Volume: 5 Issue: X Month of publication: October 2017
DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

Buckling Analysis of Ring Stiffened Circular Cylinders Using ANSYS

Kavya Aileni[1], P. Prasanna[1], P. C. Jain[2]
[1]Department of Mechanical Engineering, JNTUH College of Engineering, J.N.T.University, Hyderabad
[2]DRDL, Hyderabad

Abstract: The buckling analysis of ring stiffened circular cylinders subjected to external uniform pressure is presented in this paper. The buckling analysis is done by varying radius to thickness ratio, cylinder thickness, ring spacing and stiffener thickness. The analysis has been carried out using Finite Element Analysis. ANSYS software has been used. The ring stiffened cylinder is well suited for supporting external pressure loads and is extensively used for this purpose in sub marine hulls. The ring stiffened cylinder is made of Aluminium 2024-T3 alloy. The cylinder is modelled using SHELL 281 element in ANSYS. The linear and nonlinear buckling analysis results using ANSYS are compared with the previous experimental results of ring stiffened cylinder under uniform external pressure. The nonlinear buckling gives the closer results when compared with the experimental results. The buckling pressures of ring stiffened cylinders with stiffener cross sections of Z, Square, Rectangle, C, I and T sections are presented. During the analysis the optimal thickness, loading and boundary conditions are kept constant and the cross section of the stiffener was varied.
Key words: Finite Element Analysis, ANSYS, SHELL 281and Stiffener

I. INTRODUCTION

The strength and rigidity of any component depends on material properties and it`s form. The material properties can be improved upto a certain limit by different processes like alloying, Heat Treatment and work Hardening. The improvement of strength and rigidity by improving it`s form has some constraints, If we increase cross section area or thickness to improve strength of component the weight of the component increases , we can`t select shape of the component which gives the more strength or rigidity because the geometry of component depends mainly on application and ergonomics. By using stiffeners we can improve the strength and rigidity with small increase in weight and without changing the geometry. Thin cylindrical shells have many applications in different industries like marine, nuclear, mechanical, and civil and space structures which are highly susceptible for imperfections and they have efficient load carrying capacity with weight economy. Generally, these thin cylindrical shells fail by buckling subjected to external pressure. So the design of thin cylindrical shells under external pressure should be based on buckling criteria. Buckling occurs when most of the strain energy which is stored as membrane energy can be converted to bending energy requiring large deformation resulting in catastrophic failure. By using ring stiffeners in their flanges buckling resistance of long thin cylindrical shells greatly improved. Stiffened cylindrical shell forms are used as structural components in naval and offshore industry. Buckling analysis of these shell forms are very important in subsea
applications since compressive stress resultants are induced in shell membrane by hydrostatic pressure. If thin cylindrical shell is not ring stiffened, they will have very poor buckling resistance and they fail by non-symmetric bifurcation buckling. The ring-shell combination can collapse if the ring stiffener not strong enough. Such mode of failure is known as general instability [1,2]. The bare shell in between the ring stiffeners will collapse, if the ring stiffeners are strong enough which is called as local collapse [3]

In the present work linear and non-linear Buckling analysis cylinders is carried out using ANSYS by varying radius to thickness ratio of shells, ring spacing, and cross section of stiffeners and the results are compared to experimental values [4]Dwight F. Windenburgand Charles trilling [5] presented the theoretical and empirical instability formulas for thin cylindrical shells under external pressure. The formulas are discussed briefly and checked against the results of tests conducted at U. S. Experimental model basin for the Bureau of construction and repair, Navy department. These results are compared with the experimental results. Rolland George Sturm [6] presented a study of the collapsing pressure of thin walled cylinders. The purpose of this study is to analyse the elastic behaviour of thin circular cylindrical shells subjected to uniform external pressure, and to determine the pressure at which such shells collapse for simply supported and for fixed edges. This study also helps to study experimentally the behaviour of thin walled tubes under uniform external pressures, for comparison with the results of theoretical analysis.

Donald A. Dow[4] presented the buckling and post buckling tests of ring stiffened circular cylinders loaded by uniform external pressure. Experimental results are presented for tests of 10 ring stiffened cylinders loaded to failure by uniform external air pressure. The proportions of the aluminium alloy cylinders were such that local buckling (instability between rings) occurred before general instability (instability of rings and skin as a composite wall). Failure by general instability occurred between about ¾ atm (76kN/m^2) for the weakest cylinder to 3 atm(304 kN/m^2) for the strongest cylinder. Test results for local buckling are compared with the previous test results and with theoretical results. The test cylinders buckled locally at somewhat high pressures than those of previous test program but at lower pressures than predicted by classical theory. The results of changes in cylinder geometry on structural efficiency were assessed for the collapse strengths of the cylinders. The study indicated that efficient cylinders have thin skins with many closely spaced low mass stiffening rings. P. B. Goncalves and R. C. Batista [7] presented buckling and sensitivity estimates for ring stiffened cylinders under external pressure. An analysis of critical and post critical behaviour of cylinders under external pressures with widely spaced stiffeners is presented. The ring stiffeners are treated as discrete elements and their torsional plus bending stiffeners are taken into account and their effects on the most relevant results are evaluated. Solutions are presented to show the effect of shell and ring geometric parameters on the critical loads and imperfection sensitivity. Buckling loads are estimated and compared with previous test results and recommended design curves. SreelathaP. R [8] presented linear and nonlinear buckling analysis of stiffened cylindrical submarine hull. The objective of this work is the linear and nonlinear analysis of the stiffened cylindrical shell subjected to very high hydrostatic pressure. Finite element package ANSYS is used for modelling and analysis the submarine hull. Comparative study of linear buckling and nonlinear buckling has been done for two configurations, inter stiffener and inter bulkhead. From the linear and nonlinear analysis results it is found that failure will occur prior to buckling load. The percentage reductions in the buckling pressure in nonlinear analysis are 14.2 and 20.4 for fixed and simply supported boundary condition respectively. Considering these effects nonlinear analysis becomes even more important in the damage prediction of submarine shell. Therefore a definite need is felt for the nonlinear analysis while considering the design criteria of the submarine hull.

RinuCherian [9] presented the buckling analysis of underwater cylindrical shells subjected to uniform external pressure. In this paper, the analysis of cylindrical section of underwater pressure hull using finite element analysis is presented. The finite element method for static structural and deflection analysis of underwater cylindrical structure is done by using ANSYS 15 software. This thesis primarily focused into, large thickness variation by considering cylinder as thin, moderately thick as well as thick by varying, l/d and r/t ratio. The observation from the analysis shows that, the Donnell's relation can be applied to thin shells more precisely. Due to the increased bending or flexural effect in thick shells, the analysis shows some error value while comparing Donnell's relation with numerical solution.

Y. Zhu, J. H. Dong, B. J. Gao [10] presented buckling analysis of thin walled cylinder with combination of large and small stiffening rings under external pressure. This paper presents Eigen value buckling analysis to study the buckling pattern (BP) and critical pressure P_{cr} of thin walled cylinders with the combination of large and small stiffening rings. It is found that there is a map of buckling patterns for different ring combinations. Three BP's appear as buckling of cylinder with both large and small stiffening rings (BP-1), buckling of cylinder together with small stiffening rings but without large stiffening rings (BP-2) and buckling of cylinder without both large and small stiffening rings (BP-3). In the region of BP-1 and BP-2, values of P_{cr} increase with the size of large and small ring, but remain constant in the region of BP-3. The large ring location and sizes of both large and small rings are optimized for lightweight design of the example cylinder, which yields a reasonable result satisfying the stability requirement under external pressure.

II. BUCKLING ANALYSIS OF RING STIFFENED CYLINDER USING ANSYS

For analysis 10 cylinders with different radius to thickness ratio, ring spacing were taken. The dimensions of the cylinders are presented in table I.

The dimensions of cylinder 10 are clearly described in the figure 2.1.

The dimensional details of stiffening ring are described in figure 2.2

A. *Modelling*

The finite element model of the ring stiffened cylinder is meshed with SHELL281 elements with an element size of 10 mm. The fine mesh is required for buckling analysis, and a full 360-degree model is necessary because the deformation is no longer axisymmetric after buckling occurs.

All shell elements have uniform thickness. Five sections are created in the model with no offsets, so the shell sections are offset to the mid pane bydefault.

The geometry and FEM model of cylinder 10 is represented in figure 2.3

Table I. Dimensions of 10 cylinders

Cylinder	Ring Spacing(b_s)(mm)	Skin thickness(t_s)(mm)	Ring thickness(t_w)(mm)	r/t_s	b_s/t_s	t_w/t_s
1	63.5	.843	.384	421	75.3	.455
2	95.3	.843	.386	421	113	.458
3	127	.851	.376	418	149	.442
4	63.5	1.029	.538	346	61.7	.524
5	95.3	1.021	.528	348	95.3	.517
6	127	1.026	.516	347	123.8	.503
7	953	1.356	.655	262	70.2	.483
8	127	1.346	.632	264	94.3	.470
9	95.3	.848	.668	419	112.3	.787
10	95.3	1.034	.843	344	92.1	.816

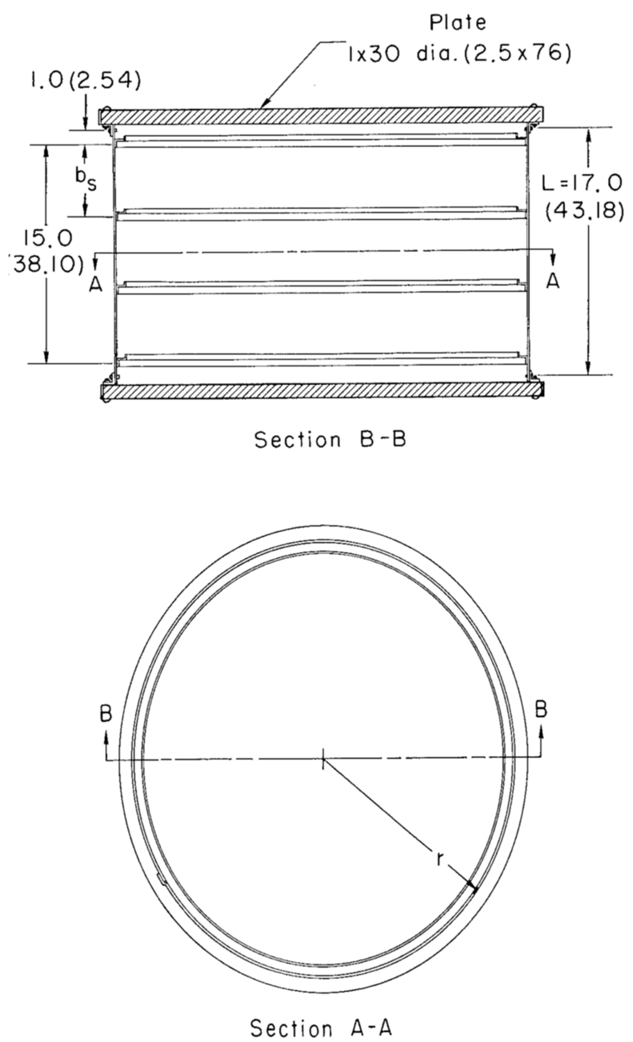


Figure 2.1 Dimensions of Cylinder 10

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

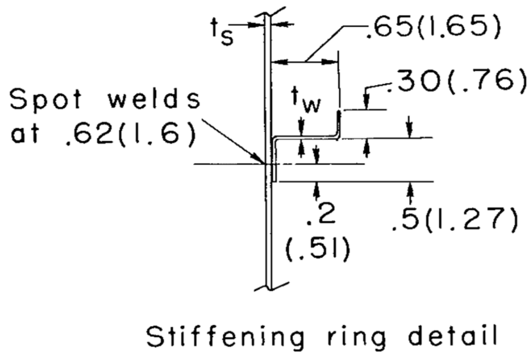


Figure 2.2 Z Section ring detail dimensions.

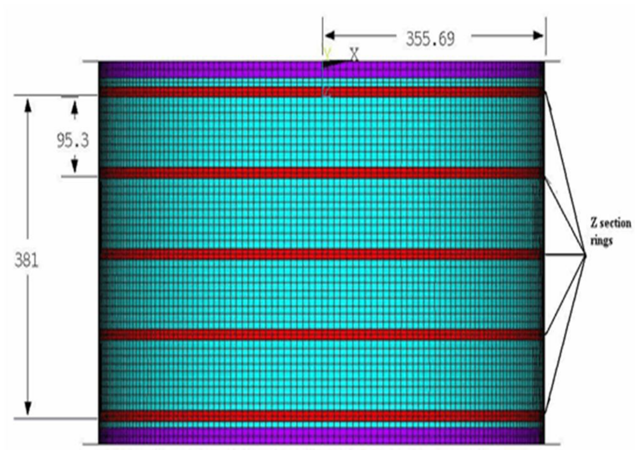


Figure 2.3 geometry and finite element model

B. Material Properties and Boundary Conditions

The cylinder rings and plates are made of 2024-T3 sheet aluminium alloy and have the following material properties (according to AMS 4037 property data):

Table II: Material properties of Aluminium 2024-T3

Cylinder, Ring, and Plate Material Properties	
Young's Modulus (GPa)	E = 73
Poisson's Ratio (v)	0.33
Yield stress (MPa)	268.9
Tangent modulus (MPa)	$E_T = 73$

The cylinder type for this problem is used extensively for supporting external pressure loads in submarine hulls and in aerospace applications; therefore, the reference experiment models the cylinder as a free-floating object for testing. For this numerical analysis, the only required boundary conditions are those to prevent the six rigid body motions. A total of six displacements are therefore applied to three nodes located on the top plate at 0, 90, and 270 degrees; the nodes are restricted so that all rigid translations and rotations are not possible for the cylinder. Loading consists of a uniformly distributed external differential pressure: P_{ext} = 0.24 MPa.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

C. Buckling Analysis Of 10 Cylinders

Cylinder 1

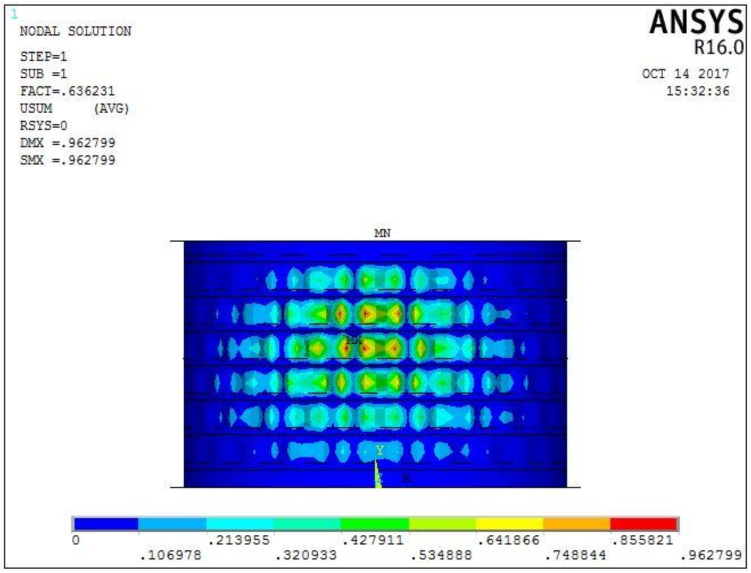


Figure 2.4: Eigen value buckling load factor for cylinder1

The buckling load factor for this cylinder is 0.636231 and pressure applied is 0.24 MPa.

Buckling load factor= $\frac{buckling\ pressure}{applied\ pressure}$

Therefore, buckling pressure is 0.1526 MPa

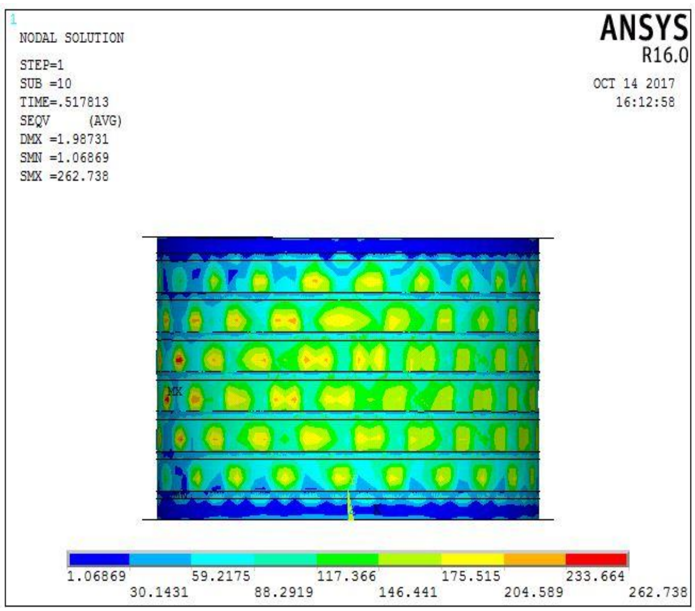


Figure 2.5 Deformation and Von Mises stress distribution at buckling initiation for cylinder 1

Similarly buckling analysis is done for remaining 9 cylinders.

III. BUCKLING OF RING STIFFENED CYLINDERS WITH VARIOUS CROSS SECTIONS

Buckling analysis is done for cylinder 1 with different cross sections such as square, rectangle section, C section, I section, and T section

These stiffeners are designed such that cross-sectional area of all the stiffeners is same.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

A. Square section

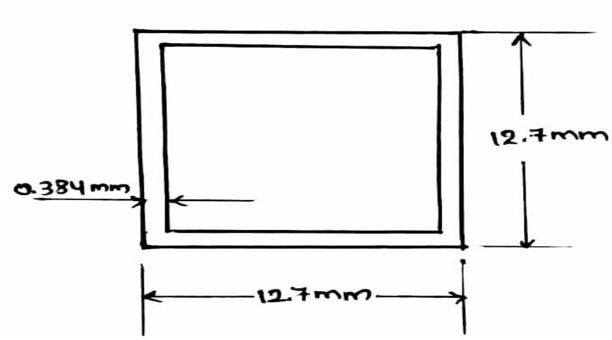


Figure 3.1 Square cross section

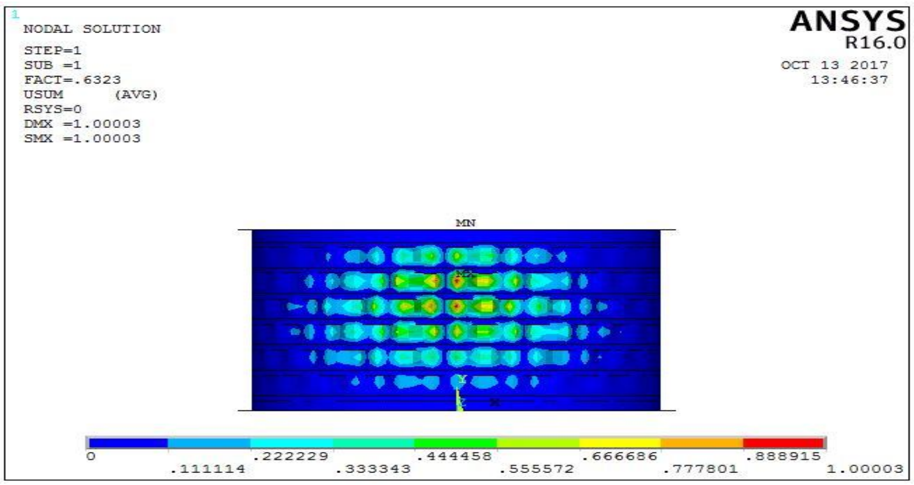


Figure 3.2: Eigen value buckling load factor for square section stiffened cylinder

IV. RESULTS AND DISCUSSIONS

Results of buckling pressure, deformations and stresses of 10 cylinders are shown in the table III.

Table III: Results data for 10 Cylinders

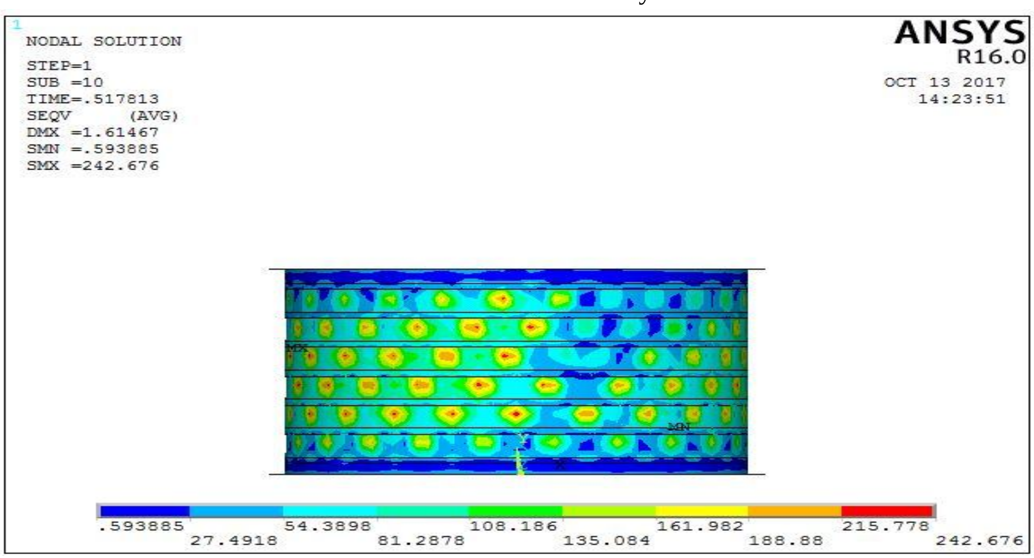


Figure 3.3: Deformation and von mises stresses for square section stiffened cylinder

Similarly buckling analysis is done for all the mentioned cross sections.

Cylinder No	Linear Buckling pressure (MPa)	Non-linear buckling pressure (MPa)	Buckling pressures from experiments [4] (MPa)	Linear deformation (mm)	Deformation at buckling initiation (mm)	Minimum shear stress (MPa)	Maximum shear stress (MPa)
1	0.1526	0.1296	0.0951	0.9627	1.9873	1.06869	262.738
2	0.087	0.0626	0.0597	0.944	1.5840	0.6537	153.775
3	0.0637	0.038	0.0494	0.9163	1.6679	0.1851	126.251
4	0.2605	0.2296	0.186	0.9057	2.7101	2.0050	312.627
5	0.1433	0.103	0.110	0.9406	1.5878	0.5764	188.889
6	0.103	0.0776	0.0855	0.9736	2.9447	0.4692	220.304
7	0.263	0.2100	0.256	0.7741	249.206	0.6693	293.753
8	0.2056	0.1579	0.169	0.9756	3.694	1.7616	283.524
9	0.0938	0.0776	0.0663	0.9637	1.6795	0.3285	190.206
10	0.150	0.124	0.121	1.0016	2.7394	0.5956	249.112

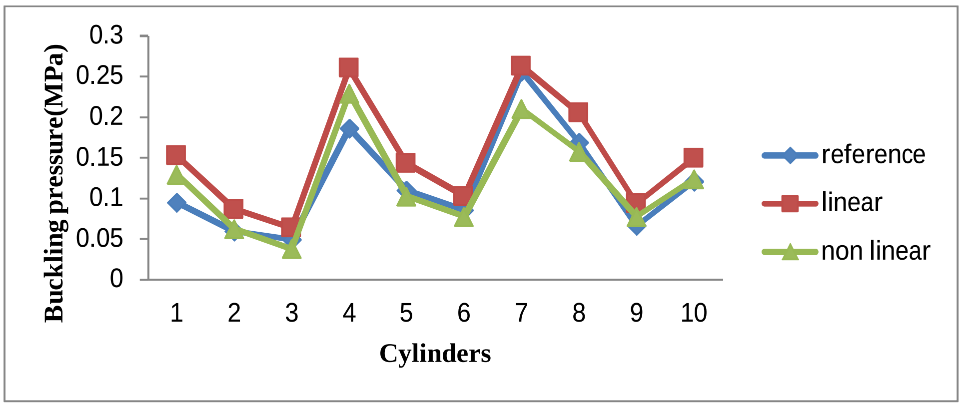


Figure 4.1 Buckling pressure Vs cylinders

In the above graph linear buckling pressure and non linear pressure for 10 cylinders is presented and are compared with the experimental results. It can be observed that Buckling pressure values as per Non linear analysis are closer to experimental results.

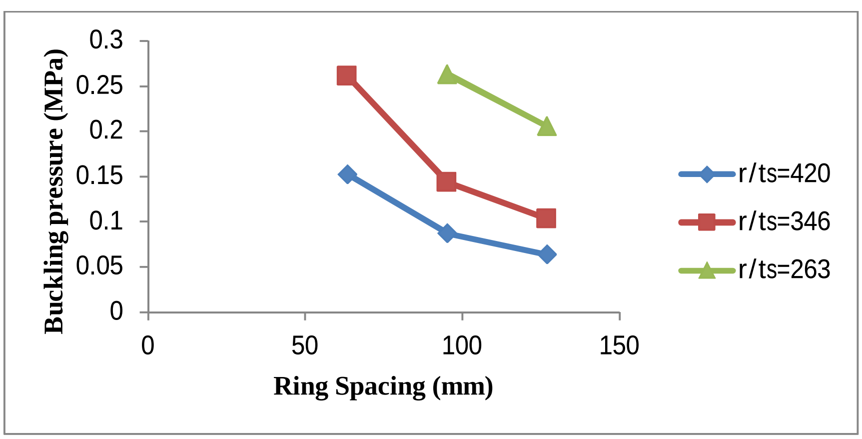


Figure 4.2: Rig spacing Vs Linear buckling pressure

From the graph of ring spacing Vs linear buckling pressure, it can be observed that for a given radius to thickness ratio, buckling pressure decreases with increase in ring spacing.

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

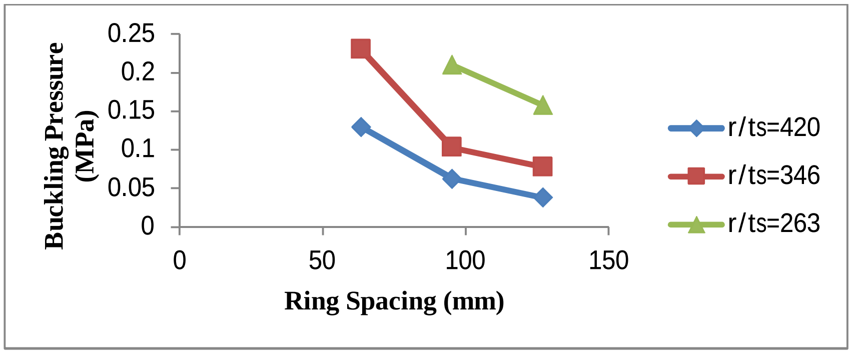


Figure 4.3: Ring spacing Vs Nonlinear buckling pressure

From the graph of ring spacing Vsnon linear buckling pressure it can be observed that for a given radius to thickness ratio, buckling pressure decreases with increase in ring spacing.

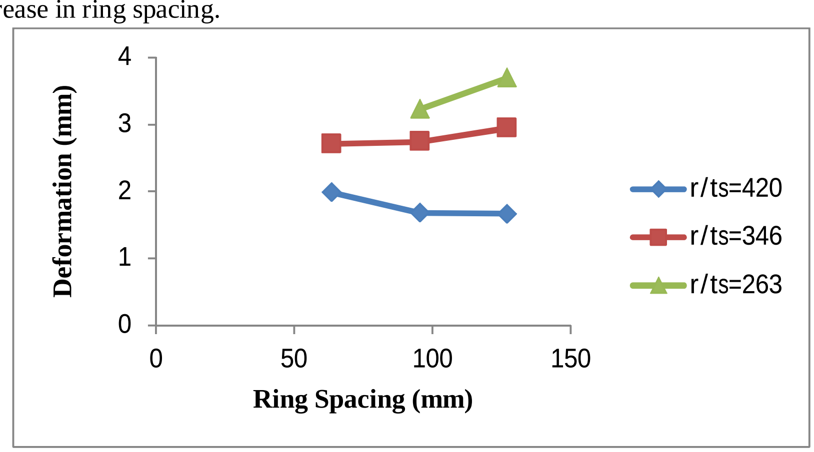


Figure 4.4: Ring spacing Vs Deformation at buckling initiation

From the above graph, for a given (r/ts) ratio Deformation at buckling initiation increases with increase in ring spacing.

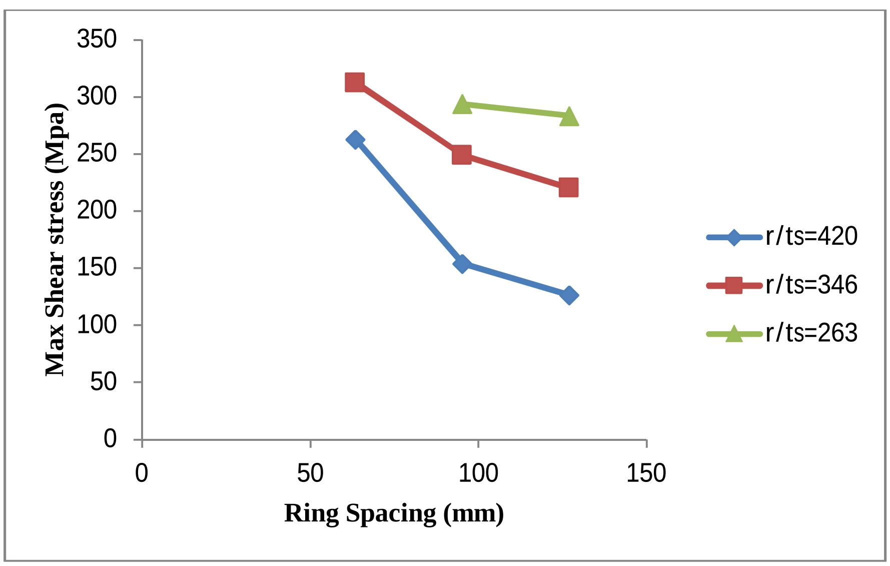


Figure 4.5: Ring spacing Vs Maximum shear stress

the above graph, shear stress decreases with increasing ring spacing as the buckling pressure also decreases.

The linear and non linear buckling pressures, stresses and deformations of ring stiffened cylinders with various cross sections of stiffeners are presented in table IV.

Table IV: Results data for different stiffener cross sections

Stiffener Cross section	Linear buckling pressure (MPa)	Non linear buckling pressure (MPa)	Linear deformation (mm)	Deformation at buckling initiation (mm)	Minimum shear stress (MPa)	Maximum shear stress (MPa)
Z section	0.1526	0.1296	0.9627	1.9873	1.0687	262.738
Rectangle section	0.1592	0.1267	1.0000	1.6737	0.3413	373.336
Square section	0.1517	0.1296	1.0003	1.6147	0.5938	242.676
C section	0.1516	0.1253	0.9237	1.8885	0.0690	258.198
I section	0.1356	0.1056	0.9943	1.392	0.6344	324.795
T section	0.1074	0.1044	1.0000	0.9456	0.2309	67.0717

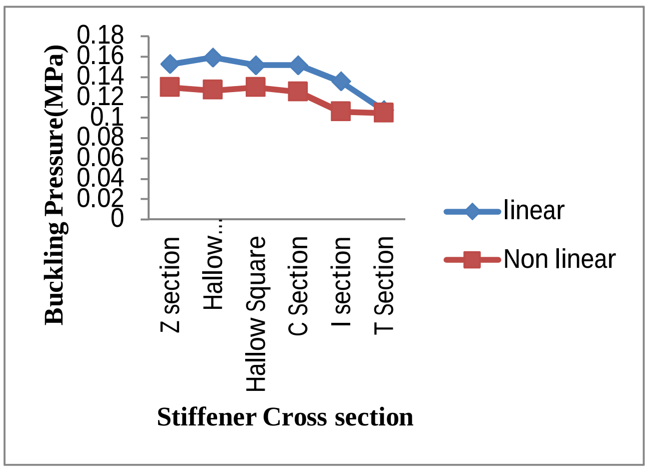


Figure 4.6: Stiffener cross sections Vs Buckling pressure

In the above graph, buckling pressures for different cross sections of stiffeners is presented. It can be observed that Z section, hallow rectangle and hallow square sections has very closer values of buckling pressures.

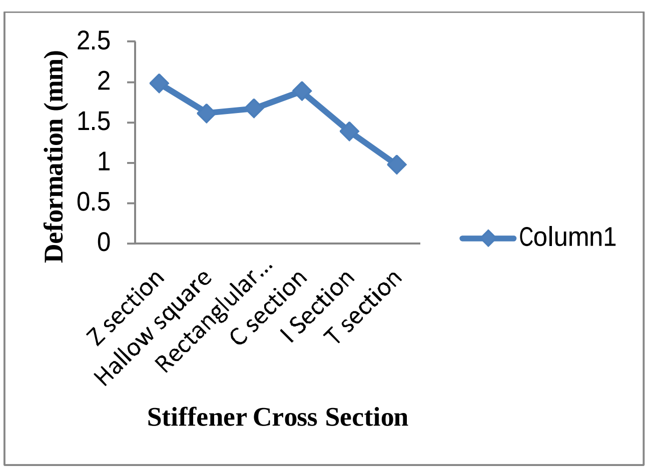


Figure 4.7: Stiffener cross section Vs Deformation

From the deformation plot it is clear that cylinder with stiffing ring of Z cross section has more deformation at buckling initiation.

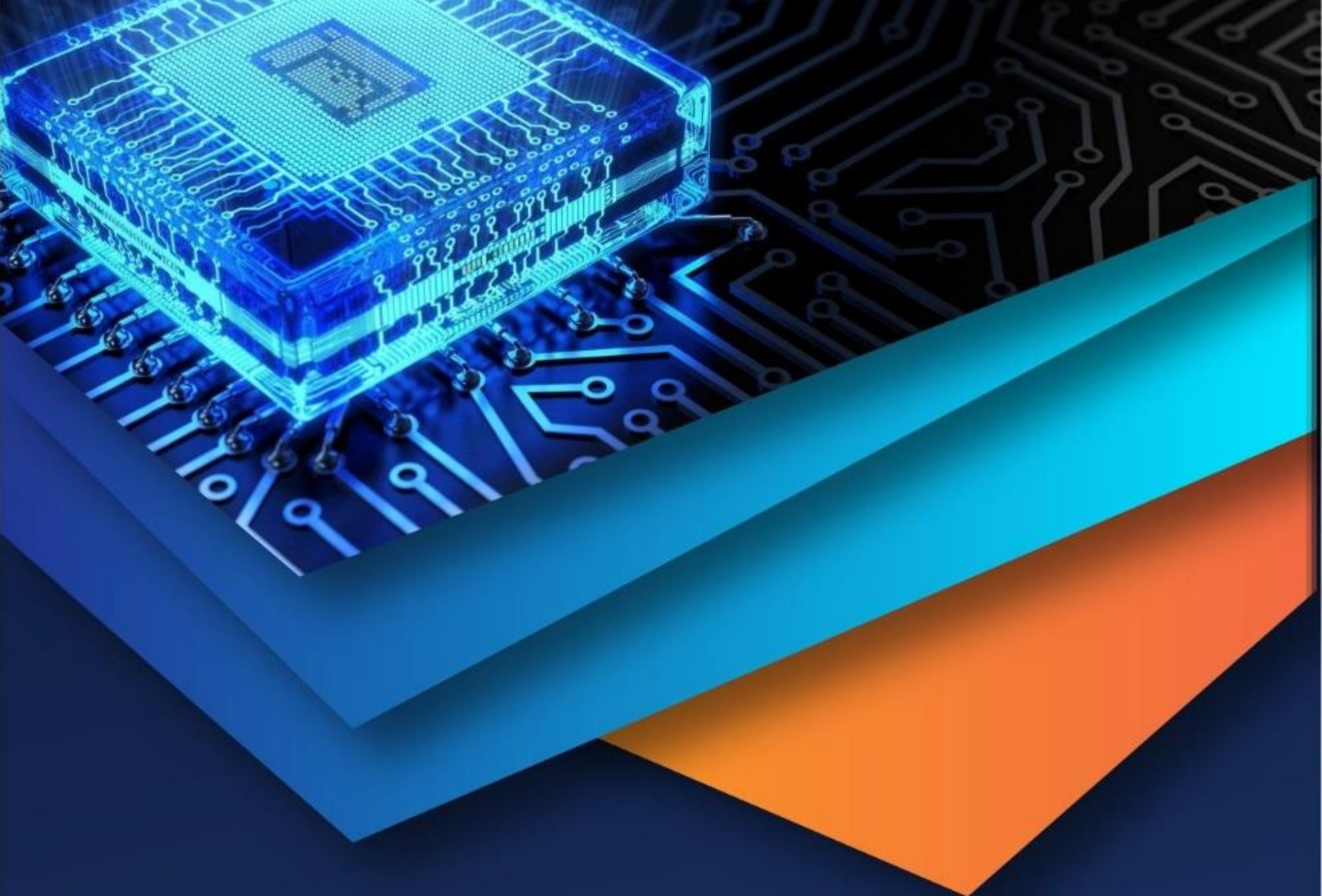
International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue X, October 2017- Available at www.ijraset.com

V. CONCLUSION

The comparison of buckling pressure from ANSYS with experimental data showed that the cylinders buckled at pressures higher than the pressures predicted by non linear buckling analysis (using ANSYS).It is observed that the buckling pressure decreases as the spacing between ring stiffeners increases for a given radius to shell thickness ratio.Buckling analysis with different stiffener cross sections such as Z section, square section, rectangular section, C section, I section and T section are presented. The results show that the Z section and square section stiffened cylinders have higher buckling pressures and Z section stiffened cylinder has more deformation at buckling initiation.

REFERENCES

[1] Ross C.T.F., Little A.P.F., Adeniyi K.A., “Plastic buckling of ring stiffened conical shell under eternal hydrostatic pressure”, Ocean Engineering 32: 21-36, 2005.
[2] Ross C.T.F., Little A.P.F., Allsop R., Smith C., Engelhardt M., “Plastic general instability of ring reinforced conical shells under uniform external pressure”, Marine Technology 44(4): 268-277, 2007.
[3] Schiender W., Brede A., “Consistent equivalent geometries imperfections for the numerical buckling strength verification of cylindrical shells under uniform external pressure”, Thin walled structures 43(2): 175-188, 2005.
[4] Donaldson A. Dow, “Buckling and Post buckling tests of Ring Stiffened Circular Cylinders Loaded by Uniform External Pressure”, NASA Technical Note NASA TN D-3111. Langley Research Centre, 1961.
[5] Dwight F. Windenburg and Charles Trilling, “Collapse by Instability of Thin Cylindrical shells under External Pressure”, Trans. ASME, Vol 56, no. 11, pp. 819-825,1934.
[6] Rolland George Sturm,“A Study of the Collapsing Pressure of Thin walled Cylinders”, Bull. No.329, EngExpt.Sta., Univ. Illinois, 1941.
[7] P. B. Goncalves and R. C. Batista, “Buckling and Sensitivity estimates for Ring stiffened Cylinders under External Pressure”, Int. J. Mech. Sci. Vol. 27, No.1, pp 1-11, 1985.
[8] Sreelatha P.R., Alice mathai, “Linear and non linear buckling analysis of stiffened cylindrical submarine hull”, International Journal of Engineering Science and Technology (IJEST), 2012.
[9] RinuCherian, “Buckling analysis of underwater cylindrical shells subjected to external pressure”, International Journal of Innovative Research in Advanced Engineering (IJIRAE) ISSN:2349-2163, Volume 1 Issue 10, 2014.
[10] Y. Zhu, J. H. Dong, B. J. Gao, “Buckling Analysis of thin walled cylinder with Combination of Large and Small stiffening rings under External Pressure”, Procedia Engineering 130(2015) 364-373, 2015.



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY