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ANALYSIS OF CYLINDRICAL SHELL STRUCTURES

P. Saranya

Department of Civil Engineering, RVS College of Engineering and Technology, Dindigul,TamilNadu

Abstract- *Cylindrical shells are widely used in civil engineering. Examples include, nuclear containment vessels, steel silos and tanks for storage of bulk solids and liquids, and pressure vessels. The loading condition for these shells is quite varied depending on the function of the shell. Axial compression, global bending, external or internal pressure and wind loading are some of the most common loading forms for realistic structures. Buckling of shells is one of the most complicated phenomenon in structural engineering. Shells are continuum structures where one dimension, the shell thickness, is very small compared to the other two dimensions. Very small deformations take place in the shell when it absorbs membrane strain energy. However, it deforms significantly when it absorbs bending strain energy. If the shell is loaded so that its strain energy is in the form of membrane compression and the loading reaches a stage where this stored membrane strain energy is converted into an equivalent bending energy, the shell deforms rather dramatically and fails in a process called buckling.*

I. INTRODUCTION

Cylindrical shell structures are used for storage of large quantities of particulate solids and fluids, a cylindrical shell metal structure with its axis vertical is usually the most economic. Metal silos and tanks are often required to be elevated above ground level to permit trains, trucks, or conveying systems to be placed beneath a hopper from which the solid or fluid is withdrawn.

Elevated silos must be supported, and access requirements often mean that the supports must be local either on columns or supported from an elevated floor system. The connection of such a support to a cylindrical shell is a long standing difficult problem in shell analysis, and most designs use only past experiences of successes and failures. Smaller silo structures are often supported on local brackets attached to the side of the shell, but very few investigations of the behaviour or strength of such an arrangement have ever been made.

II. LITERATURE REVIEW

A. *Finite Element Buckling Analysis of Composite Cylindrical Shell with Cutouts Subjected To Axial Compression (L.Gangadhar and Dr.T.Sunil Kumar, 2016)*

In many industrial applications, s hells are equipped with openings of various shapes, sizes and locations within the lateral surface. The objective of the present paper is to understand the effect of cutouts on critical buckling load of thin composite cylindrical shells. Nowadays the usages of composite cylindrical shell are gradually increased in many engineering fields. Due to the inherent tailoring properties of these composite materials have a number of unique design features such as reduce weight, high performance, increased service life and reduced system maintenance. The composite cylindrical shells are being used widely in aerospace industries, underground pipelines, submarines, etc. The problem of cylindrical shell buckling subjected to axial compressive loads has been investigated .Theoretically evaluated classical buckling load is generally much higher than the actual buckling load of the cylindrical shell and a knockdown factor is introduced to evaluate a better approximation based on an extensive experimental investigation. The buckling analysis of cylindrical shells with cutouts under axial loading. The cutouts are of different types like circular, square, and rectangle subjected to internal pressure and axial compression.

B. Buckling assessment of axially loaded cylindrical shells with random imperfections (Sheriff Saleh Safar Ally Iowa State University, 2015)

One of the primary design considerations for axially loaded cylindrical shells is buckling. A comparison of the linear theory of elasticity solution to test results shows that the theoretical solution usually implies a strong overrating of the buckling resistance of cylinders. The deviations from the classical theory solution as well as the scatter in test results increase with the increase of the cylinder radius to thickness ratio. The formulas for the buckling resistance assume that geometric imperfections are within tolerance levels. In such analysis, the major question is what imperfection configuration should be utilized. On the basis of the statistical evaluation of numerical results, a deterministic analysis was finally conducted to develop an equivalent deterministic imperfection that brings the numerical solution and lower bound of test data into an agreement. The problem of finding the worst deterministic imperfection was reduced to the determination of two variables that were computed through a simple parametric investigation.

C. Buckling of Circular Steel Cylindrical Shells under Different Loading Conditions (Lei Chen, 2011)

The study of shell structures involves a lot of areas covering small or large deformations, elastic, elastic-plastic, hardening, bifurcation, snap-through, Imperfection- sensitivity, stability, and collapse analyses. Different shell buckling problems were investigated to give a comprehensive understanding of the shell buckling phenomenon. The historical and current developments for shell buckling research were generalized. The imperfection sensitivity study of thin cylindrical shells, the elastic-plastic behaviour of thicker shells and the contents of shell buckling were all reviewed. This thesis presented a series of related studies, including cylindrical shells under global bending, uniform external pressure and wind loading. These dealt with topics which overlap but which are commonly seen as distinct.

III. CYLINDRICAL SHELL STRUCTURES

A. *Buckling of cylindrical shell structures*

Thin walled cylindrical shells are important components of industrial structures such as liquid storage tanks, silos, etc. Shell buckling is usually a major failure mode of thin walled shells under extreme loads such as earthquakes. Longitudinal and radial stiffeners are generally used in order to increase buckling capacity of thin walled shells. During an earthquake, cylindrical shells may experience global shear and suffer shear buckling. Buckling of thin walled shells is highly dependent to imperfections. In this study buckling of imperfect cylindrical stiffened tanks due to various loads are studied. Most of the literature relating to orthotropic shells deals with buckling under the simple loading conditions of uniform axial compression and uniform external pressure. By contrast, the loading conditions encountered in silos and tanks both lead to stepped-wall construction with pressures and frictional tractions that vary over the shell surface, leading to significantly more complicated pre-buckling states. The deformation and stress distribution for external pressure is studied and the optimization of the buckling will be done by changing the wall thickness and the number of stiffness brackets.

Fig 1. Buckling of silo

B. *Types of buckling of structures*

A thin-walled structure is made from a material whose thickness is much less than other structural dimensions. Buckling may evoke an image of failure of a structure with very large deformation. However, from a scientific and engineering point of view, buckling phenomena generally occur before the deformations are very large, and the structure may appear to be not deformed or only slightly deformed. Buckling of structures is an important phenomenon in structural mechanics, because buckling often (but not always) leads to failure of structures.

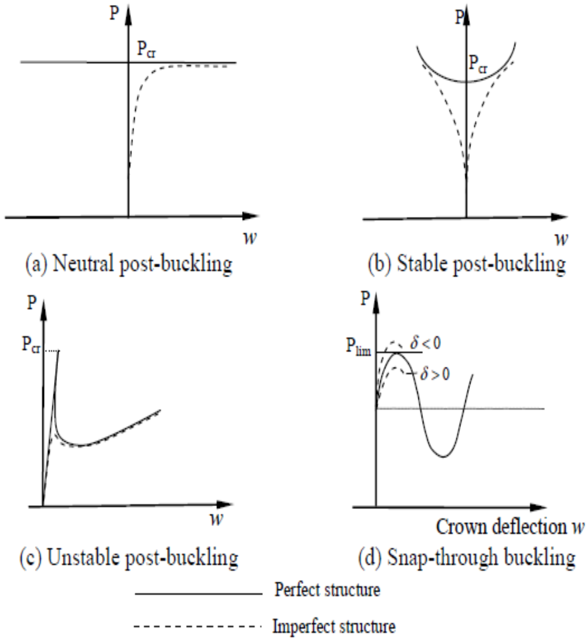


Fig 2. Types of buckling

C. *Causes of failures*

There are many different causes of silo failures shortcomings in the design procedure, construction, usage, maintenance, or some combination thereof. This, in turn, means that more than one individual or group often bears some responsibility when a failure occurs. Several committees in various countries are currently working to revise silo design codes. Many are having great difficulty in enacting new procedures for the design of silos to Potentially responsible parties include the designer, builder, building material supplier, owner, user, and others.

D. *Failures Due to Design Errors*

Silo design requires specialized knowledge. The designer must first establish the material's flow properties, then consider such items as flow channel geometry, flow and static pressure development, and dynamic effects. Problems like ratholing and vibration have to be prevented, while assuring reliable discharge at the required rate. Non-uniform loads, thermal loads, and the effects of non-standard fabrication details must be considered. Above all, the designer must know when to be cautious in the face of incomplete or misleading information, or recommendations that come from handbooks, or from people.Having established the design criteria, a competent design has to follow. Here the designer must have a full appreciation of load combinations load paths, primary and secondary effects on structural elements, and the relative flexibility of the elements. Special attention must be given to how the most critical details in the structure will be constructed so that the full requirements and intent of the design will be realized. Flow-related loading conditions which unfortunately, many designers fail to anticipate include, bending of circular walls caused by eccentric withdrawal. If the withdrawal point from the hopper is not located on the vertical centerline of the silo, and if the resulting flow channel intersects the silo wall, non-uniform pressures will develop around the circumference of the silo. Leading to horizontal and vertical bending moments. Many silo designers incorrectly account for these non-uniform pressures by only increasing hoop pressures. The problem of bending moments is particularly common when using silos with multiple hoppers in which only one or two of the hopper outlet are used at a time. Non-symmetric pressures caused by inserts. Support beams and other types of internals can impose non-symmetric pressures on the silo wall leading to unacceptable bending Stresses.Self-induced vibrations. Bins and silos sometimes vibrate. This can be either a high frequency, low amplitude type of cyclic vibration, or a low frequency, high amplitude erratic vibration leading to shocks. The latter have been known to cause structural failures. Local peak pressure at a point where a funnel flow channel intersects a silo wall. Mass flow occurring when funnel flow was Expected Migration of moisture from wet to dry particles within the stored solids, which causes the dry particles to expand and impose large radial loads on a silo. This is an uncommon problem.

E. *Failures Due to Construction Errors*

In the construction phase there are two ways in which problems can be created. The more common of these is poor workmanship. Uneven foundation settlement and faulty construction such as using the wrong materials or not using adequate reinforcement, such as insufficient quantity of rebars are but two examples of such a problem. This can usually be avoided by hiring only qualified builders, by close inspection during construction, and by enforcing a tightly written specification. The other cause of construction problems is the introduction of badly chosen or even unauthorized, changes during construction in order to expedite the work. Any changes in details, material specifications, or erection procedure, must be given careful consideration by both the builder and silo designer.

F. *Failures Resulting from Silo Usage*

If a bulk material other than the one for which the silo was designed is placed in it, the flow pattern and loads may be completely different. The load distribution can be radically changed if alterations to the outlet geometry are made, if a side outlet is put in a center discharge silo, or if a flow controlling insert or constriction is added. The designer should be consulted regarding the effects of such changes before they are implemented. Some of the problems which can occur include:

Collapse of large voids. A collapsing arch or rathole induces tremendous dynamic loads on the structure, which can cause the structure to fail. Vibrating bin dischargers have also been known to fall off bins and silos because of this mechanism. Development of mass flow in silos designed structurally for funnel flow. Mass flow can develop if the walls become smoother with time or if the properties of the bulk solid being stored change. This generally results in much higher loads at the top of the hopper section, which can result in structural failure Drastic means of flow promotion. High pressure air cannons and even dynamite are sometimes used to restore flow. The result may be more dramatic than the user and designer anticipated. Buckling of an unsupported wall below an arch of stored bulk material. Metal fatigue caused by externally-mounted bin vibrators.

G. *Failures Due to Improper Maintenance*

Maintenance of a silo comes in the owner's or user's domain and must not be neglected. There are two types of maintenance work which are required. The first is the regular preventative work, such as the periodic inspection and repair of the liner used to promote flow, protect the structure, or both. Loss of a liner may be unavoidable with an abrasive or corrosive product, yet maintaining a liner in proper working condition is a must if the silo is to operate as designed. The second area of maintenance involves looking for signs of distress, (e.g., cracks, wall distortion, tilting of the structure) and reacting to them. If evidence of a problem appears, expert help should be immediately summoned. In inappropriate response to a sign that something is going wrong can precipitate a Failure even faster than leaving it alone, including the common instinct to lower the silo fill level.

Wear due to corrosion and/or erosion can be particularly dangerous. For example, as carbon steel corrodes, the reduced wall thickness can eventually lead to a structural failure. This problem can be compounded through erosive wear of the silo wall. Erosive wear can also be a problem in reinforced concrete silos handling abrasive bulk materials such as coarse ores.

IV. TAGUCHI TECHNIQUE

One method presented in this article is an experimental design process called the Taguchi method. The Taguchi method is a technique for optimizing a process or design using multiple parameters. A researcher should always fully understand the various experimental methods in order to properly apply them to individual studies to maximize both the efficiency and the result of a study. The complete Taguchi methods are actually comprised of three main phases, which are all intended to be conducted offline. These three phases include system design, parameter design, and tolerance design. The Taguchi parameter design stage, which is the phase used in study, is commonly referred to here. This phase requires that the factors are known as that production should be in progress. The major goal of this phase is to increase the performance of the production process by adjusting the controlled factors.

The selection of parameters of inserts was based on some preliminary experiments and from literature survey. The selected parameters with their levels are listed in table.

Table 1.Parameter level

S.NO	**FACTORS NAME**	**L 1**	**L 2**	**L 3**
1	Stiffness ribs	4	6	8
2	Cylindrical shell thickness(mm)	12	13	14
3	Height (m)	2.5	3	4

A. Types of factors

1. Signal factors

These factors specify the intended value of product response.

Noise factors: factors that cannot be controlled by the designer are termed as noise factors.

Factors whose settings are difficult or expensive to control are also called noise factors. The noise factors themselves can be divided into three broad classes.

- External (environmental and load factors)
- Unit to unit variation (manufacturing non-uniformity)
- Detoriation (wear-out , process drift

2. Control factors

Factors that can be specified by the designer are under the category of control factors. Their settings are selected to minimize the sensitivity of the products response to all noise factors.

V. ORTHOGONAL ARRAYS

In this stage one has to decide whether to go for a full factorial or fraction Factorial experiments. A full-factorial experiment is acceptable when only a few factors are to be investigated, but not very acceptable when there are many factors. If a full-factorial experiment is used, there is a minimum of 2f possible combinations that must be tested (f=the number of factors each at two levels).

The selection of which OA to use predominantly depends on these items in order of priority.

1. The number of factors and interactions of interest
2. The number of levels for the factors of interest
3. The desired experimental resolution or cost limitations.

B. Types of Orthogonal Arrays

Two basic kinds of OAs are available. When all factors involved have 2 levels the available arrays are L4, L8, L12, L16, and L32. Similarly for 3-level the available arrays are L9, L18, L27. The number in the array designation indicates the number of trails (different possible test combinations) in the array. An L8 has eight trials and L27 has 27 trials. A factor may be assigned to anyone of the columns in OA. The 1s, 2s and 3s within the trials of the OA designate the appropriate level of the factor assigned to that column to be used for that specific trial.

C. *Selection of orthogonal array*

Stiffness ribs, shell thickness and height of the cylinder are the parameters selected in this work. It was decided to study only the main effects. The number of levels used in the factors should be used to select either two level or three level types of OAs. The nonlinear relationship among the process parameters, if it exists, can only be revealed if more than two levels of the parameters are considered. Thus each selected parameters are considered. Thus each selected parameters was analyzed at three levels. Hence we have to select arrays from 3 level orthogonal arrays.

It was decided to study only the main effects because the interactions are minimal has four columns.

Table 2.Orthogonal array

Modal No	**Ribs (no's)**	**Thick(mm)**	**Height (m)**
1	4	12	2.5
2	4	13	3
3	4	14	4
4	6	12	3
5	6	13	2.5
6	6	14	4
7	8	12	4
8	8	13	2.5
9	8	14	3

VI. SHELL MODELLING

A. Geometric modelling of a shell

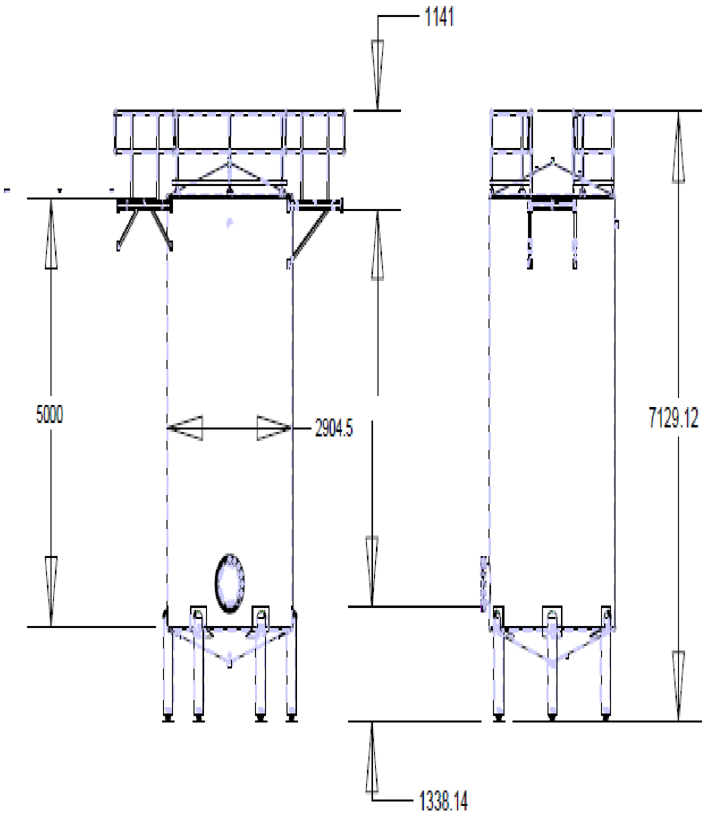


Fig 3. Geometric modelling

B. Solid modelling of a shell

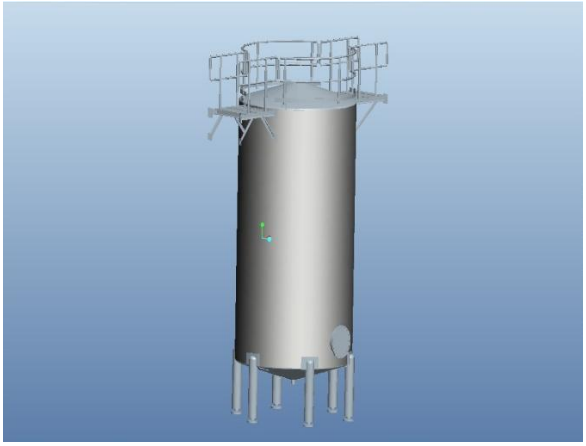
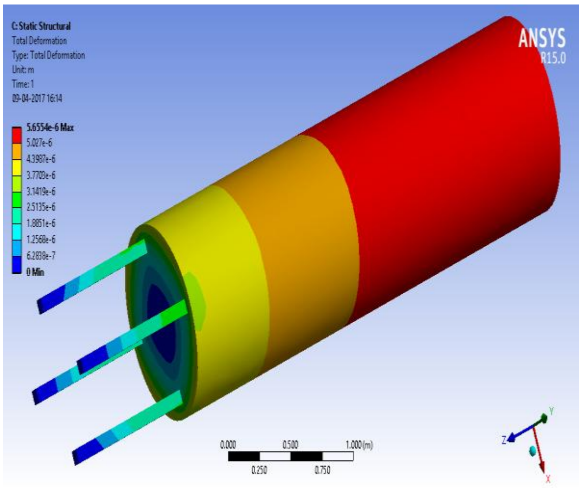
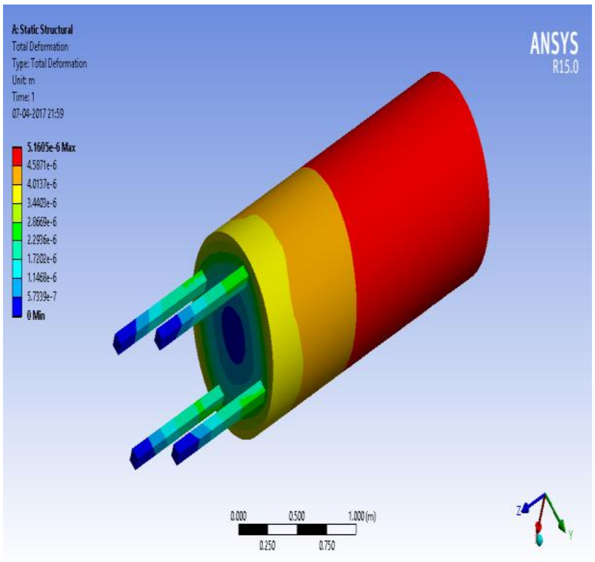


Fig 4. Shell modelling

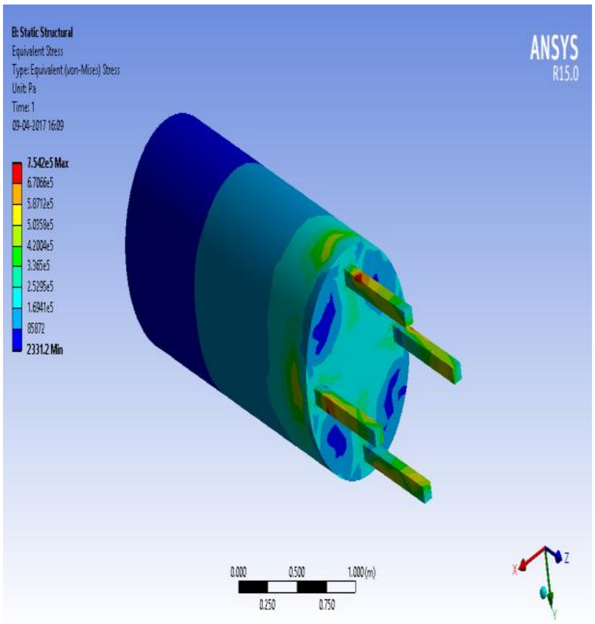
VII. ANALYSIS OF CYLINDRICAL SHELL

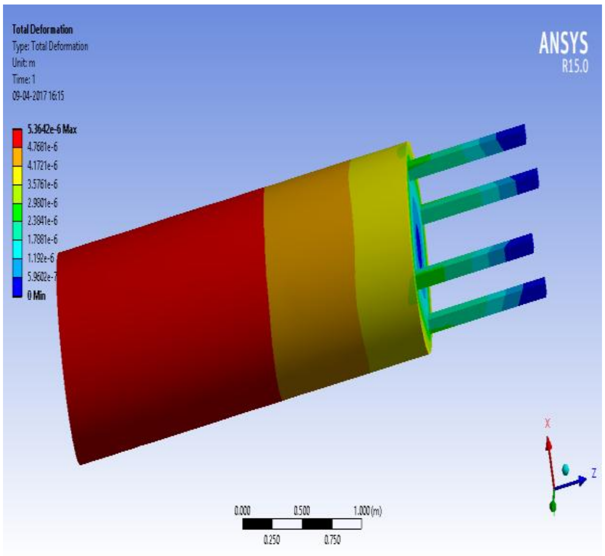
A. For model 1:





B. For model 2

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4.1721e-6
3.5761e-6
2.9801e-6
2.3841e-6
1.7881e-6
1.192e-6
0 Min
ANSYS
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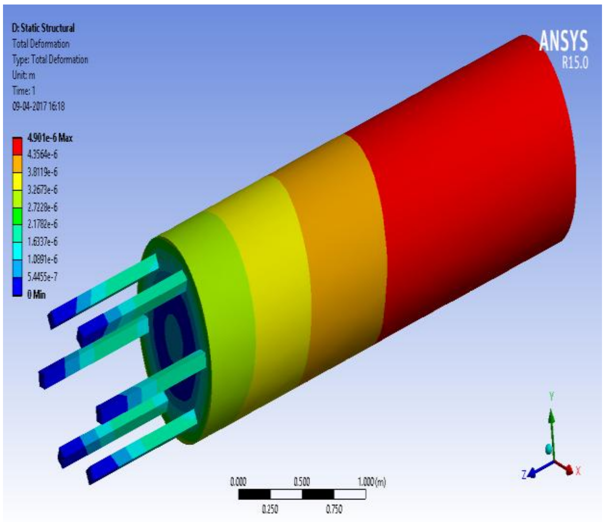
0.500
1.000 (m)
0.250
0.750

C. *For model 3*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Type: Total Deformation
Unit: m
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3.2673e-6
2.7228e-6
2.1782e-6
1.6337e-6
1.0891e-6
5.4455e-7
0 Min
ANSYS
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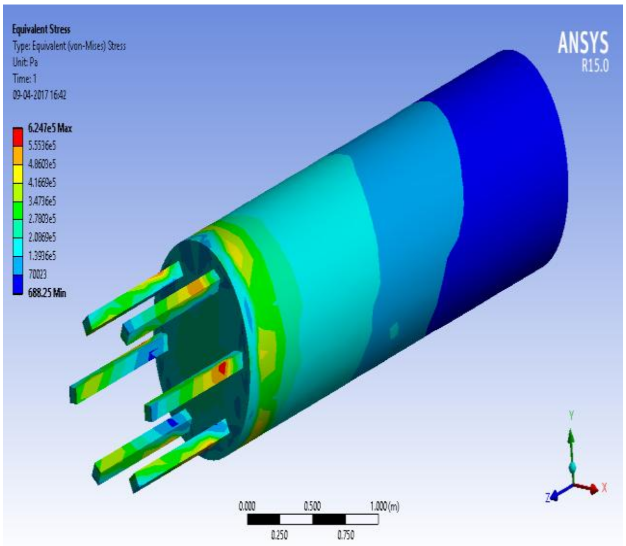
0.000
0.500
1.000 (m)
0.250
0.750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4.1669e5
3.4736e5
2.7803e5
2.0869e5
1.3936e5
70023
688.25 Min
ANSYS
R15.0
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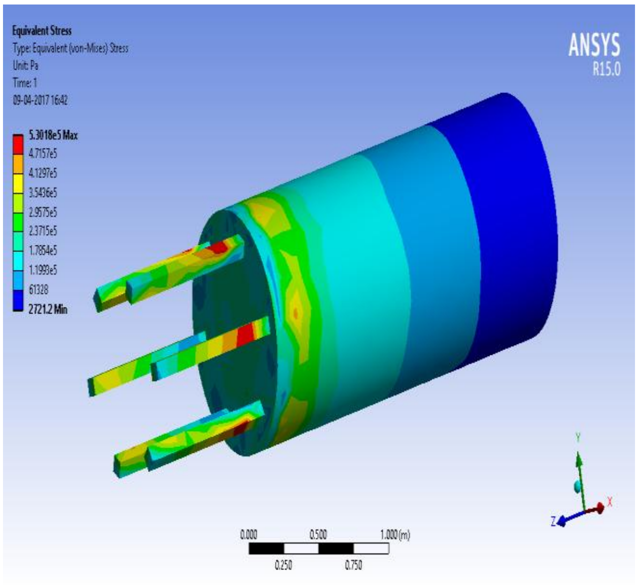
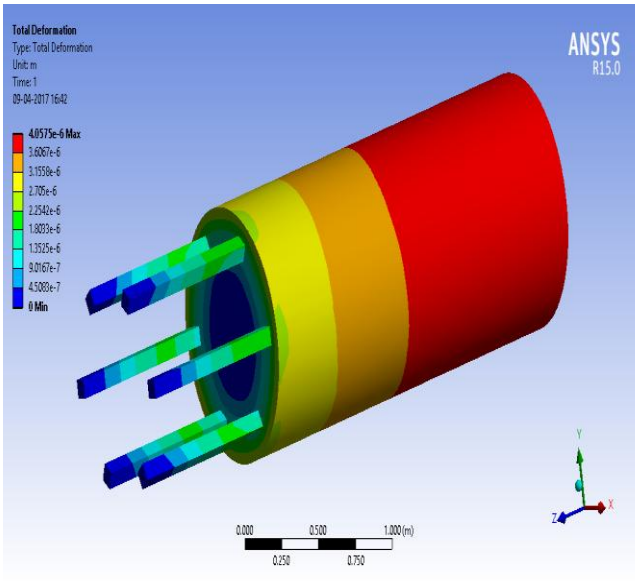
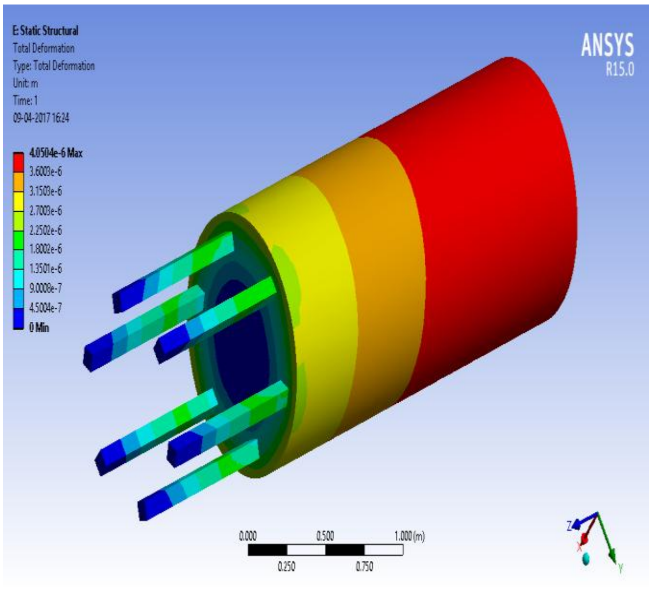
0.500
1.000 (m)
0.250
0.750

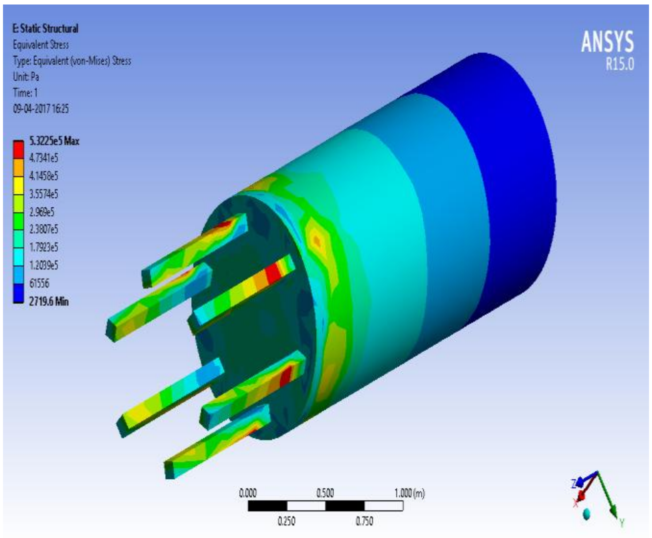
D. For model 4





E. For model 5

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4.1458e5
3.5574e5
2.969e5
2.3807e5
1.7923e5
1.2039e5
61556
2719.6 Min
ANSYS
R15.0
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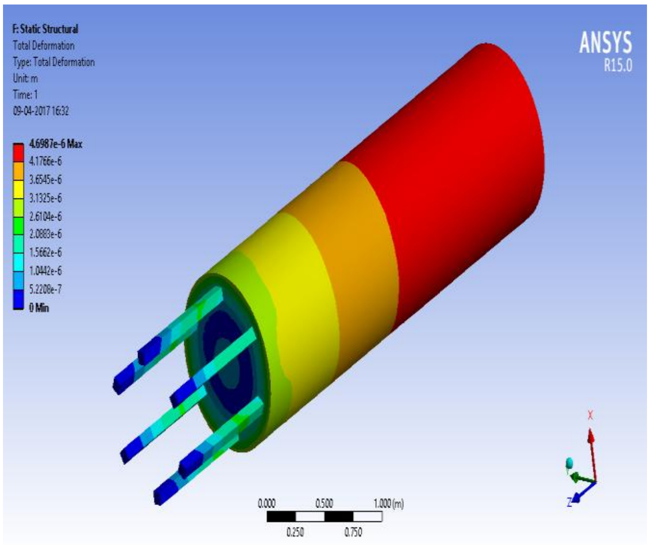
1.000 (m)
0.250
0.750

F. *For model 6*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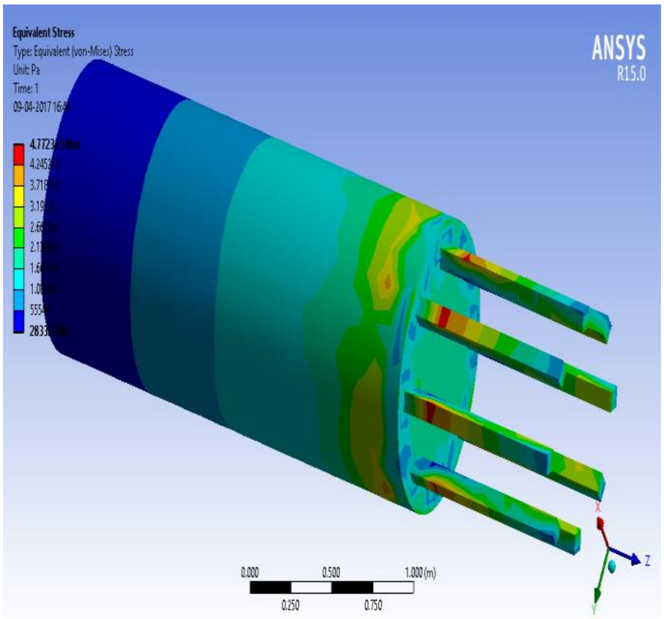
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ANSYS
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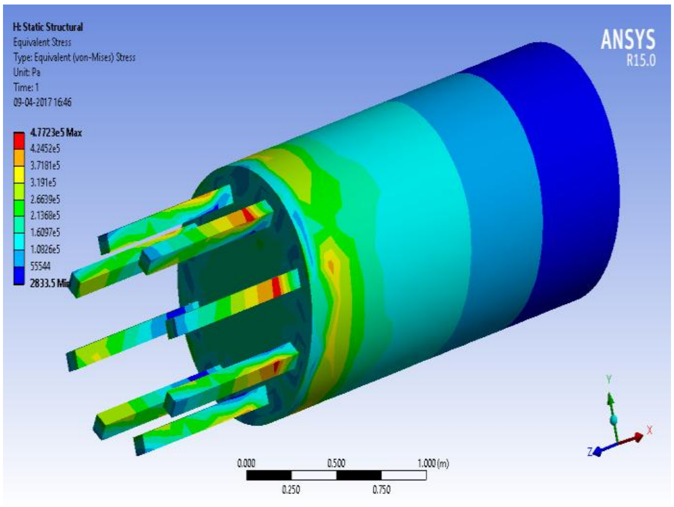
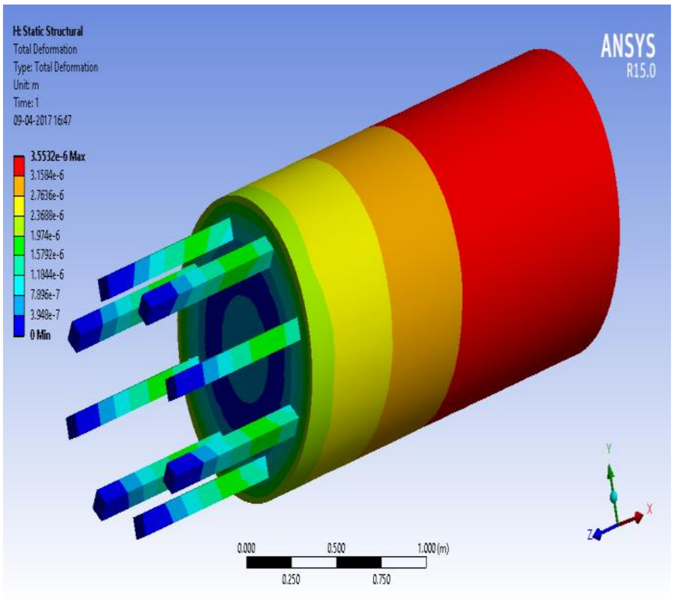
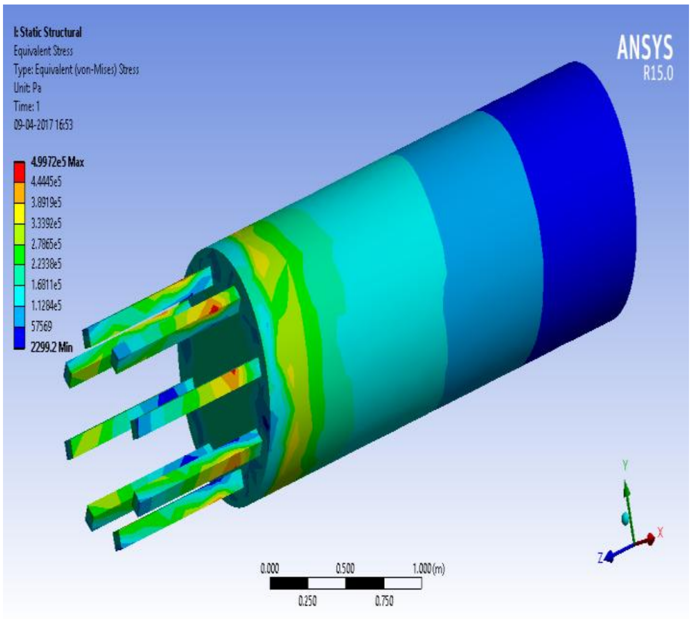
0.750

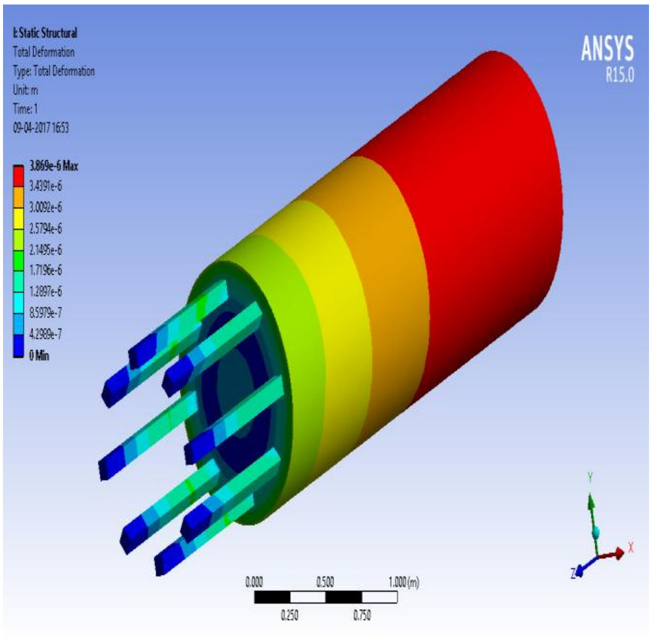
G. For model 7





H. For model 8





I. Tabulation for this analysis

J.

Table 3. Stress deformation table

Modal No	Ribs (no's)	Thick (mm)	Height (m)	Stress	Deformation
1	4	12	2.5	7.1286e5	5.1605e-6
2	4	13	3	7.542e5	5.3642e-6
3	4	14	4	7.9055e5	5.6554e-6
4	6	12	3	6.247e5	4.901e-6
5	6	13	2.5	5.3018e5	4.0575e-6
6	6	14	4	5.3225e5	4.0504e-6
7	8	12	4	4.7723e5	4.6987e-6
8	8	13	2.5	4.7723e5	3.5532e-6
9	8	14	3	4.9972e5	3.869e-6

By this analysis model no 8 have less deformation value. So we have to use stiffness ribs 8 no's ,thickness 13 mm and height of the cylinder 2.5 m.

VIII. CONCLUSION

The buckling of cylindrical shell structures have been studied in this paper. The design of cylindrical shell has been done by using Auto CAD software. After that Analysis is done by using ANSYS 15 software. This is useful to know about stress and deformation.The model provides sufficient scope for studying the effect of edge and internal cracks on the fundamental frequency of vibration of the laminated cylindrical shell structure. That has provided information about the buckling behavior of cylinders subjected to various types of load, such as the wind load model. There has been found out how a cylindrical shell behaves under uniform and non-uniform loads.

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