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Design and Analysis of Wire Wound Cylinder

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Abstract— **The main objective of this paper is to conduct stress analysis on a thin walled air compressor cylinder. The stresses are calculated by numerically and also by FEA. It is observed that the stresses induced are very high. Therefore a wire wound cylinder is proposed. In the present work the stresses are determined for wire wound cylinder by numerically and FEA. It is observed from the results the stresses induced in wire wound cylinder is less than the stresses induced in existing cylinder. Modeling and FEA are conducted by using Solid works and Ansys.**

Index Terms— **Fluid Tank, Fluctuating Load, Cylinder With Closed Ends, and Static Structural Analysis.**

I. INTRODUCTION

Storage tanks are containers that hold liquids, compressed gases or mediums used for the short or long term storage of heat or cold. The storage tanks like a pressure vessels briefly defined as “The fluids stored under pressure or without pressure in the vessel is known as a fluid tank or fluid cylinder. In this fluid tank is uses to store the compressed air are known as compressed fluid storage tank. In this storage tanks means in America or Britain is Reservoirs. The fluid tanks are designed with great care because rupture of cylinder means an explosion which may cause loss of life and property. The material of cylinders may be brittle such that cast iron or ductile such as mild steel. In this fluid storage tanks or pressure vessels are available in different shapes. They are Vertical Cylinder, Horizontal Cylinder and Wire wound cylinder. Wire wound cylinder is a type of fluid tank cylinder. Wire is wounded externally on the cylinder. There are two types of cylinders. They are thin and thick cylinders. If $d/t<20$ then it is thick cylinder, $d/t\geq20$ then it is thin cylinder. In thin two types of stresses are induced. They are Circumferential or Hoop stress and Axial or Longitudinal stress. One more stress is induced i.e radial stress but it is small so it is negligible. Three types of stresses induced in thick cylinder. They are Circumferential or Hoop stress, Axial or Longitudinal stress and Radial stress.

II. LITERATURE SURVEY

V. V. Wadkar (2015) et al. made a study of stress concentration factor in pressure vessels. The main objective of this study is to design the pressure vessel and the stresses developed in solid wall pressure vessel and head of pressure vessel is analyzed by using ANSYS. Finally they compared the theoretical values and ANSYS values for both solid wall and head of pressure vessels.

Dr. M. V. Mallikarjuna (2015) et al. made an analysis on different pressure vessels elements such as shell, dish end, operating manhole ,support leg based on standards and evaluation of shell and dish end analyzed by means of ansys and to check the behavior of pressure vessel.

Dr. Mohamad Tariq (2014) et al. made an analysis of the stress developed in the thick and thin cylindrical pressure vessels is numerically solved by using software in C++.The analysis has been done for two different materials and also varying thickness to the pressure vessel.

III. Design And Analysis Of Compressor Cylinder

A mono block vessel contains a single cylinder shaped casing, with sealed finishes. Due to high internal pressure and large thickness, the shell is considered as a 'thin' cylinder. Multilayer vessels are built up by wrapping a series of sheets over a core tube. The construction involves the use of several layers of material, usually for the purpose of quality control and optimum properties. Multilayer construction is used for higher pressures. It provides inbuilt safety, utilizes material economically and no stress relief is required.

Design Considerations:

a) A joint efficiency of 100% for longitudinal seam inner shell is taken
b) The thickness of subsequent layers is considered as 6 mm.

Specifications:

Diameter of shell: 50cm
Length of shell: 96cm
Thickness: 6mm
Maximum Allowable pressure:9MPa

Outlet valve:

Inner diameter, d_1 = 8cm
Outer diameter, d_2 = 10cm

Inlet valve:

Inner diameter, d_1= 13cm
Outer diameter, d_2 = 15cm

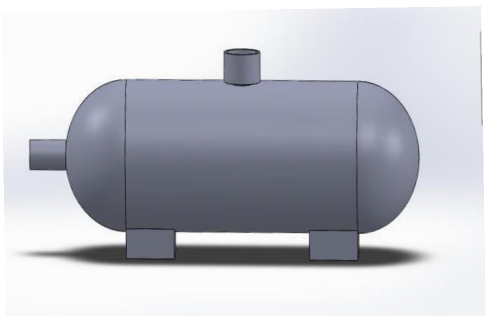

Fig.1 Existing Air compressor cylinder

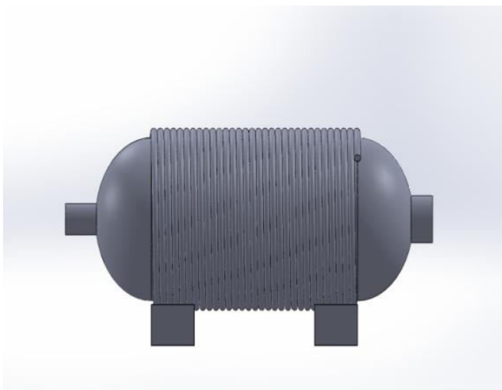

Fig.2 Proposed Air compressor cylinder

Specifications of Wire wound cylinder

Diameter of shell, D = 50cm
Length of shell, L = 96cm
Thickness, T = 6mm
Max. Allowable pressure, P_{max} = 9MPa

Inlet valve:

Inner diameter, d_1 = 13cm
Outer diameter, d_2 = 15cm

Outlet valve:

Inner diameter, d_1 = 8cm
Outer diameter, d_2 = 10cm

Wire:

Wire diameter d = 3cm
No of coils n = 40
Pitch p = 3.01cm

Theoretical Calculations

Expressions for Existing Compressor Cylinder:

Circumferential stress, $\sigma_c = \frac{\mathrm{Pd}}{2\mathrm{t}}$

Longitudinal stress, $\sigma_l = \frac{pd}{4t}$

Equivalent Von-Misses stress, $\sigma_v = \sqrt{½(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}$

Total Deformation, $\delta = \frac{\rho g L^2}{2E}$

Maximum Principal Stress, $\sigma_y = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$

Expressions for Wire Wound Compressor Cylinder:

Circumferential stress, $\sigma_c = \frac{\mathrm{PD}}{2\mathrm{t}+30}$

$D = d + d_w$

Longitudinal stress $\sigma_l = \frac{\mathrm{PD}}{4\mathrm{t}+30}$

Equivalent Von-Misses stress, $\sigma_v = \sqrt{½(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}$

Total Deformation, $\delta = \frac{MgL}{2AE}$

Maximum Principal Stress, $\sigma_y = \sqrt{\sigma_1^2 - \sigma_1\sigma_2 + \sigma_2^2}$

TABLE I PARAMETER COMPARISON BETWEEN WIRE WOUND VS. EXISTING COMPRESSORS

S. No.	Obtained Values of Individual	Existing Compressor Cylinder	Wire Wound Compressor Cylinder
		9MPa	9 MPa
1.	Total Deformation(mm)	$1.77e10^{-3}$	$4e10^{-4}$
2.	Equivalent Von- Misses Stress(MPa)	349	293
3.	Maximum Principal stress(MPa)	126	150
4.	Normal stress (x)(MPa)	375	113
5.	Normal stress (y)(MPa)	187	88.33

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IV. Analysis

In this work, analysis is done using Finite Element Method based software ANSYS. FEA analysis in ANSYS is done in three steps namely, Pre-processing, Solution and Post processing. The modelling of the cylinder has been done with solid works and then it has been meshed by using Hyper mesh and then loading conditions have been imposed. After imposition of the boundary conditions and loading conditions the FEA model has been solved in ANSYS through static analysis. Then the cylinder is analysed for displacements along x,y,z directions and Von Mises stress. Following tables and figures represent the outcomes of the analysis.

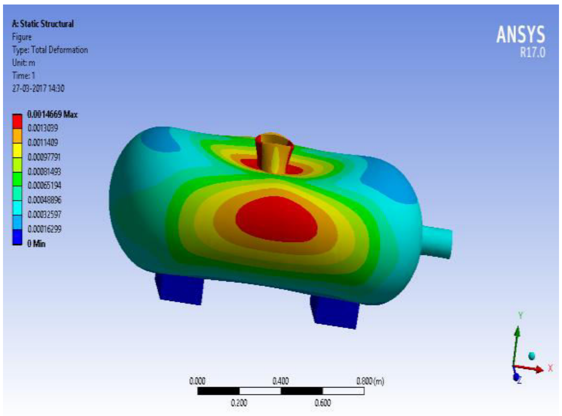

Fig. 3 Total Deformation of the Cylinder

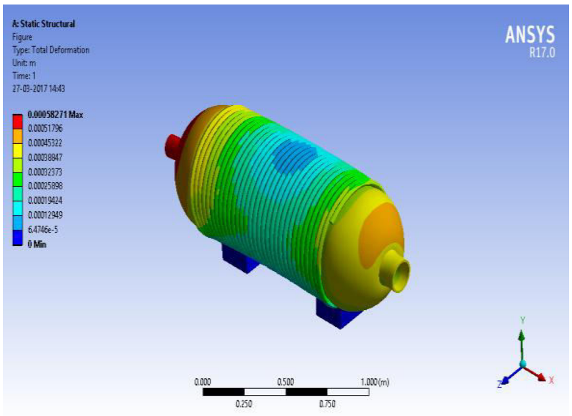

Fig.4 Total Deformation of the Wire Wound Cylinder

TABLE II Comparison of Total Deformation of Existing and Proposed Cylinder

	Existing compressor cylinder			Wire Wound compressor cylinder		
Obtained values of individual	3MPa	6MPa	9MPa	3MPa	6MPa	9MPa
Total Deformation(mm)	0.063	1.047	1.466	0.043	0.049	0.058

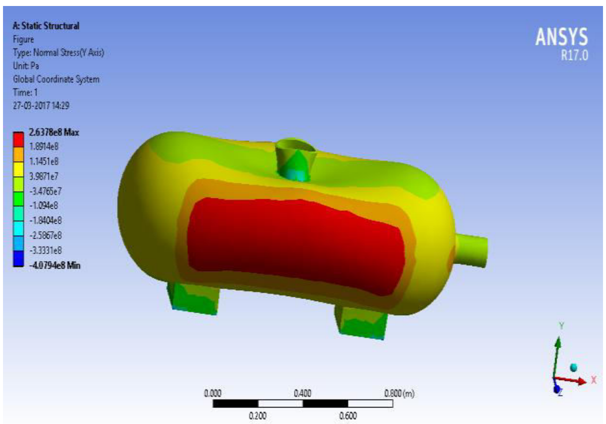

Fig.5 Longitudinal stress of a cylinder

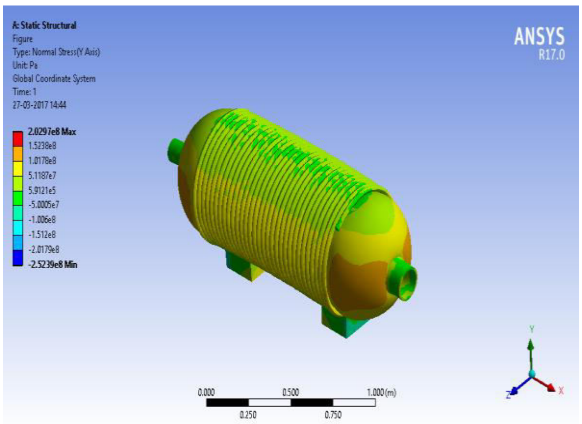

Fig.6 Longitudinal stress of Wire wound Cylinder

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TABLE III COMPARISON OF LONGITUDINAL STRESS OF EXISTING AND PROPOSED CYLINDER

	Existing compressor cylinder			Wire Wound compressor cylinder		
Obtained values of individual	3MPa	6MPa	9MPa	3MPa	6MPa	9MPa
Longitudinal stress (N/mm^2)	91.81	177.79	263.78	65.59	167.64	202.97

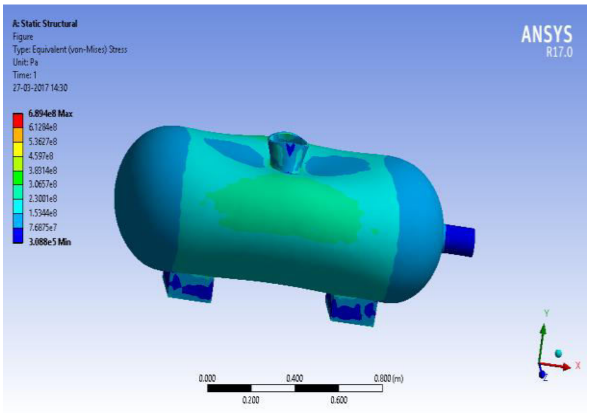

Fig.7 Equivalent Von-Mises stress of cylinder

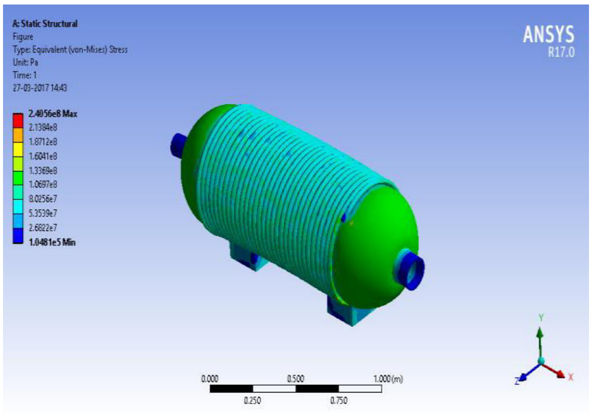

Fig.8 Equivalent Von-Mises stress of Wire Wound Cylinder

TABLE IV COMPARISON OF VON-MISES STRESS OF EXISTING AND PROPOSED CYLINDER

	Existing compressor cylinder			Wire Wound compressor cylinder		
Obtained values of individual	3MPa	6MPa	9MPa	3MPa	6MPa	9MPa
Equivalent Von- Mises Stress(MPa)	319.85	460.94	689.4	156.12	198.18	240.56

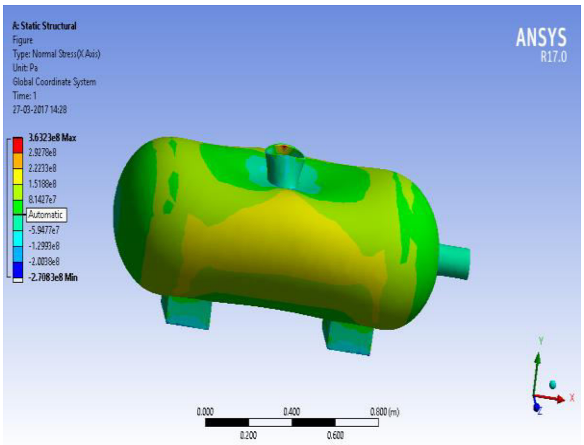

Fig.9 Circumferential Stress of a Cylinder

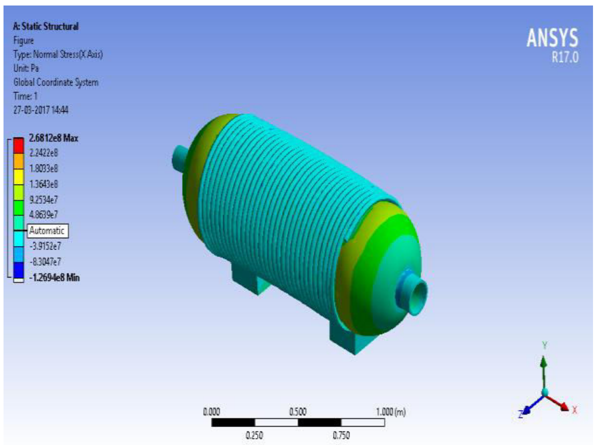

Fig.10 Circumferential Stress of a Wire Wound Cylinder

TABLE V COMPARISON OF CIRCUMFERENTIAL STRESS OF EXISTING AND PROPOSED CYLINDER

	Existing compressor cylinder			Wire Wound compressor cylinder		
Obtained values of individual	3MPa	6MPa	9MPa	3MPa	6MPa	9MPa
Circumferential stress (MPa)	124.76	244	363.23	89.26	221.87	268.12

V. OBSERVATIONS AND CONCLUSIONS

An attempt has been made to know the pressure capacity of a wire wound cylinder with exiting cylinder. The analysis carried on the cylinder is structural analysis. Empirical relations are employed to obtain the theoretical deflections and stresses of both existing and proposed cylinders and observed that stresses in wire wound cylinder is less compare to existing cylinder. Since it is a new proposed model for this analysis carried out by using Finite Element Tools to predict the actual deflection and stress behaviour along the cylinder

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