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Investigation of Stresses in Ring Stiffened Circular Cylinder

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***Abstract*— This study deals with the stress analysis of cylinder using Finite Element Method. The analysis is carried out in ANSYS. The FE results are compared with theoretical results. The proposed work is aimed to analyze the cylinder with the stiffeners under static load conditions. From the analysis it is found that, there is a good agreement between analytical and FE results. From the analysis of cylinder with stiffener it is concluded that the minimum hoop and radial stresses are developed for cylinder with inner triangular stiffener. When the number of stiffeners increases then the buckling pressure capacity also increases and deformation decreases. So, the stiffener are recommended not to reduce the stress levels but to increase buckling load capacity of cylindrical vessesls.**

***Index Terms*— Stress Analysis , Stiffener, Buckling , Cylinder.**

I. Introduction

The cylindrical shells structures play an important role for underwater applications, space vehicles and aircrafts in terms of its buckling, stiffness, strength and weight etc. Hence the importance of lightweight and high strength materials such as aluminum alloys, titanium alloys and composite materials have become significant. In the present work the problem of cylinder with stiffener of varying dimensions at different locations under static load conditions is analyzed using analytical as well as FE approach. The proposed analysis involves the study of cylinder with different cross-section of stiffener ring with same cross-sectional area of stiffener for each of the cases. The cross-sectional view of the cylinder with stiffener ring for three cases is shown in fig 2.1, 2.2 & 2.3 for rectangular, triangular & trapezoidal stiffener respectively.

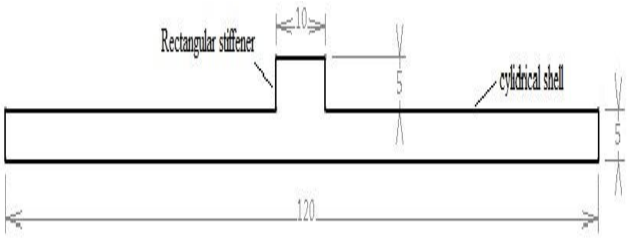

Fig 1.1 Cylinder with Rectangular Stiffener

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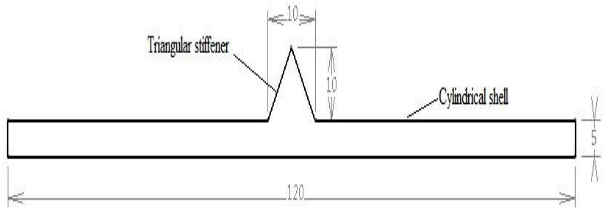


Fig.1.2 Cylinder with Triangular Stiffener

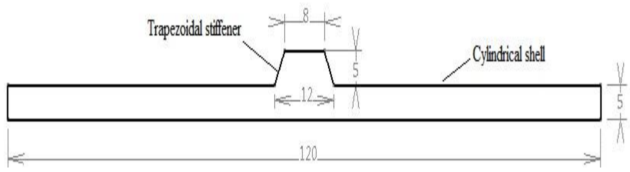


Fig.1.3 Cylinder with Trapezoidal Stiffener

A. *Investigation of Stresses in Cylinder:*

Following data is assumed for analysis:
Internal pressure = P_i = 10 Mpa
Yield strength = $\sigma_t = 250$ Mpa
Inner diameter= d_1 = 100 mm

Thickness (t) of simple cylinder is given by equation (1),

$$\text{thickness} = t = r_i\left[\sqrt{\frac{\sigma_t+p_i}{\sigma_t-p_i}}-1\right] \tag{1}$$

Hoop stress is given by equation (2),

$$\sigma_\theta = \frac{p_i(r_2^2+r_1^2)}{(r_2^2-r_1^2)} \tag{2}$$

Radial stress at the inner surface is given by equation (3),

$$\sigma_r = \frac{p(r_i)2}{(r_o)2-(r_i)2}\left[1-\frac{(r_o)2}{x^2}\right] \tag{3}$$

To verify the analytical result for hoop stress and radial stress of cylinder FE model is prepared with same geometric dimensions.
The comparison of analytical and FE results of cylinder is shown in table 2.1.

Table 2.1 Comparison of Analytical and FE results:

Results	Analytical	FEA	Error (%)
Hoop stress (Mpa)	105.24	105.171	0.065
Radial stress (Mpa)	-10	-9.933	0.67

II. Effect of Stiffening Ring on Stresses and Deformation in Cylinder:

Circumferential stiffeners have been considered for cylinder. FE analysis is carried out by using ANSYS considering different types and location of stiffener. The specifications of the cylinder for FE analysis considered are as follows

Inner diameter (d_i) = 100 mm

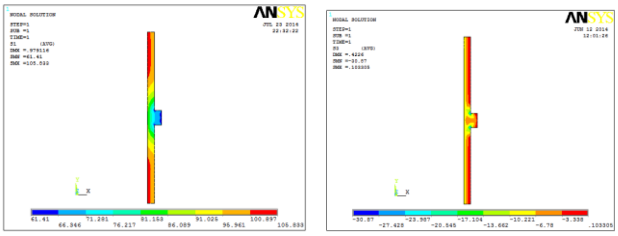
Thickness (t) =5 mm

Internal pressure (p_i) = 10 MPa

Modulus of elasticity (E) = 200 $\times 10^3$ N/mm^2

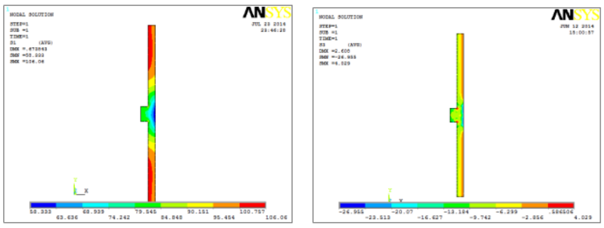
Poisson's ratio (μ) = 0.3

The stress contours for various stiffeners on cylinder has shown in fig.3.1 to 3.6 for inner & outer rectangular stiffener, fig.3.7 to 3.12, for inner & outer triangular stiffener & fig.3.13 to 3.18 for inner & outer trapezoidal stiffener.



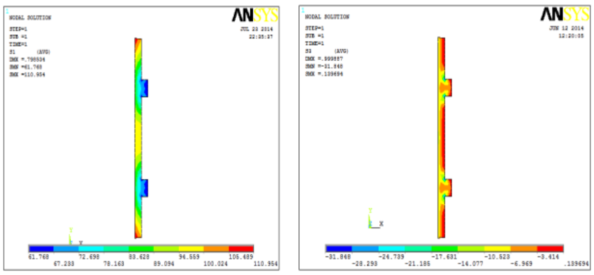
(a) Hoop stress (b) Radial stress

Fig: 3.1 Cylinders with one Rectangular outer Stiffener



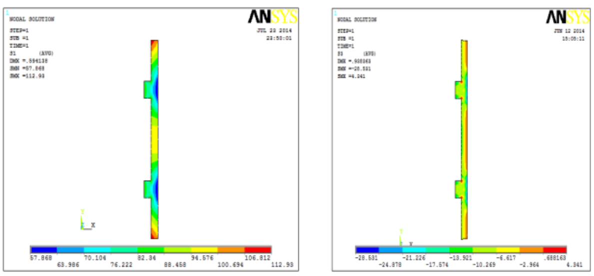
(a) Hoop stress (b) Radial stress

Fig: 3.2 Cylinder with one Rectangular inner Stiffener



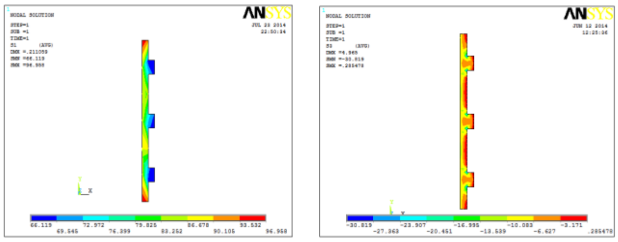
(a) Hoop stress (b) Radial stress

Fig: 3.3 Cylinder with two Rectangular outer Stiffeners



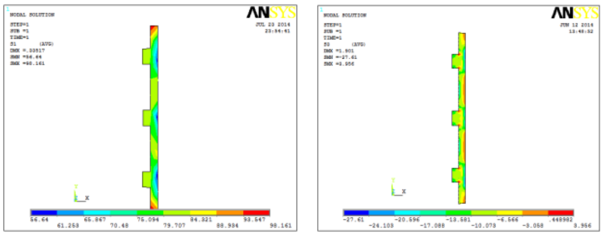
(a) Hoop stress (b) Radial stress

Fig: 3.4 Cylinder with two Rectangular Inner Stiffeners



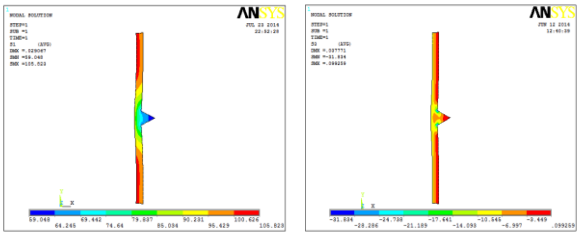
(a) Hoop stress (b) Radial stress

Fig: 3.5 Cylinder with three Rectangular outer Stiffeners



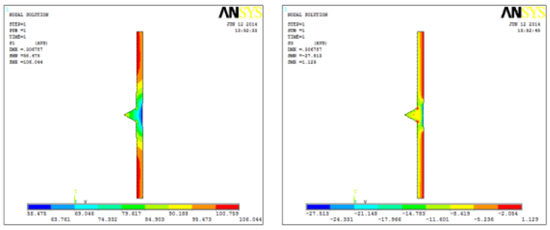
(a) Hoop stress (b) Radial stress

Fig: 3.6 Cylinder with three Rectangular inner Stiffeners



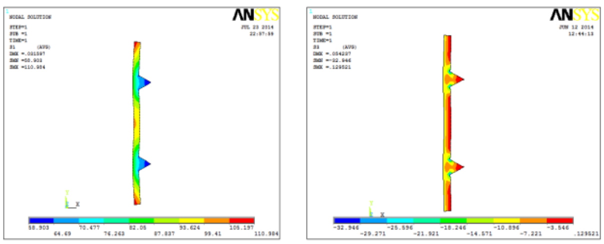
(a) Hoop stress (b) Radial stress

Fig: 3.7 Cylinder with one Triangular outer Stiffener



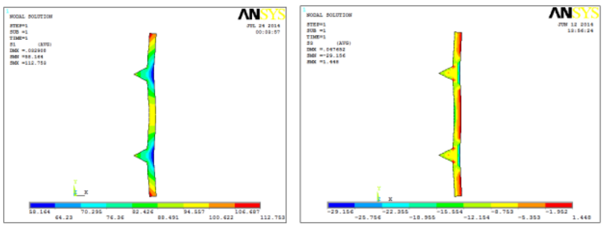
(a) Hoop stress (b) Radial stress

Fig: 3.8 Cylinder with one Triangular inner Stiffener



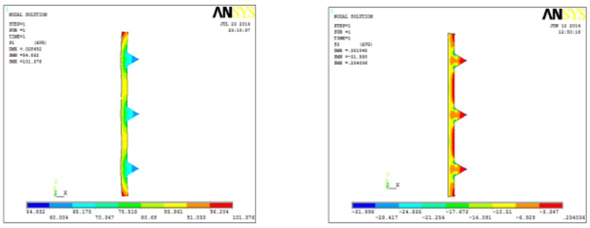
(a) Hoop stress (b) Radial stress

Fig: 3.9 Cylinder with two Triangular outer Stiffeners



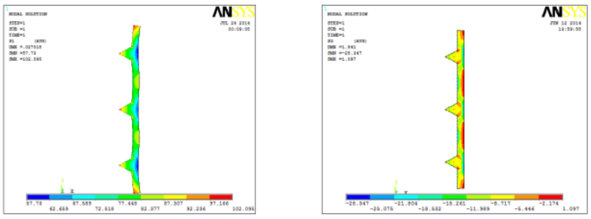
(a) Hoop stress (b) Radial stress

Fig: 3.10 Cylinder with two Triangular inner Stiffeners



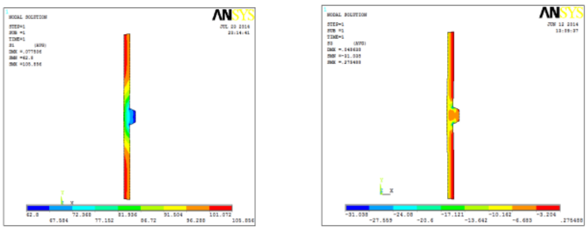
(a) Hoop stress (b) Radial stress

Fig: 3.11 Cylinder with three Triangular outer Stiffeners



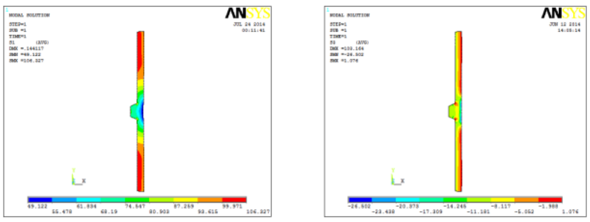
(a) Hoop stress (b) Radial stress

Fig: 3.12 Cylinder with three Triangular inner Stiffeners



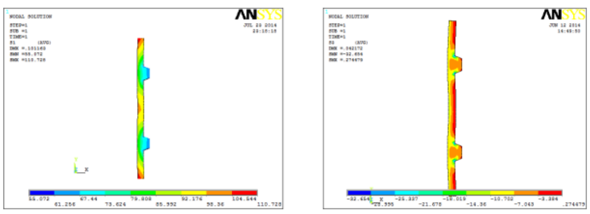
(a) Hoop stress (b) Radial stress

Fig: 3.13 Cylinder with one Trapezoidal outer Stiffener



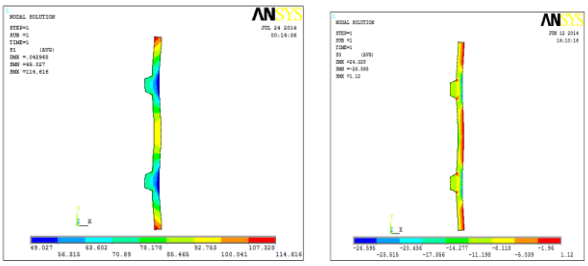
(a) Hoop stress (b) Radial stress

Fig: 3.14 Cylinder with one Trapezoidal inner Stiffener



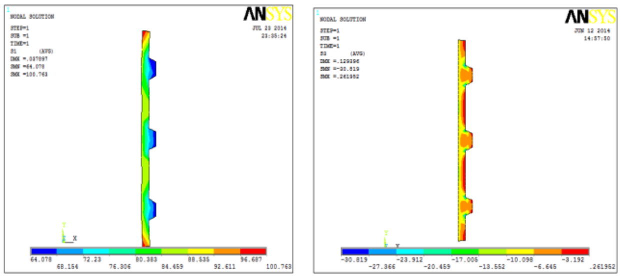
(a) Hoop stress (b) Radial stress

Fig: 3.15 Cylinder with two Trapezoidal outer Stiffeners



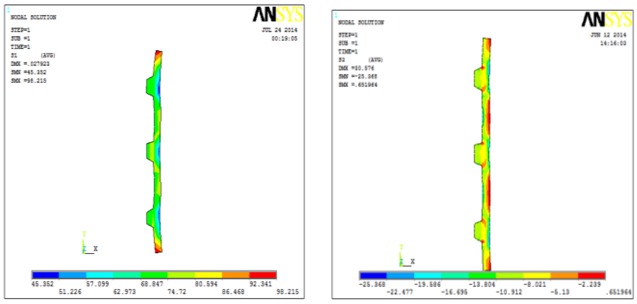
(a) Hoop stress (b) Radial stress

Fig: 3.16 Cylinder with two Trapezoidal inner Stiffeners



(a) Hoop stress (b) Radial stress

Fig: 3.17 Cylinder with three Trapezoidal outer Stiffeners



(a) Hoop stress (b) Radial stress

Fig: 3.18 Cylinder with three Trapezoidal inner Stiffeners

The variation of number of stiffening ring on Deformation is shown in fig 3.19 to 3.24 for cylinder with rectangular, triangular & trapezoidal stiffeners.

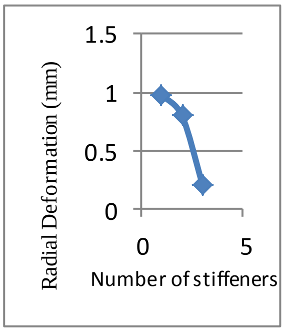


Fig 3.19: Effect of no. of outer rectangular stiffeners on deformation in cylinder

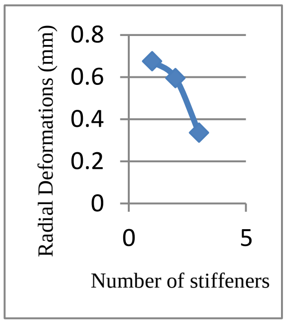


Fig 3.20: Effect of no. of inner rectangular stiffeners on deformation in cylinder

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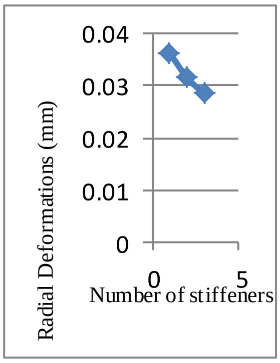

Fig 3.21: Effect of no. of outer triangular stiffeners on on deformation in cylinder

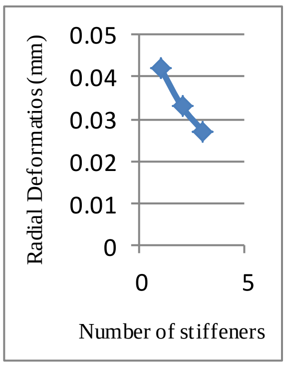

Fig 3.22: Effect of no. of inner triangular stiffeners deformation in cylinder

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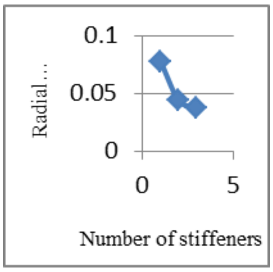

Fig 5.23: Effect of no. of outer trapezoidal stiffeners deformation in cylinder.

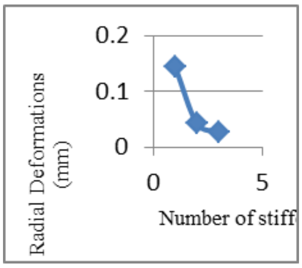

Fig 3.24: Effect of no. of inner on trapezoidal stiffeners on deformation in cylinder

III. Determination of Buckling Load Capacity of Cylinder:

Based on the classical theory, a simple expression for the buckling load under external pressure for two dimensional isotropic shells in plain strain is given by equation (4).

$$Pcr = \frac{1}{4} \times \frac{E}{1-\mu^2} \times \frac{h^3}{a^3} \qquad (4)$$

Where,

A = radius of shell

h = Thickness

E = Modulus of elasticity

μ = Poisson ratio

The specification for above analysis are specified as follows-

E = Modulus of elasticity= 210×10^3 Mpa

μ = Poisson's ratio = 0.3

h = Thickness of the cylinder = 5 mm

a = Radius of cylinder

P_{cr} = Critical pressure.

$$Pcr = \frac{1}{4} \times \frac{210\times10^3}{1-(0.3)^2} \times \frac{5^3}{50^3} = 57.69 \text{ MPa}$$

The solid model of cylinder, the meshing of FE model, the pressure loading on cylinder & the result of buckling load capacity are shown in fig. 4.1, 4.2, 4.3, & 4.4 respectively.

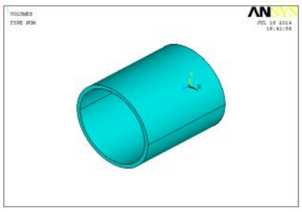

Fig: 4.1 FE Model of Cylinder

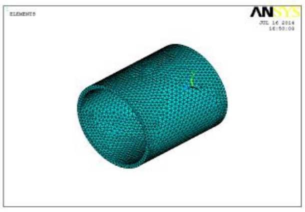

Fig: 4.2 Meshing of FE Model

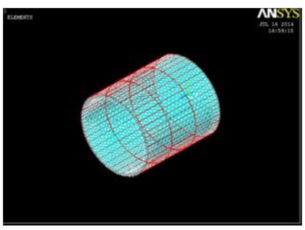

Fig: 4.3 External Pressures on Cylinder

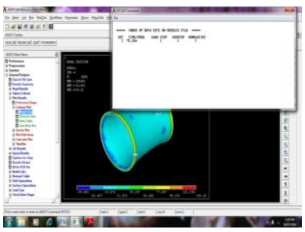

Fig: 4.4 Display Result

Effect of Stiffening Ring on Buckling Load Capacity of Cylinder:

The specification of the cylinder for buckling load capacity FE analysis is considered as follows-

Inner diameter (d_i) = 100 mm

Thickness (t) =5 mm

External pressure (p_o) = 10 MPa

Modulus of elasticity (E) = 200 $\times10^3$ N/mm^2

Poisson's ratio (μ) = 0.3

The specification of rectangular stiffener for FE analysis is considered as follows

Breadth of stiffener = 10 mm

Thickness of stiffener = 5 mm

The effect of stiffening ring on buckling load capacity of cylinder is shown in fig.5.1 to 5.5

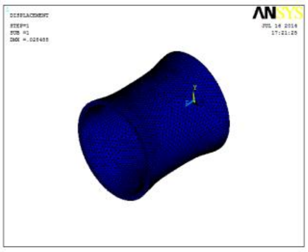

Fig: 5.1 Buckling of cylinder

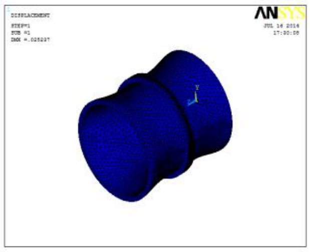

Fig: 5.2 Buckling of cylinder With one stiffener

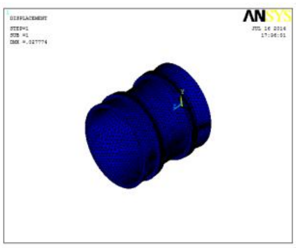

Fig: 5.3 Buckling of cylinder with two stiffeners

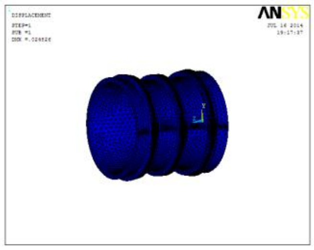

Fig: 5.4 Buckling of cylinder with three stiffeners

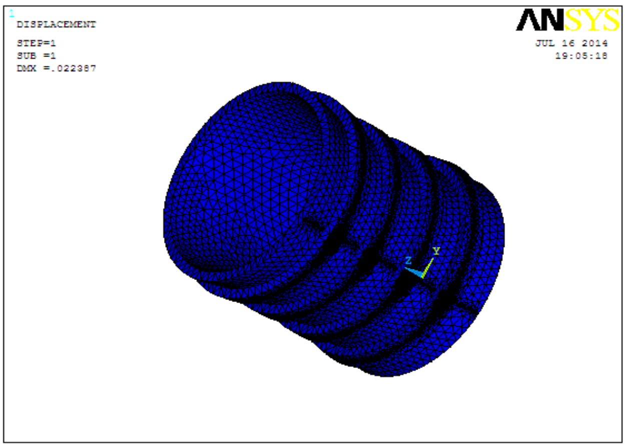

Fig: 5.5 Buckling of cylinder with four stiffeners

The variation of number of stiffening ring on buckling load capacity in cylinder is shown in fig.5.6

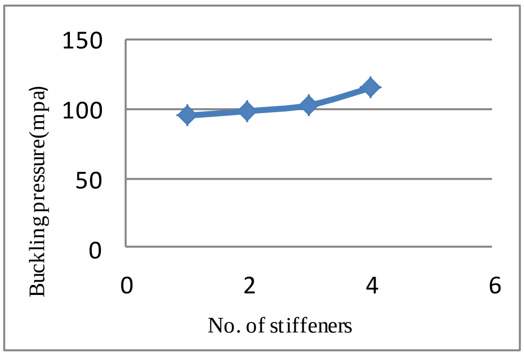

Fig 5.6 No. of Stiffeners Vs Buckling Load Capacity

IV. Results, Discussion & Conclusion:

The comparison of analytical and FE result of cylinder is shown in table 6.1

Table 6.1 Comparison of Analytical and FE result of cylinder

Results	Hoop Stress (MPa)	Radial Stress (MPa)
Analytical	105.24	-10
FEA	105.171	-9.933
Difference	0.065%	0.67%

The Comparison of Stresses in Cylinder with Inner and Outer Stiffeners is given in table 6.2.

Table 6.2 Comparisons of Stresses in Cylinder with Inner and Outer Stiffeners

Parameters	Outer stiffener			Inner stiffener		
	Hoop stress (MPa)	Radial stress (MPa)	Deformation (mm)	Hoop stress (MPa)	Radial stress (MPa)	Deformation (mm)
Cylinder with rectangular stiffener	81.578	-17.104	0.9791	80.437	-13.184	0.6738
Cylinder with two rectangular stiffeners.	83.37	-17.63	0.7985	82.931	-13.921	0.5941
Cylinder with three rectangular stiffeners.	79.417	-16.996	0.2110	77.403	-13.581	0.3351
Cylinder with triangular stiffener.	79.855	-17.641	0.0364	79.617	-14.783	0.0419
Cylinder with two triangular stiffeners.	82.041	-18.246	0.0315	82.251	-15.554	0.0329
Cylinder with three triangular stiffeners.	77.844	-17.693	0.0284	76.665	-15.261	0.0270
Cylinder with trapezoidal stiffener.	82.502	-17.121	0.0775	81.091	-14.245	0.1441
Cylinder with two trapezoidal stiffeners.	83.998	-18.011	0.0437	83.397	-14.277	0.0429
Cylinder with three trapezoidal stiffeners.	80.83	-17.005	0.0378	78.767	-13.804	0.0279

Comparison of buckling pressure is shown in Table 6.3.

Table 6.3 Comparison of Buckling Pressure

Type of Analysis	Buckling Pressure (MPa)	Error (%)
Analytical	57.69	23.35
FE (Eigen value buckling analysis)	75.266	

The Comparison of Buckling Load as Per Number of Stiffener is given in table 6.4.

Table 6.4 Comparison of Buckling Load as Per Number of Stiffeners

Parameters	Buckling Pressure (MPa)	Deformation (mm)
Simple cylinder	75.266	0.02848
Cylinder with 1 rectangular stiffener	95.102	0.02523
Cylinder with 2 rectangular stiffeners	98.366	0.02501
Cylinder with 3 rectangular stiffeners	102.53	0.02482
Cylinder with 4 rectangular stiffeners	114.95	0.02238

From the analysis it is observed that the inner and outer stiffeners provided on cylinder does not appreciably reduce the stress levels but the deformations are reduced considerably.

It is also seen that the effect of reduction in stress value is more for inner stiffener as compared to outer stiffener but the difference is very marginal.

The buckling analysis revealed that, the buckling load capacity of cylinder increases with increase in number of stiffeners. So, the stiffeners are recommended to reduce the deformation and to increase the buckling pressure capacity.

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