Design and Analysis of Hat-Stiffened Conical Shell for Axial Compression

M. Barath[1], Rajesh K R[2]
[1]M. Tech Student, Machine Design Dept., REVA University, Bangalore
[2]Asst. Professor, School of Mechanical Engineering, REVA University, Bangalore

Abstract— this study aims to design and analysis of Hat stiffened conical shell for under axial compression. Shells may be subjected to axial compression, bending, twisting or external or internal pressure anyone of which can cause failure. Depending on the geometry of the conical shell either local or overall buckling failures can occur. To provide additional strength, axially compressed conical shells are sometimes Hat stiffeners are placed. Further, the Hat stiffeners are placed on the inner periphery of the skin for the model. Moreover, hat stiffeners placed on the inner periphery provides more BLF than the stiffeners placed in the outer periphery of the skin. Buckling load carrying capacity of the stiffened conical shell is compared with analysis software Abaqus.in this study only aims buckling analysis. Theoretical calculations are also carried out for verify the results obtained from finite element analysis. Aircraft aluminum alloy (AA2014 T6) is chosen for these project.

Index Terms— shells, buckling, stiffeners

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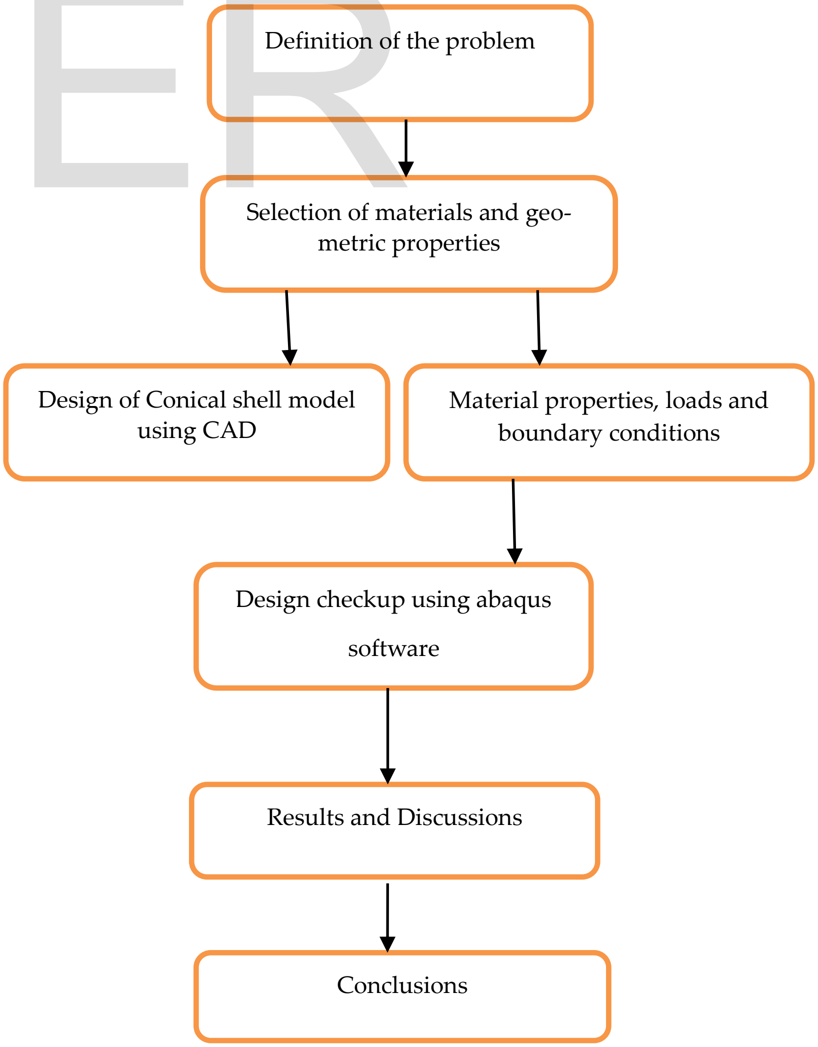
1 INTRODUCTION

A launch vehicle is a vehicle which carries a payload / satellite from surface of the earth through the outer space, either to another surface point or into space. A launch system usually consists of the launch vehicle, the launch pad and other infrastructure. A launch vehicle generally consists of several different segments or stages, with each stage playing its own role. The **first stage** of the rocket or the launch vehicle usually contains fuel that is needed to lift the satellite and launch vehicle from the ground and into the sky. A launch vehicle at lift-off weighs hundreds of tons, so the rockets have to be very strong. After all the fuel has been used up by the vehicle, the first stage will get broken offs from the remaining structure and then falls to the ground.The **second stage** of the launch vehicle contains smaller rockets which ignite after the first stage is finished. The rockets of second stage carry their own fuel tanks. It is used to transport the satellite into space similar to that of the first stage and finally it breaks off after all the fuel has been used up and burns in the atmosphere.The **final stage** of the launch vehicles is connected to the satellite itself, which is enclosed a metal shield commonly known as fairings. The fairings break apart once the satellite is above the atmosphere of the earth and burns up in the earth's atmosphere. The rocket of the upper stage gets fired after the satellite in exact location where it is needed.in the fina lstage conical shell playing important role in each and every launch vehicle. The failure of the conical shell which is compressed in one or another way is represented by buckling.The phenomenon of the buckling process generally occurs when the deformations are very high.The criteria's such as specific strength,stability and deflection requirements should be met by the structure to be designed. The design procedures recommended for isotropic conical shells under such loading conditions as axial compression, bending, hydrostatic pressure, and torsion, along with those of combined loads.But this report aims only isotropic conical shell for axial compression.To design the structure, hat stiffeners are provided on the conical shell surface. Hat stiffener is provided in order to increase the stiffness of the conical shell. The Hat stiffeners are attached throughout the length of conical shell. AA2014 T6 Aluminium alloy used for this design.

2 LITERATURE REVIEW

J. Singer [2] discussed about the experimental and theoretical study of the buckling of closely stiffened conical shell under axial compression to determine the influence of the stiffener geometry and spacing based on linear theory. The experimental results were correlated with theory and appropriate design criteria are developed. **Seide, P [3]** presented and solved stability equations for thin circular orthotropic conical shells for external pressure, axial compression and combined loading. The general instability of closely stiffened conical shells under hydrostatic pressure is also analysed by accurate approach. Preliminary experimental results for buckling of ring-m stiffened conical shells under hydrostatic pressure are presented and discussed. **Weingarten, V.I [4]** results of an extensive experimental program on the stability of cylindrical and conical shells under axial compression are presented and discussed. The stability of cylindrical and conical shells under axial compression is a problem that has been discussed both theoretically and experimentally. And this paper discussed about the buckling and post buckling behaviour of the thin-walled cylindrical and conical shells under axial compression. **Hausrath A.H.; and Dittoe, F.A [5]** many studies have been conducted of the buckling of conical shell under various loading conditions. While the behaviour of two types of shells appears to be similar, significant differences in experimental results remain unexplained. In addition, some important loading cases and the effects of edge conditions remain to be explained. And this paper present recommended design procedures for isotropic conical shells under axial compression, bending, along with those of combined loads. **H. L. Cox [7]** briefed the Buckling of Plates and Shells loading under the hydrostatic pressure and lateral pressure varying in the axial direction. The stability equations for thin conical shells derived in this paper and stability equation in the radial direction is derived in a modified form similar to that given by galerkin method. Typical cases are analyzed. The results for hydrostatic pressure loading are compared with results found by other investigators and with those obtained by Hoof and the author in an analysis restricted to small cone angles. **David L.Block, Michael F.Card [8]** derived from energy principles based on small-deflection theory for buckling of stiffened orthotropic cylinders which includes eccentricity (one-sided) effects of the stiffeners. The calculations of the conical shell effects are large even with large diameter shells and should be obtained from the buckling analysis. **C. Huhne, R. Rolfes, J. Tebmer [9]** discussed the Thin- walled shell structures like circular cylindrical shells are prone to buckling. The results of test and numerical analysis indicate that this new deterministic approach has the potential to provide an improved and less conservative shell design in order to reduce mass and cost of thin- walled shell structures made from the different types of materials. **L. W. Rehfield [10]** the volume of literature concerned with the buckling of circular cylindrical shells subjected to axial compression and bending is overwhelming, confused and filled with conflicting opinions, theories and statements. The approach is indirect a beings by considering the applied stress level as a primary design variable. A new method for he sizing and spacing of rings is outlined and illustrated. The design calculations as the classical theory are to be correlated with the test results. **C.J Balasubramaniam, S. Sirajudeen Ahmed [11]** studied the effect of stiffener eccentricity on the buckling strength of closely stiffened cylindrical shell. Using the theoretical calculation, a parametric study is carried out to assess the influence of stringers and rings inside and outside shell structures. Theoretical formulation results were compared with finite element buckling analysis results. It was found that outside stiffened structures, buckling capacity varies from 150% to 220% of inside stiffened structure. **Matthew A. Dawson, Lorna [13]** addressed the optimization of cylindrical shells with compliant cores. Thin-walled shell with a compliant core presented discussed the optimal design for a given radius, prescribed materials, and specified axial load. The analysis also reveals more effective than a foam core configuration. Theoretically, the optimized cylinder with a honeycomb, compliant core demonstrates substantial improvement in load bearing capability over the comparable designs, including the equivalent hollow cylinder, the optimization hat-stiffened cylinder and the optimized sandwich designs. **Bo Wang, Shiyang Zhu, Peng Hao [14]** discussed the buckling of quasi- perfect cylindrical shell under axial compression. Finite element numerical procedure for predicting the buckling load was developed. Results shows buckling load predicted by the FE analysis is very close to that from the test. And buckling behaviour also discussed based on Fourier series method. **Kaifan Du, Kuo Tian, Yu Sun [15]** in this paper analysis was carried out on the hat-stringer-stiffened flat panels in order to assess their buckling and post-buckling responses when exposed to axial compression. The effect of test fixtures on buckling, post-buckling and failure type of the plate were investigated. Panel tested with test fixtures had a large pre-buckling and post-buckling and post- buckling axial stiffness. Test fixtures playing the significant role in experiments and accurate test results need good test fixtures. The results showed that hat-stringer flat panel had large load capacity after initial buckling.

3 METHODOLOGY



4 DESIGN OF CONICAL SHELL AND STIFFENER

Design a closely stiffened conical shell construction for a load of 817.5KN. The configuration of the conical shell is shown in figure

Upper Diameter = 1425 mm
Lower diameter = 2800 mm
Height = 645 mm
Axial Load = 817.5 KN

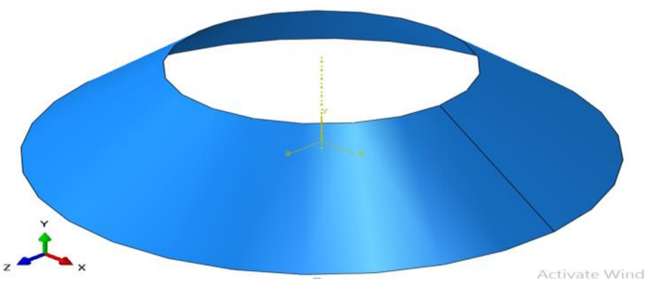


Fig. 1. conical shell without hat stiffener

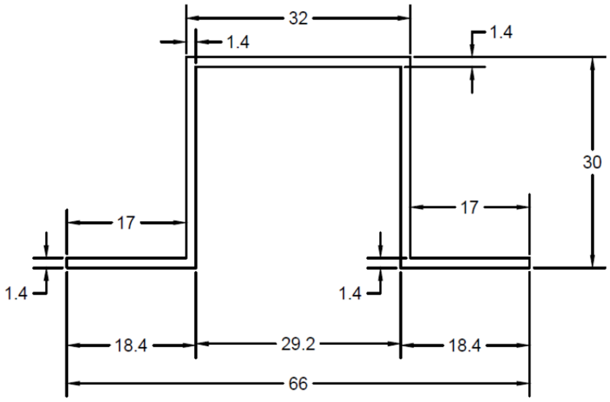


Fig. 2. Configuration of Hat- stiffener

Property of Alloys	AA 2014 T6
Density (g/cc)	2.8
Brinell Hardness (BHN)	135
Tensile Strength (MPa)	414
Ultimate Strength (MPa)	483
Poisson's Ratio	0.33
Modulus of Elasticity (MPa)	686700

Table. 1. Propeties of the material

4.1 ANALYSIS OF CONICAL SHELL

FIGURE: BUCKLNG FIRST MODE WITHOUT HAT STIFFENER

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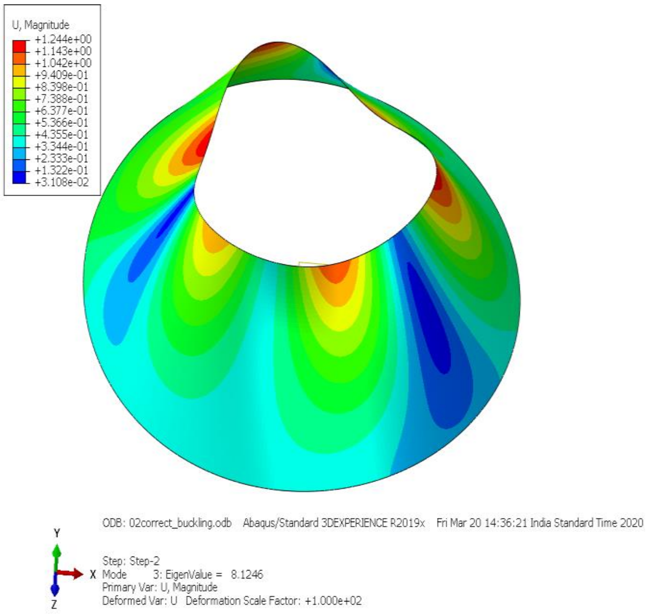


ODB: 02correct_buckling.odb Abaqus/Standard 3DEXPERIENCE R2019x Fri Mar 20 14:36:21 India Standard Time 2020

Step: Step-2
Mode 3: EigenValue = 8.1246
Primary Var: U, Magnitude
Deformed Var: U Deformation Scale Factor: +1.000e+02

Fig.4. Conical shell –Buckling second mode

FIGURE: BUCKLING THIRD MODE WITHOUT HAT

STIFFENER

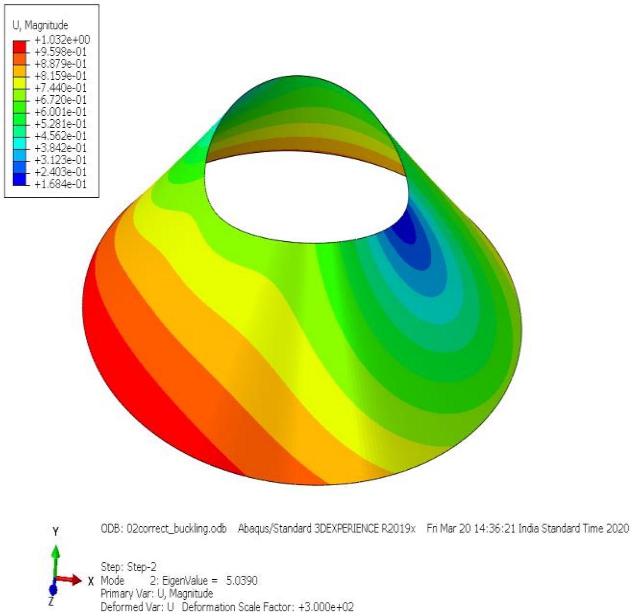
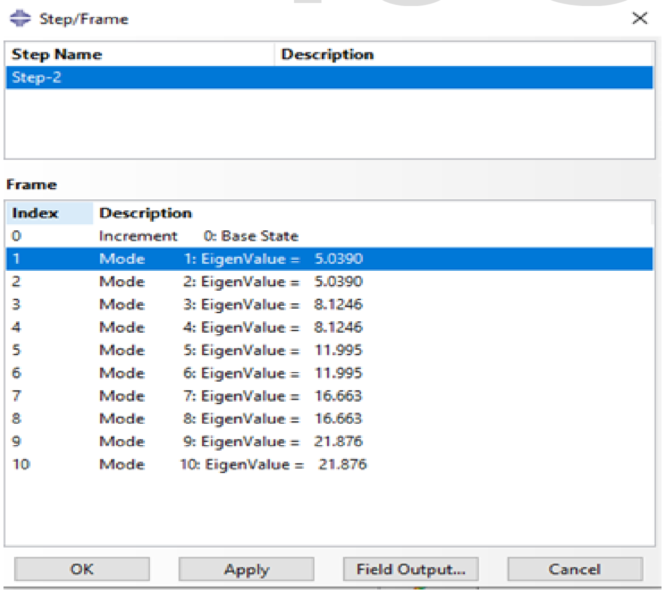


Fig.5. Conical shell –Buckling third mode

THE BUCKLING – EIGEN VALUE (BUCKLING LOAD FACTOR) AS SHOWN IN THE FIGURE



Step Name	Description
Step-2	

Frame

Index	Description
0	Increment 0: Base State
1	Mode 1: EigenValue = 5.0390
2	Mode 2: EigenValue = 5.0390
3	Mode 3: EigenValue = 8.1246
4	Mode 4: EigenValue = 8.1246
5	Mode 5: EigenValue = 11.995
6	Mode 6: EigenValue = 11.995
7	Mode 7: EigenValue = 16.663
8	Mode 8: EigenValue = 16.663
9	Mode 9: EigenValue = 21.876
10	Mode 10: EigenValue = 21.876

Fig.6. Conical shell –Buckling Eigen value

In the buckling analysis to find the margin of safety,

Margin of safety = (Buckling load factor * Knock down factor)

Buckling load factor = 5.03

Knock down factor = 0.3

= 1.5

FIGURE: CONICAL SHELL MODEL WITH HAT STIFFENER

To design the structure, hat stiffeners are provided inside the conical shell. Hat stiffeners are provided in order to increase the stiffness of the conical shell. The hat stiffeners are attached throughout the length of closely stiffened conical shell.

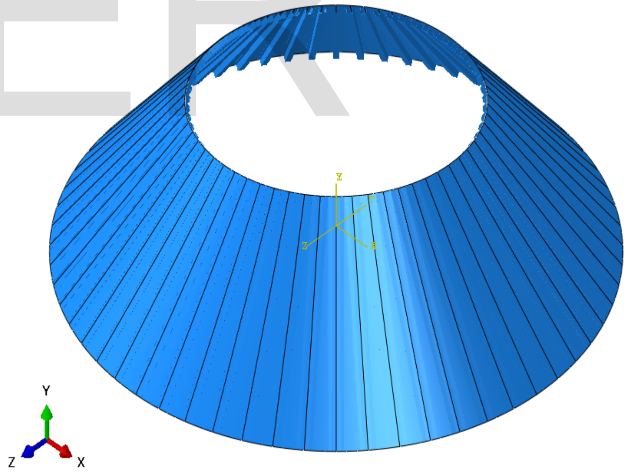


Fig.7. Conical shell –with hat stiffeners

In this analysis inside hat stiffeners are used and inside hat stiffeners are more stiffened and having higher buckling strength. Inside hat stiffened structures buckling capacity varies from 150% to 220% of outside stiffened structure.

The buckling load factor is the indicator of the factor of safety against buckling, BLF = Buckling load / applied load

The buckling load factor if equal to one then the applied load is exactly equal to the critical load buckling is expected. The buckling load factor is less than one then the applied load exceeds the estimated critical loads buckling will occur.

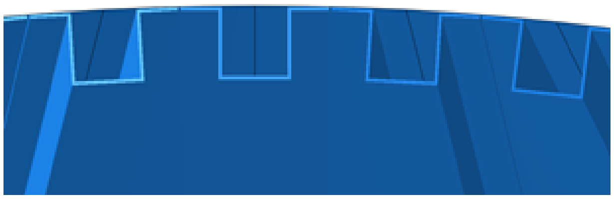
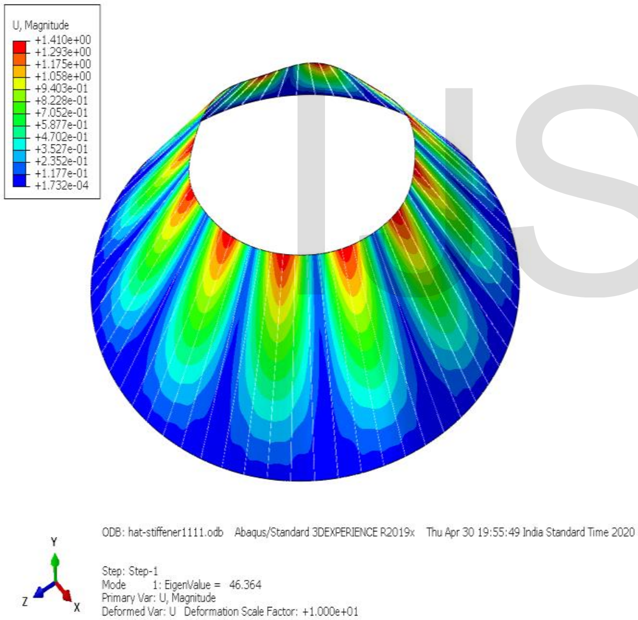


Fig.8. inside hat stiffeners

FIGURE: BUCKLING FIRST MODE WITH HAT STIFFENER



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ODB: hat-stiffener1111.odb    Abaqus/Standard 3DEXPERIENCE R2019x    Thu Apr 30 19:55:49 India Standard Time 2020

Step: Step-1
Mode      1: EigenValue =   46.364
Primary Var: U, Magnitude
Deformed Var: U   Deformation Scale Factor: +1.000e+01
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Fig.9. Conical shell –Buckling first mode

FIGURE: BUCKLING SECONF MODE WITH HAT STIFFENER

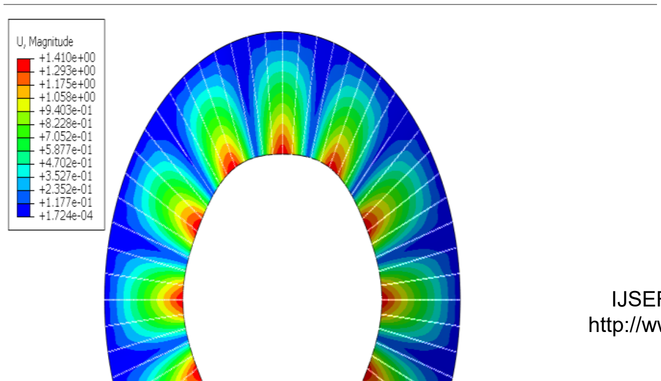
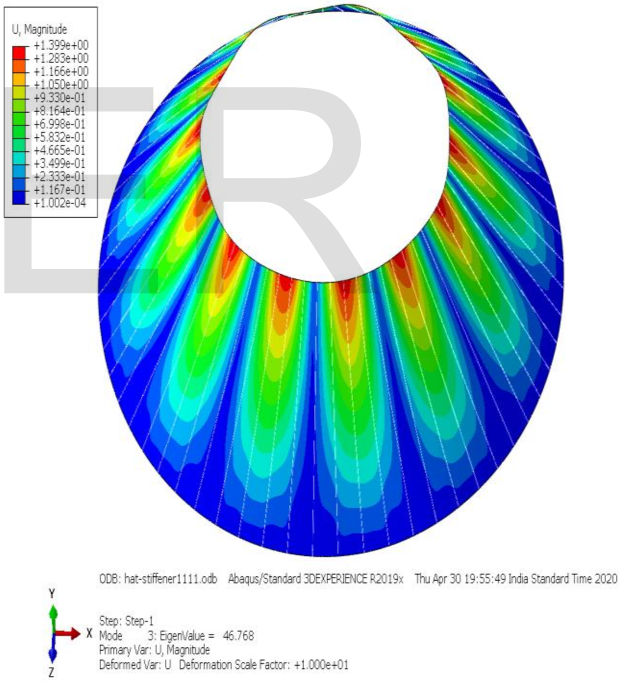


FIGURE: BUCKLING THIRD MODE WITH HAT STIFFENER



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ODB: hat-stiffener1111.odb    Abaqus/Standard 3DEXPERIENCE R2019x    Thu Apr 30 19:55:49 India Standard Time 2020

Step: Step-1
Mode      3: EigenValue =   46.768
Primary Var: U, Magnitude
Deformed Var: U   Deformation Scale Factor: +1.000e+01
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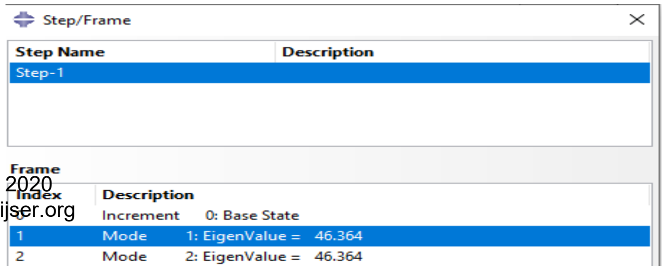
Fig.11. Conical shell –Buckling third mode

THE BUCKLING – EIGEN VALUE (BUCKLING LOAD FACTOR) AS SHOWN IN THE FIGURE



Step Name	Description
Step-1	

Frame

Index	Description
0	Increment 0: Base State
1	Mode 1: EigenValue = 46.364
2	Mode 2: EigenValue = 46.364

In the buckling analysis to find the margin of safety,

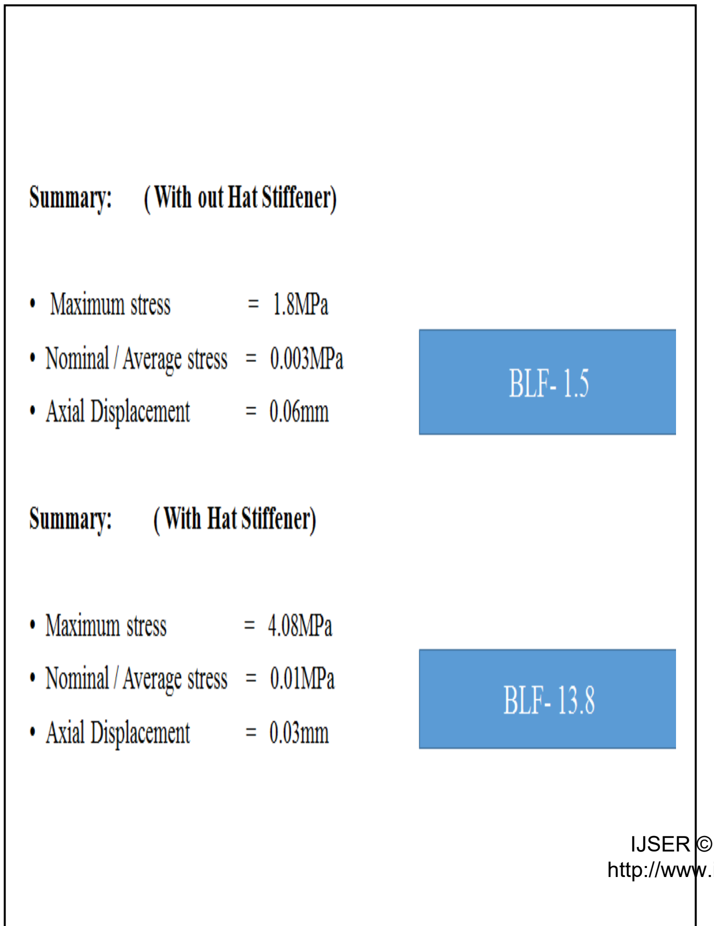
Margin of safety = (Buckling load factor * Knock down factor)

Buckling load factor = 46.3

Knock down factor = 0.3

= 13.89

5 RESULTS AND DISCUSSIONS



Summary: (With out Hat Stiffener)

- Maximum stress = 1.8MPa
- Nominal / Average stress = 0.003MPa
- Axial Displacement = 0.06mm

BLF- 1.5

Summary: (With Hat Stiffener)

- Maximum stress = 4.08MPa
- Nominal / Average stress = 0.01MPa
- Axial Displacement = 0.03mm

BLF- 13.8

6 CONCLUSIONS

1. Study of buckling load factor for hat stiffened conical shell for axial compression.
2. Static and Buckling analysis has been carried out to estimate the von misses stress, deformation and buckling load factor.
3. BLF is determined through FE analysis for hat stiffened conical shell and hat stiffeners mounted at the inside the conical shell.
4. The difference between with and without hat stiffeners buckling load factor has been carried out.
5. Finally with hat stiffeners conical shell is high stiffer than without hat stiffener.

7 ACKNOWLEDGMENT

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