Finite Element Analysis for the Buckling Load of Corrugated Tubes

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Abstract—*The buckling behavior of the geometry subjected to static loading (compression) is presented. The columns under consideration were made with corrugation perpendicular to the line of action which coincides exactly with the unstrained axis of the column. Four different arrangements of tubes have been considered for all the conditions taken into consideration. The thickness of the tubes, the number of corrugation, and diameter of the tubes, pitch and depth of the tubes have been varied accordingly. Analysis of the prepared tubes was performed using ANSYS 17.0. A linear buckling analysis was performed to calculate the critical load of the corrugated tubes. The effect of buckling and maximum critical load of the FEM models are discussed.*

Keywords— Corrugated Tubes, FEM, Static Loading, Buckling, Critical Load.

I. INTRODUCTION

The term "corrugated" in general describes a series of parallel ridges and furrows [1]. Any structure that has a surface with the shape of corrugation are made by either folding, molding or any other manufacturing methods are usually referred as corrugated structures. Three quintessential corrugated structures may be categorized as: corrugated sheet, corrugated pipe, and corrugated panel. The most quotidian feature of all corrugated structures is their supremely anisotropic behavior; high stiffness athwart to the corrugation direction than acquiescence along the corrugation direction [2]. These corrugation has been seen as a manageable and potent means of making lightweight structures, stability under load and energy absorption potential. This has been used to good advantage in many and various industrial applications and academic research. In past few years, there have been several innovational progress to corrugated structures, considering more intricate and ingenious corrugation geometries and coalition of corrugations with advanced materials.

Instability of structural components are observed under static loading when minuscule load increases or other bijou disturbances will induce the structure to change from one stable configuration to another of a disparate character. For some structures and loadings the two configuration may vary vaguely and gargantuan changes of shape develop gradually with an increase in load. In this case, the initial buckling load merely shows a change in the character of the deformation will occur. Usually, a more noteworthy load is the ultimate load of the structure which may be reached either when the material fails plastically or when the structure slumps. In other situations the two equilibrium configurations differ profoundly and the transformation from one to the other is eminently fast. The structure significantly loses its potential to withstand further load increases or it undergoes large deformations that render it unsafe for further use. The paramount design complication is the thwarting of the buckling that leads to unenviable configurations- in particular collapse. The enormity of the critical static load of a structure usually depends on its geometric proportions, the modus operandi in which it is stiffened and in which it is supported, the bending and extensional stiffnesses of its different components. In this monograph a changed geometric pattern is investigated and its critical load is analyzed i.e. Corrugated tubes are used and buckling load is observed .Other determinant that affect buckling are cutouts, non-uniform stiffnesses and variation of loading with time.

Thin-walled metal structures are low-cost and exhibit high strength, high stiffness to weight ratio and excellent bearing capacity. Axial impacts are most effective of attenuated metal tubes during elastic and plastic deformation.

Several types of design schemes and cross-section have been proposed to improve the load bearing of thin-wall tubes. It has been recognized that the buckling failure modes of stiffened tube can be categorized at three levels, which are (1) local face buckling, (2) unit corrugation buckling, and (3) entire corrugation buckling [2]. They are lightweight, economical, and have much higher load carrying capacities which ensure their popularity and have attracted research interest since they were introduced. The corrugation shape provides continuous stiffening which permits the use of thinner tubes. Furthermore , the corrugation patterns reduce compressive force fluctuations.

Corrugation have been reckoned as way of revamping the stability of shells. Semenyuk and Neskhodovskaya [3,4] provide a complete analysis of these complication using deep shell theory. It is shown that under certain state the use of corrugation on a cylindrical shell can significantly raise the critical buckling load. Furthermore, the shell approximation used advocate than an adaptation to the curved surfaces of a true wing may be viable and may be a further appendage to include the upshot of surface pressure along the path of Semenyuk et al [5].

II. NUMERICAL CALCULATION

The buckling behavior was analyzed using the finite element method with the ANSYS 17.0 [6]. The linear buckling analysis and geometrical non-linear problems were solved. The linear buckling analysis was carried out to find the critical load. The tubes are meshed with the element size of 200mm and condition of constraints are: one end is fixed while load is applied on the remaining free end.

The geometrical model is composed of a simple arc tangent or sinusoidal corrugated cylindrical tube. The length of the column under analysis is equal to 500 mm and is kept constant throughout the analysis as shown in Fig.1. The depth and pitch of the corrugation are 17.5mm and 75mm respectively as shown in Fig.2 which are in accordance to Bureau of Indian Standards 2003 [7].

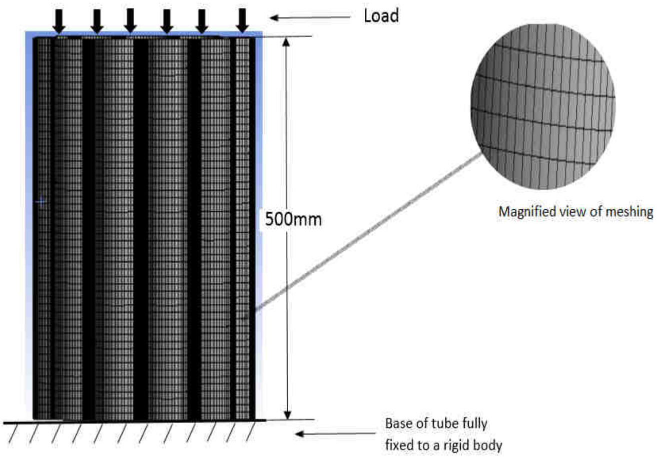


Fig.1:Finite element model of the column

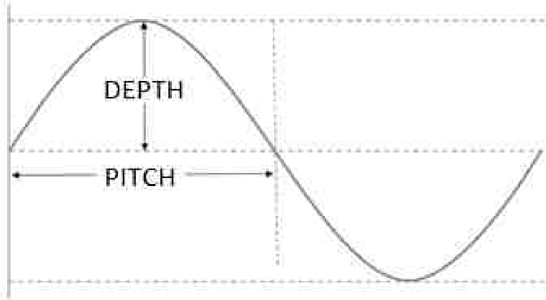


Fig.2:Depth and Pitch of Corrugation

The models are categorized into three sections and analyzed accordingly. One sections includes the tubes with same diameter but with varying number of corrugation. The number of corrugations taken are 8, 10, 11, and 13 as shown in Fig.3. Another section also includes four models but with varying diameter and same number of corrugations. The diameter is varied of the tube in which number of corrugation is 13. Whereas in the third section the thickness of the tubes have been varied and the trend on buckling load is shown.

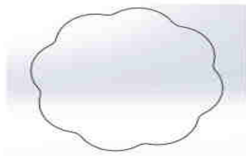
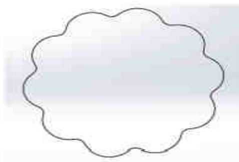
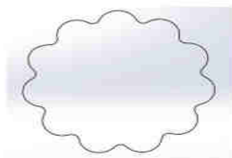
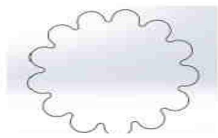
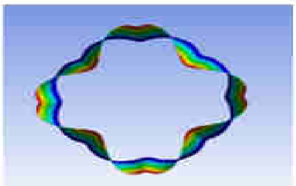
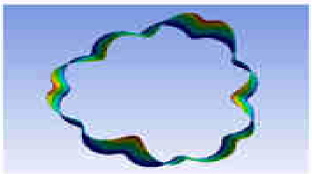
No. of corrugation	Section
8	
10	
11	
13	

Fig.3:Number of Corrugation

No. of Corrugation	Deformed Section
8	
10	
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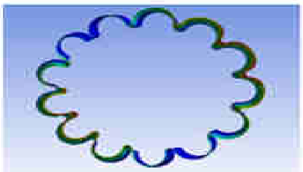
13	

Fig.4:Deformation of Corrugated tubes (Top View)

The material used is structural steel with following material properties: Density 'kg/m^3'=7850; Young's Modulus 'GPa'=200; Poisson's Ratio= 0.3 and Yield Strength 'MPa'=250.

3. **Results**

The buckling load of the structural steel corrugated tubes under quasi static compressive loading conditions. The corresponding results for the corrugated tubes are presented based on their geometrical shapes and conditions. For each corrugated tubes simple loading was done one the free end and the buckling load was calculated.

Results according to different parameters are:

1. Effect of varying number of corrugation with constant diameter

When the number of corrugation of the tubes have been varied by keeping the diameter constant it has been concluded from the below fig. 4 that the buckling load is highest of the tube with maximum number of corrugation i.e. as the number of corrugations in the tube increases the buckling load of the corrugated tube increases.

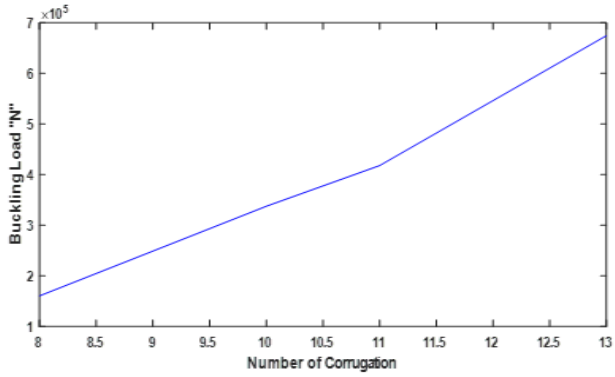


Fig.4:Effect on buckling load for different number of corrugation

2. Effect of varying diameter when number of corrugation is kept constant

When the diameter of the tubes have been varied by keeping constant number of corrugation(taken 13 corrugation for this case) it has been concluded from the below fig. 5 that the buckling load is higher of the tube with smaller diameter i.e. as the diameter of the tube is increased with constant number of corrugation the buckling load decreases.

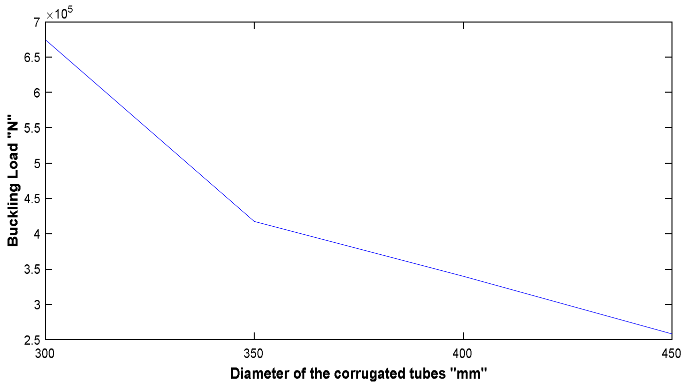


Fig.5:Effect on buckling load by varying diameter of the tubes

3. Effect of thickness on the corrugated tubes

When the thickness of the tubes have been varied (taken 13 corrugation for this case) it has been concluded from the below fig. 6 that buckling load is higher of the tube with maximum thickness i.e. as the thickness of the tubes is increased the buckling load also increases.

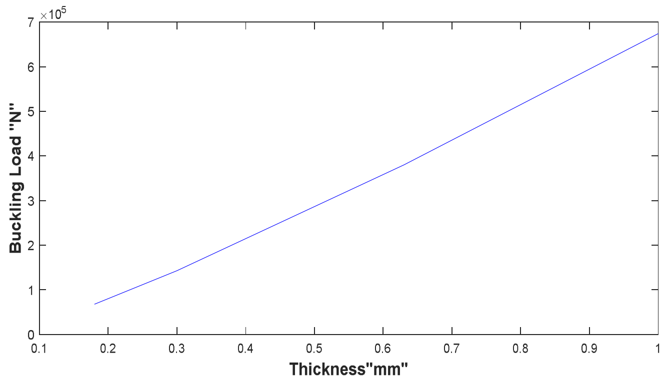


Fig.6:Effect of thickness on buckling load

4.Effect of change of pitch on the corrugated tubes

When the pitch of the tubes have been varied it is observed from the fig. 8 given below that the buckling load is highest of the tubes with maximum pitch (i.e. 90mm) and also the buckling load is increasing as the pitch of the corrugated tubes have been increased.

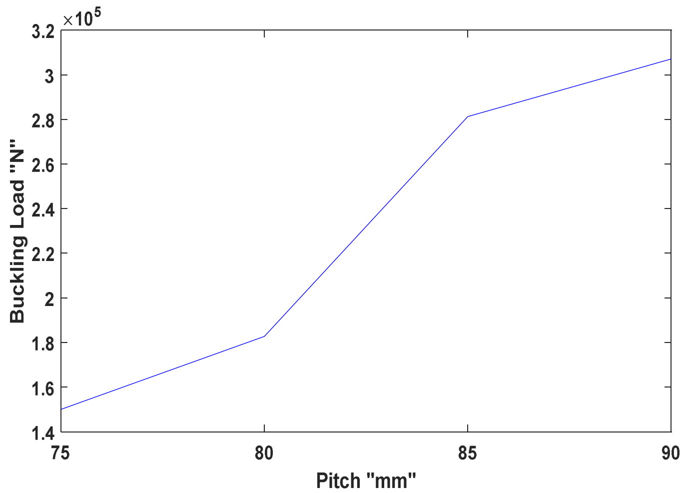


Fig.8:Effect of change of pitch on the corrugated tubes

5.Effect of change of amplitude or depth of the corrugated tubes

When the amplitude of the tubes have been varied it is observed from the fig. 9 that the tube with maximum amplitude (i.e. 20.5mm) has the maximum buckling load also it can be clearly inferred as the amplitude it kept of increasing the buckling load of the corrugated tubes keep on increasing.

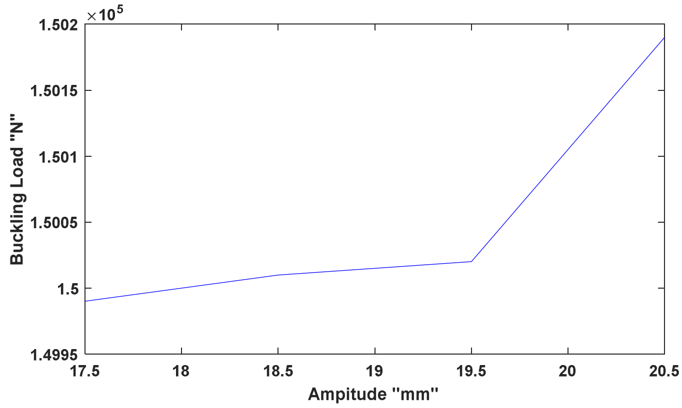


Fig.9:Effect of change of amplitude or depth of the corrugated tubes

The pattern of deformation of the tube is shown in fig.7. It had been observed that the deformation is almost symmetric irrespective of the change in number of corrugation. Also from fig.4 it has been investigated that tube with maximum number of corrugation have greatest buckling load i.e. the tube with 13 number of corrugation deforms least whereas the tubes with 8 number of corrugation deforms that most as it has the least buckling load.

III. CONCLUSIONS

The man aim of the investigation presented in this paper was to calculate the buckling load of the corrugated geometry using numerical simulation. Buckling load of the thin-walled corrugated tubes with 4 different archetype under four different conditions were taken into consideration. Based on the numerical results following important conclusion can be drawn from this investigation:

(1) Buckling load of the corrugated tubes increases with increase in the number of corrugation.
(2) With the increase in the diameter of the same corrugated tubes the corresponding buckling load decreases.
(3) Symmetric deformation is seen in the corrugated tubes irrespective of the number of corrugation.
(4) When we increase the pitch or depth of the corrugated tubes than also the buckling load increases.
(5) Since these tubes have greater buckling load therefore can be used as a replacement of circular tubes without or very minimal change in the weight of the structures.

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