International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-9 Issue-2, December, 2019

Buckling Load Predictions of Panel and Shell using Vibration Correlation Technique

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Abstract: Prediction of buckling loads is a very important phenomenon for aerospace and marine industry. In this paper buckling predictions of a submarine hull is considered by using a shell element and a rectangular panel is considered by using a plate element. The buckling load of a submarine hull can be predicted by using vibration correlation technique. Determination of these buckling loads can be carried out based on the boundary conditions of the submarine hull structure. The technique will be carried by considering both surface conditions and to determine the crippling load of a hull. This paper aims to use VCT for a submarine hull structure used in marine, ocean and can compare the results to aerospace industry by considering a rectangular panel for which buckling is predicted using vibration correlation technique . VCT is not very extensively used in case of thermal buckling. However in this paper, VCT is applied to verify the thermal buckling of a simple thin rectangular panel subjected to parabolic loading.

Keywords: Buckling, Thermal buckling, Vibration correlation technique.

I. INTRODUCTION

Composite laminated plates are widely used in aerospace industries, ship industries and civil applications because of their strength to weight, strength to stiffness ratio. It is essential to find the buckling strength of these plates as these are subjected to axial forces in practice [1]. The natural frequencies of a structure can be estimated through vibration correlation technique. The change in the natural frequencies is then observed by enhancing the applied load. The buckling loads and vibrational modes are identical to each other; therefore a curve can be plotted between the applied load and square of the natural frequencies. Buckling loads of the structure are then estimated from the sequence of values from the curve to zero frequency [2]. VCT is successfully applied to various structures yield a straight line has been driven between the frequencies which is squared at the compressive load [2]. The material selection for the manufacturing process of SPFRC is made of two Al6063-T6 above and below of eleven various configurations of glass fiber layers to form as a sandwich panel. [3]

This relationship can be written as:

$$(f/f_o)^2+(P/P_o)^2=1\text{----------}(1)$$

Where f and P are natural frequency (in Hz) and the applied compressive load, respectively, $f_o$is the natural frequency at zero and P_o is the buckling load of the structure.

The results of any thin walled structure or model can be validated through non destructive testing methods which are the important experimental methods performed for most of the aerospace structures problems. Various critical loads can be estimated for different types of structures by considering appropriate boundary conditions of a particular problem wherein vibration correlation plays an important technique to estimate these boundary conditions [3]. VCT is specifically important for under water systems as the design is mostly buckling dominated, in this the work is carried out to apply vibration correlation techniques on a submarine hull. Vibration correlation technique is then applied to thermal buckling, which is a frequent phenomenon in aerospace structures.

II. METHODOLOGY

VCT applied to Submarine hull

A shell element(2 node 188 of ANSYS) is used to construct a cylinder of radius 5m, depth 4m and thickness 0.05m.The Hull thus formed is clamped on one side and fixed in x and y direction on the other side. The Pressure loads applied on nodes of the Hull and are gradually increased to monitor the frequency changes. Buckling loads and the vibrational modes are identical and therefore we can plot a graph between the applied loads and the natural frequencies that render us to estimate the buckling loads of any type of structure.

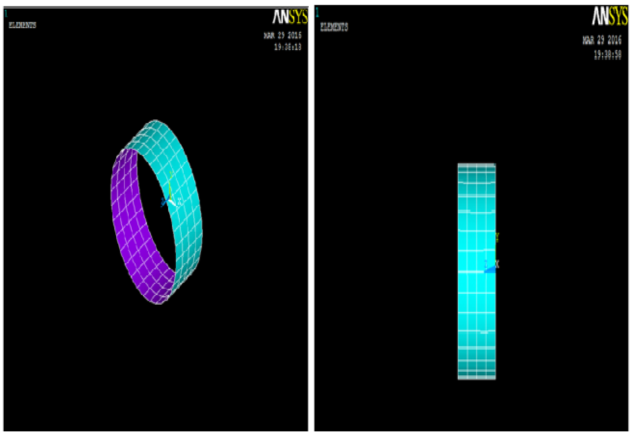

Fig 1: Meshed cylinder-Isometric view and side view

Revised Manuscript Received on December 30, 2019.

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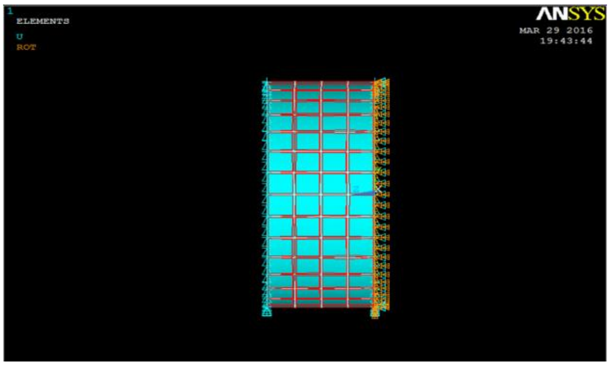

Fig 2: Hull with displacement loads and applied pressure loads

Table-I: Load vs frequency^2 for the given submarine hull

ω(Hz)	Pressure load(Pa)	ω^2
57.215	1	3273.556
57.188	5000	3270.467
57.161	10000	3267.38
56.943	50000	3242.505
56.669	100000	3211.376
54.292	500000	2947.621
50.347	1000000	2534.82
46.065	1500000	2121.984
41.342	2000000	1709.161
35.51	2500000	1260.96
27.016	3000000	729.8643
9.61	3600000	92.3521
6.2731	3650000	39.35178
2.735	3680000	7.480225
0	3690000	0
0	3700000	0

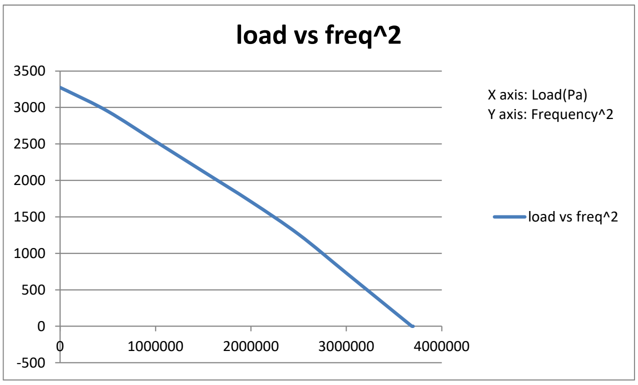

Fig3: Graph of load (x-axis) vs frequency squared (y-axis) of a hull

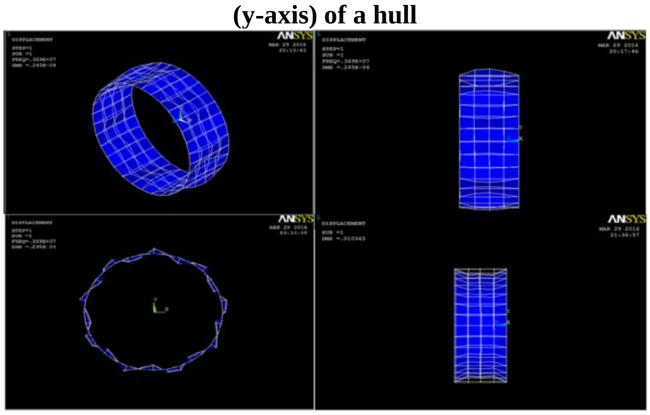

Fig 4: Deformed shape of a hull due to buckling-Isometric view, side view, and top view (clockwise).

The frequency becomes zero when the applied pressure reaches 3.7e07 Pa relatively equal to the crippling load 3.6861e+06Pa obtained from the Eigen buckling (ANSYS).

III. ANALYSIS USING ANSYS

A shell element (8 node 181 of ANSYS) is used to make 0.25 X 0.25 m^2 panel of 0.00232m thickness and it is clamped on all sides as the edges in the aircraft panel are attached to a heat sink and according to that we assign thermal loads, in such a way that the temperature at the edges are zero and slowly the temperature increases as we move to center [6]. An equivalent model of the stiffened panel majorly used to study post behavior structure of buckling and its panel failure. The safeguard must be taken while applying load across the edge. We see different deformations for different modes, below are the different modes and deflections at T=10ºC.

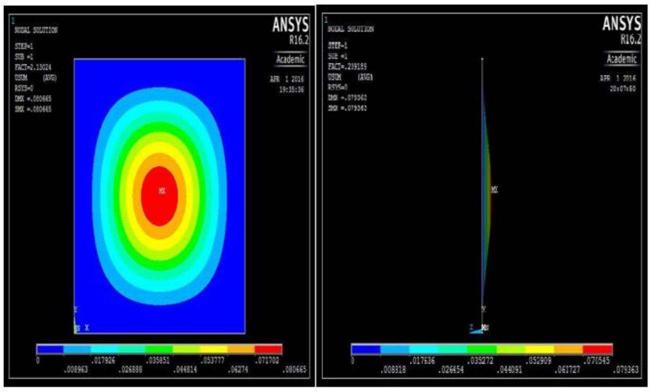

Fig 5: Mode1 front view and side view.

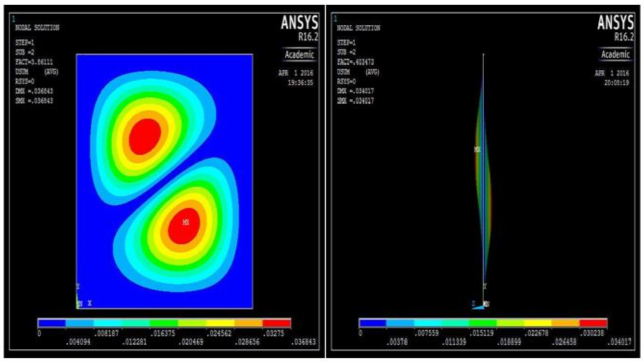

Fig 6: Mode2 front view and side view.

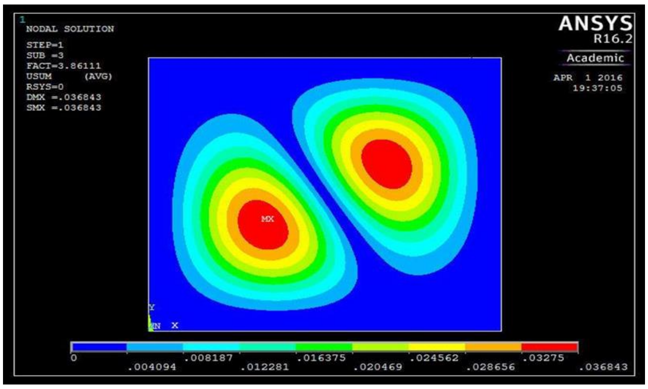

Fig 7: Mode3 front view.

Retrieval Number: B2679129219/2019©BEIESP
DOI: 10.35940/ijeat.B2679.129219
Journal Website: www.ijeat.org

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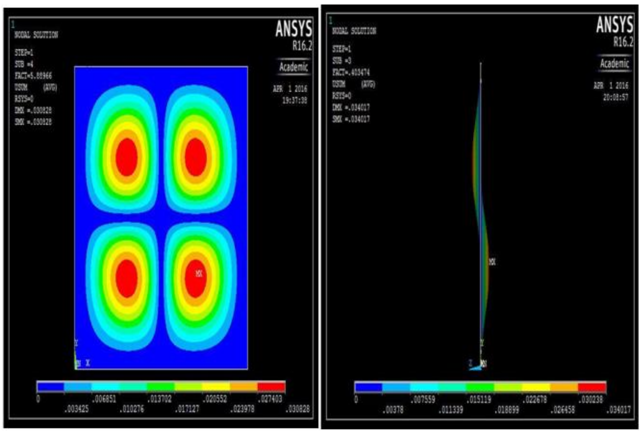

Fig 8: Mode4 front view and side view.

We take the frequency values by going to general postproc>read results>by pick
We get the following value for T=10°C.

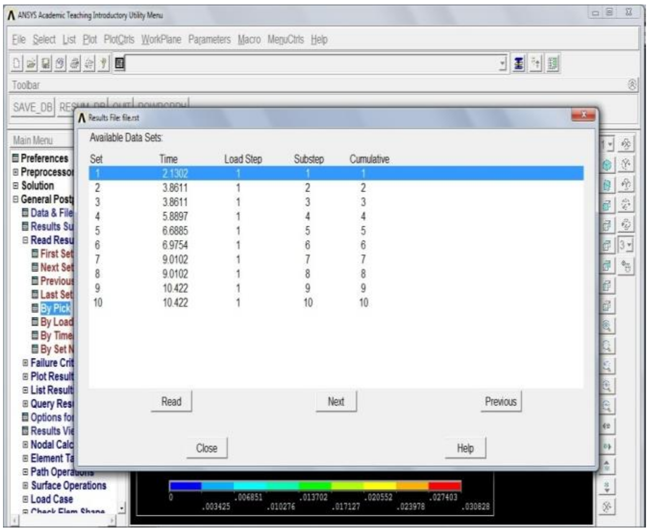

Fig 9: frequency values for T=10°C.

Similarly, we find out the frequency values for different thermal loads. And plot the graph correlating the thermal loads and the frequency.

Table-II: load vs frequency^2 for the plate with thermal buckling.

Temperature (°C)	mode 1	mode 2	mode 3	mode 4
0	4.61	9.35	9.35	14.12
10	2.13	3.86	3.86	5.88
20	1.0042	1.74	1.74	2.65
30	0.655	1.12	1.12	1.7
40	0.48	0.82	0.82	1.25
50	0.4	0.72	0.72	1.12
60	0.38	0.65	0.65	0.99
70	0.32	0.54	0.54	0.82
80	0.231	0.403	0.403	0.613

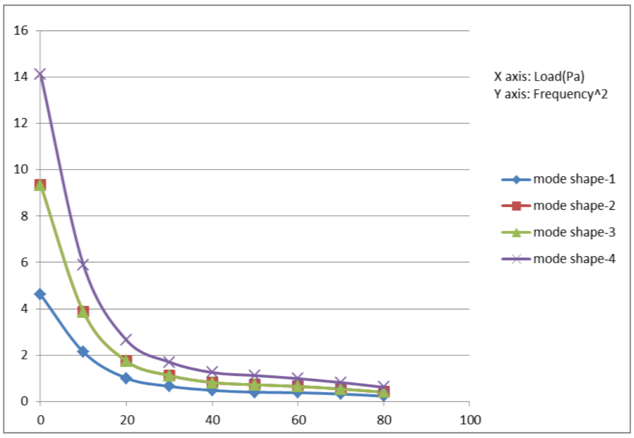

Fig 10: Frequency versus thermal loads.

From the above results we can conclude that there is fall of the frequency due to rise in temperature which tells us that the temperature increase can also make the plate buckle as we can see from the above figures. The curve is not linear.

IV. CONCLUSION

Buckling loads of plate and shell have been interpreted by vibration correlation technique. Finite element method was used to calculate loads under compression which was compared with the results obtained through VCT. The results are in good agreement with the experimental and analytical results. In this report we found its (VCT) validation with a submarine hull. And for the thermal buckling analysis the similar results were seen, where the results correlated well. However, the curve obtained was not linear, which we are expecting to overcome in future with an improved version of VCT. The VCT was applied using ANSYS. The actual buckling was estimated by EIGEN BUCKLING in ANSYS. The modal behavior of the structures was investigated using MODAL analysis in ANSYS. Natural frequencies of the structures were recorded as a function of the applied axial compression load and were correlated.

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