Design and Analysis of Pressure Vessel Components as per ASME Sec. VIII Div. III

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***Abstract*— The pressure vessels are important component for Process industry which serves for various purposes. These vessels are designed considering the operating parameters such as Type of fluids, Quantity, Volume, and mainly temperature and pressure. The aim of this project is to perform the detailed design & analysis of pressure vessel for optimum thickness using ANSYS software. The selected components of pressure vessel like Shell, Heads, Nozzles, Supports and Lifting Lugs etc. are compared with Standard available thickness and optimization being done for the allowable stresses for MOC. The thickness of the pressure vessel is checked for different load cases. This results in the optimization of pressure vessel component thickness and hence reduces the overall weight and the cost the pressure vessel due optimum wall thickness for same service conditions. The optimized pressure vessel will be able to withstand all conditions applied on the pressure vessel during the service period of time with same safety factor but lower weight compared to the existing model.**

***Keywords* - ANSYS (software), MOC (Material of construction) ASME (American society of Mechanical engineers) etc.**

I. INTRODUCTION

Pressure vessels are containers used to handle fluids which are highly toxic, compressible and which work at high pressures. Pressure vessels have applications in variety of industries such as Oil and Gas, Petroleum, Beverage industries, chemical industries, power generation industries, food industry, etc. Failure of pressure vessels has adverse effects on the surrounding and the industry which can cause loss of life, property and damages.

The design of pressure vessel depends on factors such as pressure, temperature, material selected, corrosion, loadings, and many other parameters depending on the applications. This report elaborates the work done in design of pressure vessels to reduce failures in the pressure vessels and study of the parameters such as operating pressure and temperature, developing stresses, modes of failure etc. which cause fatigue or permanent failure or stress concentration in the vessels. The use of Finite Element Methods and Analysis techniques that provide results on failure in pressure vessels are to be studied. The future scope and advancements in pressure vessel design with software is to be utilized for simulation before actual modelling takes place.

A pressure vessel is a container having a pressure differential with respect to the atmosphere. The purpose of a pressure vessel is to store or process a high pressure high temperature fluid. The fluid can be toxic such as chemicals as well as nontoxic such as steam. The pressure vessel has to be designed according to the standard available codes such as ASME (American Society of Mechanical Engineers) Section VIII Division 1, EN/DIN (European) Code, IS (Indian Standard) Code. These codes have been designed by experimentation to obtain standards that fit to any application. Generally, these codes are designed considering the factor of safety between 3 to 4.5. The design of pressure vessel is based on parameters such as pressure, temperature, corrosion, material selection, etc., the study of such parameters helps in designing of the vessel. Variety of materials is available which are to be selected according to the application. The failure of pressure vessel can cause loss of life, property and damage to the system for which it is used. Hence the failures of pressure vessels are studied and methods are developed to avoid such failures. The stresses generated in the vessel are studied and determined using analytical procedures obtained from the codes as well as using software such as ANSYS, ABAQUS, PV Elite and CAESAR II for piping. Software such as PV Elite help to design and develop the vessels in less time and provide accurate results as per the code selected. Also, care is taken that they work continuously for years without much maintenance.

II. PROBLEM DEFINITION

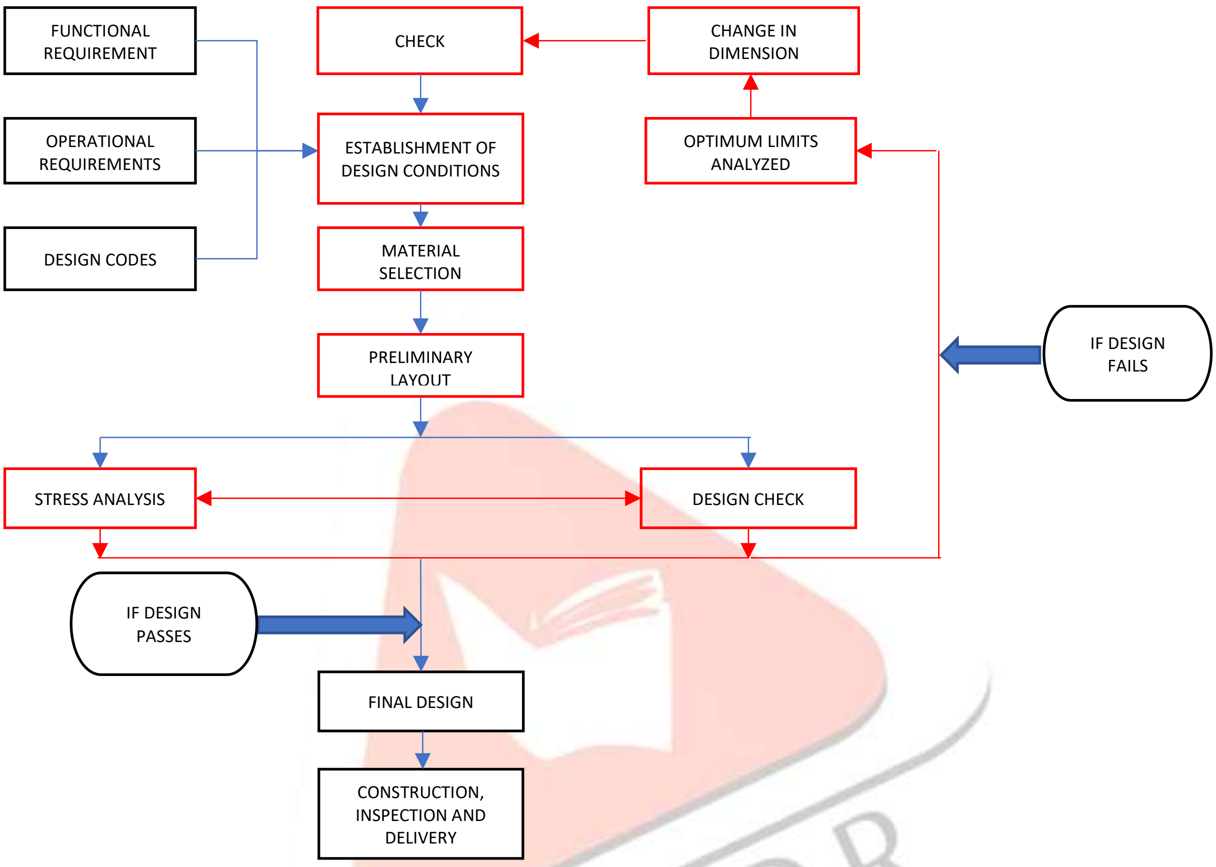
1.Requirement of Design and Analysis

The industrial pressure vessel's design is carried out using various softwares. The values and the design data obtained is further used for manufacturing of the vessel. The designer utilizes considerably higher values of the dimensions as per the code in order to make vessel safer during operation and intern increasing fatigue life. But the dimensions used for the construction and manufacturing result in heavier construction. This increases the amount of material utilized, overall cost and the transportation cost of the vessel. This paper focuses on minimizing the overall weight and cost of vessel by determining the optimum wall thickness for the vessel construction.

To achieve the purpose of this project this methodology is been used. This is the basic procedure of designing a pressure vessel which is than modified by adding the optimization method. In short, the procedure consists of modelling, designing by standard codes and then analyzing by using ANSYS software.

2.Methodology

This method focuses on stress analysis of the vessel for the working condition. The optimization is done by carrying out number of iterations. Design check is done to insure the safety of the vessel while in operation. The chart for the methodology used is as below:



III. DESIGN AND CALCULATIONS

1. Analysis Input Data

Design Internal Pressure (for Hydrotest)	15.000 kgf/cm²
Design Internal Temperature	220 °C
Hydrotest Position	Vertical
Minimum Design Metal Temperature	-29 °C
Type of Construction	Welded

2.Shell Design Data

Element Type	Cylinder
Description	Shell
Distance "FROM" to "TO"	360.00 cm
Inside Diameter	1800.0 mm

Element Thickness	14.000 mm
Internal Corrosion Allowance	1.0000 mm
Design Internal Pressure	15.000 kgf/cm²
Design Temperature Internal Pressure	220 °C
Design External Pressure	0.0000 kgf/cm²
Design Temperature External Pressure	40 °C
Effective Diameter Multiplier	1.2
Material Name	SA-240 316
Efficiency, Longitudinal Seam	1.0
Efficiency, Circumferential Seam	1.0

3. Dished End Design Data

Element Type	Elliptical
Description	Dished End
Distance "FROM" to "TO"	5.0000 cm
Inside Diameter	1800.0 mm
Element Thickness	14.000 mm
Design Internal Pressure	15.000 kgf/cm²
Design Temperature FOR Internal Pressure	220 °C
Design Temperature FOR External Pressure	40 °C
Yield Stress, Operating	1477.0 kgf/cm²
Material Name	SA-240 316

Figure 1. Model of the vessel

The material used for all following computations is SA-240-316. In detail, the mechanical properties of SA-240-316 are described in Table I.

Description	Unit	Value
Density	kg/m3	7888.77284

Yield strength	MPa	205
Ultimate tensile strength	MPa	515
Modulus of elasticity	GPa	200
Poisson's ratio		0.265

Table 1. Mechanical Properties of Material Used

Then, the geometry model is imported to ANSYS and the analysis as well as the optimization is carried out in ANSYS. Meshing is performed using auto-meshing, one of the features provided in ANSYS. Finally, the boundary conditions are applied to ensure the right solution.

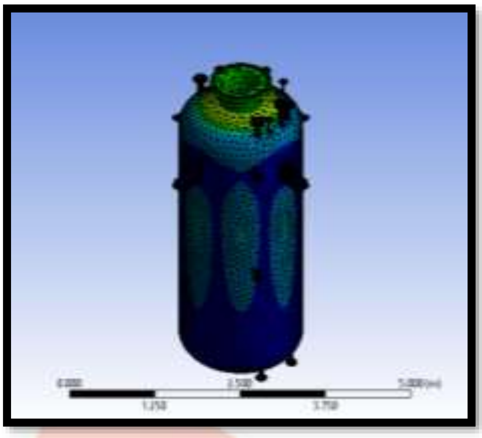


Figure 2. Analyzed model of vessel in ANSYS

The main aim here is to minimize the weight or mass of the pressure vessel by reducing the thickness of the pressure vessel using optimization method. As the reduction of the thickness of whole pressure vessel may be a risk factor for the pressure vessel, so only some specific components which plays a better role in achieving the results is to be optimized. The components selected from the pressure vessel results a better difference which leads to achieve the actual aim of this paper. For checking the safety of the pressure vessel, the von misses stress is being compared with the yield stress of the material used to produce the pressure vessel.

IV. RESULTS OF ANALYSIS

The reduction of weight of the pressure vessel is done by optimization method using the ANSYS software. The components selected for the optimization are listed below: -

1. **Cylindrical Shell**

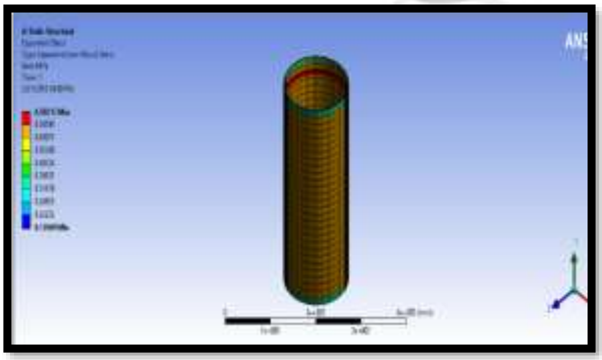


Figure 3. Stress distribution for 14 mm thickness of shell

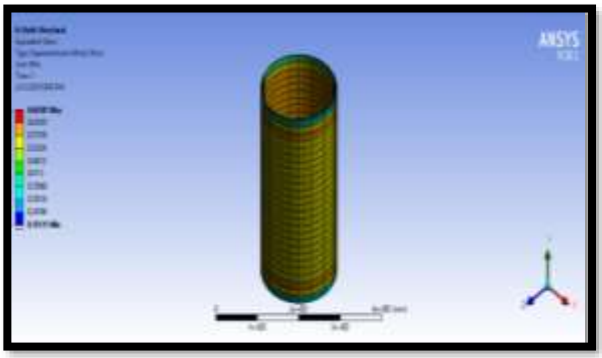


Figure 4. Stress distribution for 12 mm thickness of shell

Cylindrical shell	At 14 mm	At 12mm
Von misses stress (MPa)	0.59217	0.6837

Table 2. Results of the shell analysis

The above comparison concludes that the von misses stress at thickness 14 mm and 12 mm has less difference and is less than the yield stress of material (SA-240-316) which is used to produce the pressure vessel.

2. Dished End

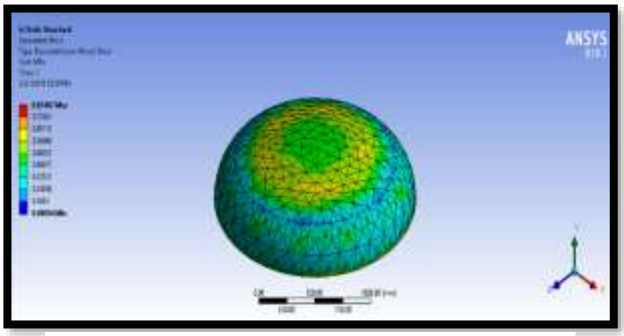


Figure 5. Stress distribution for 14 mm thickness of dish end

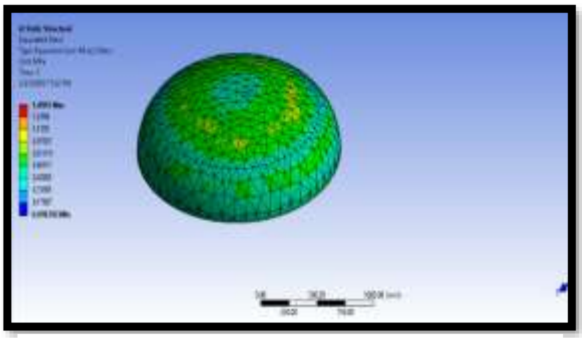


Figure 6. Stress distribution for 12 mm thickness of dish end

Dish end	At 14 mm	At 12mm
Von misses stress (MPa)	0.8297	1.4955

Table 3. Results of dished end analysis

The above comparison concludes that the von misses stress at thickness 14 mm and 12 mm has less difference and is less than the yield stress of material (SA-240-316) which is used to produce the pressure vessel.

3. Supporting Lug

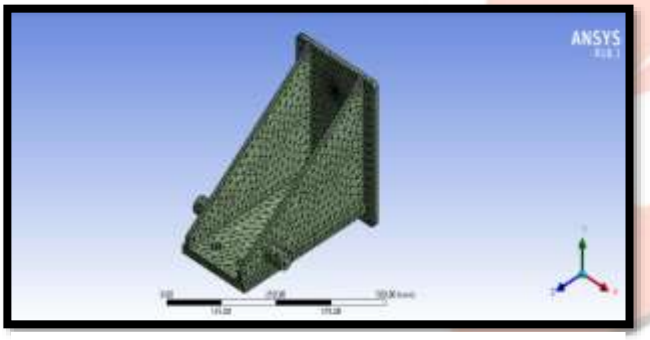


Figure 7. Meshed model of supporting lug

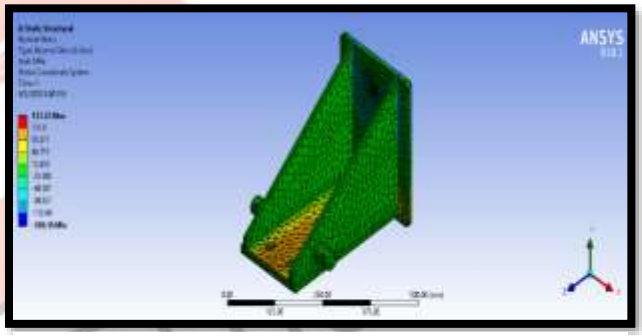


Figure 8. Result of stress analysis

4. Flange

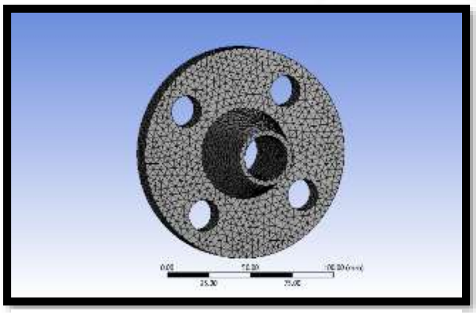


Figure 9. Meshed model of flange

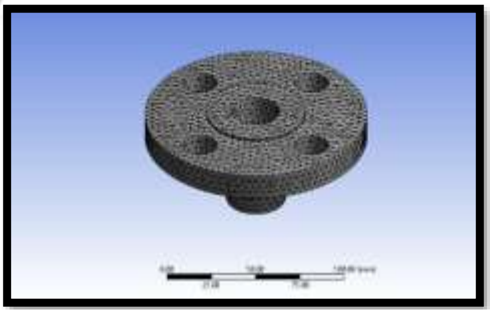


Figure 10. Isometric view of meshed model

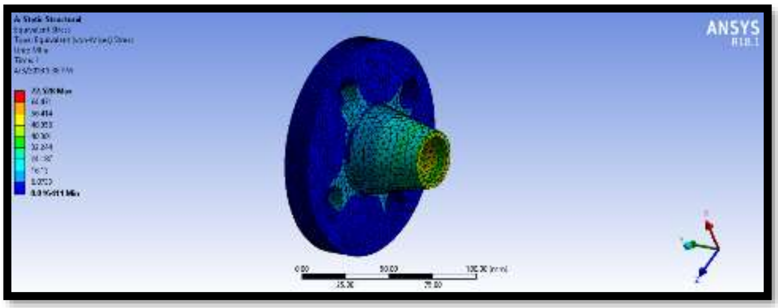


Figure 11. Result of the stress analysis

The optimized dimensional values of shell and dished end are resulting to be in proper geometrical shapes (in terms of thickness). Therefore, shell and dished end are optimized. But outcomes of the dimensions for the Support Lugs and Flanges result in improper geometrical shapes. And the support lugs and flanges are available in standard sizes. Therefore, weight reduction is not possible.

Name of Component	Original Weight (at 14 mm)	Reduced Weight (at 12 mm)	% Reduction in Weight
Cylindrical Shell	2254.7 KG	1923.6 KG	14.8%
Dish End	500.77 KG	440.2 KG	12.09%

Table 4. Results of weight reduction

V. OPTIMIZATION METHOD

In order to optimize the thickness of pressure vessel and reduce the weight, optimization method is used. The optimization method is a modified method of the standard design procedure of pressure vessel. The design of the pressure vessel depends on operating conditions and volume of service fluid. The pressure vessel is being designed with the help of design codes like ASME Sec VIII Div. III, an alternative rule mentioned in the codes. The operating condition are applied on the pressure vessel, are considered on the Design basis for which the material being selected and Equipment data sheet being produced. Pressure vessel after designing with the theoretical conditions, is been analyzed over two parameters, such as Stress analysis for allowable stresses as per MOC and Design check with Internal and External Conditions. The preliminary layout of the pressure vessel is then designed accurately with all the parameters considered and the geometry is produced. After the model is produced it is analyzed under the two parameters mentioned above. Analysis software ANSYS is used to result the boundary conditions applied on the pressure vessel. After the analysis if the design found safe through various condition for the optimized thickness and reduced weight which does not endanger the safety of pressure vessel; it is then forwarded for future procedures for fabrication and online inspection. The main aim of the paper is to optimize the thickness of the pressure vessel considering the specific components which will result the main outcome of the project. After number of iterations if the design fails then the number of iterations will be increased until the design passes.

VI. CONCLUSION

This paper is all about the pressure vessel optimization for minimizing the overall Weight, Labor, Handling Cost and Transportation Cost without endangering the Operational Safety of Pressure Vessel. Various components of the pressure vessel were optimized, such as Shell, Dish ends, using the optimization method which resulted in optimum thickness, reduced cost and weight. The pressure vessel and its components were optimized using the analysis ANSYS software. The dimensions of thickness obtained for the shell and the dished end of the vessel were found to be excess in terms of the operating conditions required. Therefore, those thickness dimensions were optimized to lower optimum values which were for the operating conditions.

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