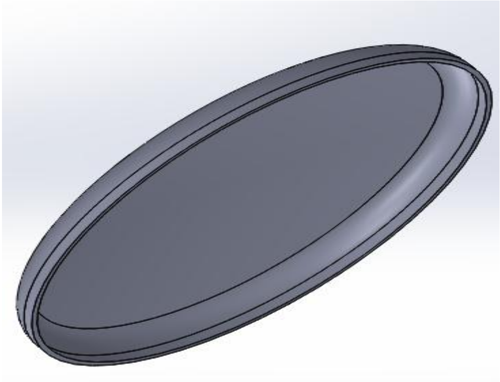

Fig 4. 3D model of the Dished End

For analyzing the model, a lot of software are present that are precise and consumes very less time. The programs have built in FEA algorithms that helps to calculate the stresses and strains at a finer level of accuracy.

One of such software used is ANSYS. It is used for the analysis of the CAD models and gives us the stress, strains, deformations precisely. The generated model file was exported to ANSYS software for loading it with the forces and getin the results.

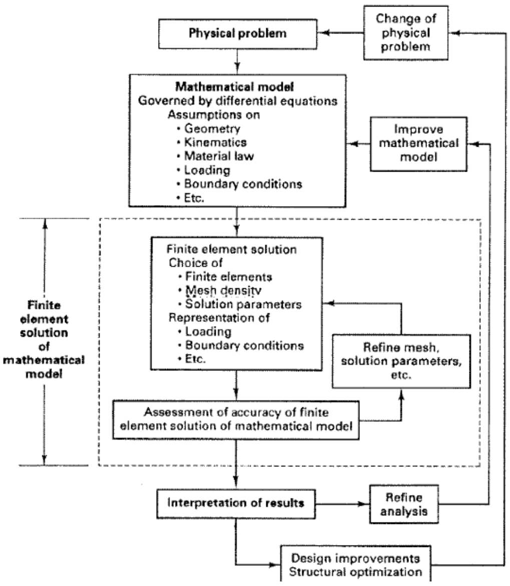

Fig 5. Computer based FEA

After importing the model in Ansys, meshing for proper result generation is done. This process generated nodes on which the load acts.

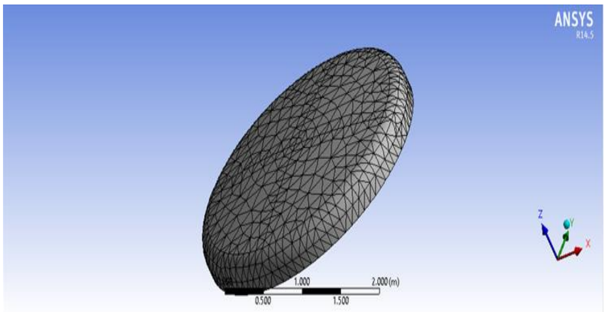

Fig 6. Meshing of the head

Once the meshing is done, the loads that are acting on the plate in the industry while manufacturing are to be applied.

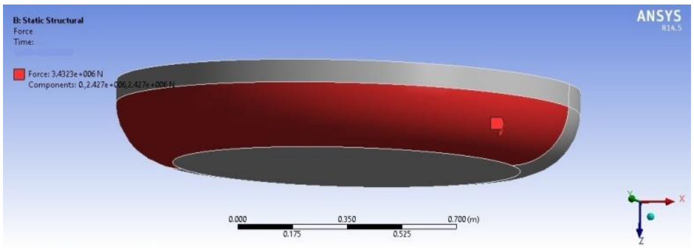

Fig 7. Loading on the head

After loading the plate, the solution is generated and the results are interpreted, where we get various strains and stresses getting induced in the plate.

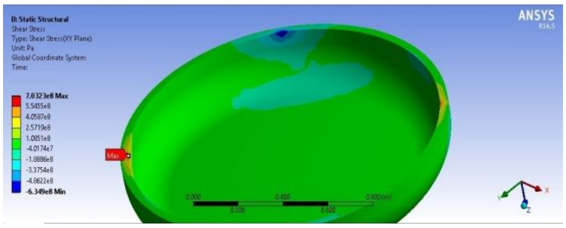

Fig 8. Results

The analysis of the plate has been done with the initial load as 250 tons where the plate is bent successfully and is taken upto the load in tons where the shear stress crosses the UTS of the plate and rupture of the plate has been found. The results are as under:

TABLE 2. RESULTS FROM ANSYS

LOAD(TONS)	STRESS(MPA)
250	509
260	522
270	542
280	562
290	583
300	603

Clearly, it can be seen that at 290 tons, the shear stress crosses the UTS of the plate. So the load at which the plate ruptures is at 290 tons, and since the material remains the same, the load that is to be applied should be less than 290 tons so as to bend the plate successfully. The results generated in the software can also be validated from the analytical results.

Fig 9. Cracks generated in the plate at edges

III. RESULTS:

From the analytical calculations and software analysis, it has been found that the material fails because of the load of higher intensity being applied to the plate.

TABLE 3. COMPARISON OF RESULTS

LOAD(TONS)	STRESS(CALCULATION) MPA	STRESS(SOFTWARE) MPA
250	497	509
260	517	522
270	537	542
280	556	562
290	577	583
300	596	603

From the above table, it can be seen that the analytical and calculated values matches each other. Also we can see that the load of 300 tons induces the stresses that have the value which exceeds the UTS of the material. The plate will possibly break at the same load.

IV. CONCLUSION AND FUTURE RECOMMENDATIONS

Pressure vessels are among the most important parts in the manufacturing industries. The pressure vessels are used for storage of high temperature and high pressure fluids. To keep the capability of the pressure to work under the required condition, it is necessary to design it to the best quality and also make it cost effective. For the same, the variables are needed to be changed like the material, thickness of the material, working conditions and the most important-process of manufacturing. Still sometimes, even after keeping every condition proper, the pressure vessel fails. At such condition, there is a need to analyze the problem and find a better solution.

In this project, the problem was occurring in the dished end in form of generation of cracks. To prevent such problems arising again, the art was needed to be analyzed and hence the results were to be interpreted and conclusions drawn. From the analysis, it can be concluded that the main factor for the generation of cracks was the heavy load which was applied for the bending of the plate which ultimately had effect on the value of stress, which was exceeding the ultimate tensile strength of the material.

It is recommended that the bending process should be carried out using the load which crosses the yield strength value, but should be below the Ultimate Tensile Strength of the material which in our case is EN 10028-2 p265GH. It will not only prevent the plate from rupturing, but also it will save the enormous money which would be required for the repairing and maintenance of the vessel heads. Successful implementation of the used methods will also ensure the improvement in the methods for production and application of pressure vessel dish ends.

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