Analysis on Thin Walled Aircraft Structure

Hanamkonda Abishek[1], K.S.Naidu[2]

[1] PG Student, Department of Aeronautical, MLR Institute, Hyderabad Telangana, India
[2] Assistant Professor, Department of Aeronautical, MLR Institute, Hyderabad Telangana, India

---***---

Abstract - ***Thin walled members are very important part of aircraft structures. These thin walled structures constitute thin plates fixed on open section beams whose Centroid does not coincide with shear center. The attention here is focused on open section channel beam subjected to buckling loads. Both rounded closed end and rounded open flange end are studied where the main variables are thickness of the sheet, radii of the ends. Finite Element Analysis of these structures for buckling is done using ANSYS. Also, the influences of various shapes and sizes of the flanges are analyzed to get the critical moments.***

Key Words: *Finite Element Method, Thin Walled Beams, Channel Sections, Aircraft Structures.*

1. INTRODUCTION

If we look at the early design of aircraft such as the Wright Flyer in there can really be no misunderstanding of the construction style. The entire aircraft, including most notably the wings, forward and rear structures were all constructed from rectangular frames that were prevented from shearing (forming a parallelogram) or collapsing by diagonally stretched wire. There were two major innovative thoughts behind this design philosophy. Firstly, the idea that two parallel wings would facilitate a lighter yet stronger structure than a single wing, and secondly, that these two wings could be supported with two light wires rather than with a single, thicker wooden member. The structural advantage of the biplane construction is that the two wings, vertical struts and wires form a deep light beam, which is more resistant to bending and twisting than a single wing. Much like a composite sandwich beam it can be treated as two stiff outer skins for high bending rigidity connected by a lightweight "core" to provide resistance to shear and torsion.

1.1 FINITE ELEMENT METHOD (FEM)

In mathematics, finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems. It uses variational methods to minimize an error function and produce a stable solution. Analogous to the idea that connecting many tiny straight lines can approximate a larger circle, FEM encompasses all the methods for connecting many simple element equations over many small sub domains, named finite elements, to approximate a more complex equation over a larger domain.

1.2 ANSYS Introduction:

ANSYS is a general-purpose finite-element modeling package for numerically solving a wide variety of mechanical problems. These problems include static/dynamic, structural analysis (both linear and nonlinear), heat transfer, and fluid problems, as well as acoustic and electromagnetic problems.

In general, a finite-element solution may be broken into the following three stages.

1. Preprocessing: defining the problem

The major steps in preprocessing are

i. define key points/lines/areas/volumes,
ii. define element type and material/geometric properties, and
iii. Mesh lines/areas/ volumes as required.

The amount of detail required will depend on the dimensionality of the analysis, i.e., 1D, 2D, axisymmetric, and 3D.

2. **Solution**: assigning loads, constraints, and solving

Here, it is necessary to specify the loads (point or pressure), constraints (translational and rotational), and finally solve the resulting set of equations.

3. **Post processing**: further processing and viewing of the results

In this stage one may wish to see

i. lists of nodal displacements,
ii. element forces and moments,
iii. deflection plots, and
iv. stress contour diagrams or temperature maps.

2. Buckling of Thin Walled Structures

In science, buckling is a mathematical instability, leading to a failure mode. Theoretically, buckling is caused by a bifurcation in the solution to the equations of static equilibrium. In practice, buckling is characterized by a sudden failure of a structural member subjected to high compressive stress, where the actual compressive stress at the point of failure is less than the ultimate compressive stresses that the material is capable of withstanding mathematical analysis of buckling makes use of an axial load eccentricity that introduces a moment, which does not form part of the primary forces to which the member is subjected. When load is constantly being applied on a member, such as column, it will ultimately become large enough to cause the member to become unstable. Further load will cause significant and somewhat unpredictable deformations, possibly leading to complete loss of load-carrying capacity. The member is said to have buckled, to have deformed fig shows different stages of buckling.

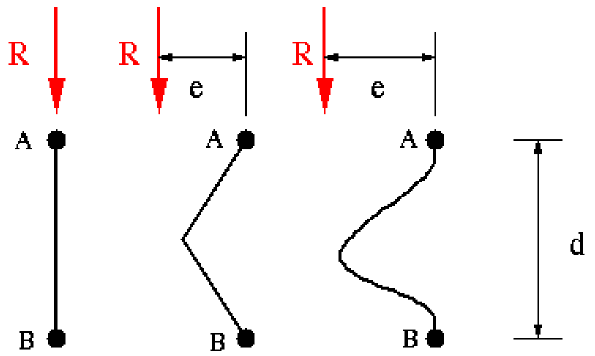


Fig: Buckling of the column

The ratio of the effective length of a column to the least radius of gyration of its cross section is called the slenderness ratio(sometimes expressed with the Greek letter lambda, λ). This ratio affords a means of classifying columns. Slenderness ratio is important for design considerations.

In 1757, mathematician Leonhard Euler derived a formula that gives the maximum axial load that a long, slender, ideal column can carry without buckling. An ideal column is one that is perfectly straight, homogeneous, and free from initial stress. The formula derived by Euler for columns with no consideration for lateral forces is given below. However, if lateral forces are taken into consideration the value of critical load remains approximately the same.

$$F = \frac{\pi^2 EI}{(KL)^2}$$

where
F = maximum or critical force (vertical load on column),
E = modulus of elasticity,
I = area moment of inertia,
L = unsupported length of column,
K = column effective length factor, whose value depends on the conditions of end support of the column, as follows.
For both ends pinned (hinged, free to rotate), K = 1.0.
For both ends fixed, K = 0.50.
For one end fixed and the other end pinned, K = 0.699....
For one end fixed and the other end free to move laterally, K = 2.0.
KL is the effective length of the column.

3. Lateral Buckling Analysis of Open Section C Channel Beam With Elongated Circular Ends Using FEA

Here the behavior of the channel beam with Circular ends under lateral buckling and finding the critical moment of the beam with change in various parameters such as the length, thickness of the sheet, radius of the round ends, ratio of breadth and height with the help of finite element analysis.

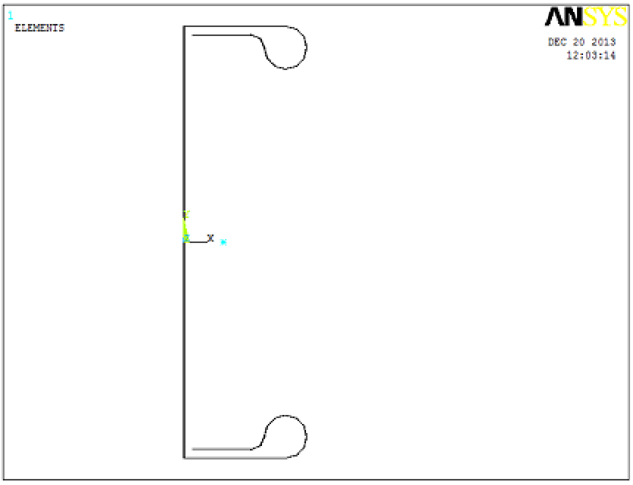


Fig : Open Section C Channel Beam With Elongated Circular Ends

4. RESULTS AND DISCUSSIONS.

The results of the buckling analyses of the channel beam with elongated circular ends section for Case 1 the selected length is 1600 mm and lateral restraints along the two longitudinal edges of web panel, for this the ratios of flange to web widths (b/a) is varied from 0.5 to 2. The curve of the circular end channel is plotted between critical moment and flange to web ratio. As the flange width increases to 156.8 mm, the value of Mcr reduces to 10779 N-m after reaching its peak value of 24917N-m when the flange to web ratio is 1,starting from 7691.3N-m when b/a ratio is 0.25.while the thickness remains at 3.14mm and the radius of the round end is 7.84mm.
The behavior of the channel beam with Circular ends under lateral buckling was examined in order to find critical moment of the beam.
The behavior was studied for two types of thin walled C channel beams

- Elongated Open Circular Ends
- Closed Circular Ends.

This behavior of the beams was examined by changing various parameter involved such as the length, thickness of the sheet, radius of the Circular ends, ratio of breadth and height with the help of finite element analysis.

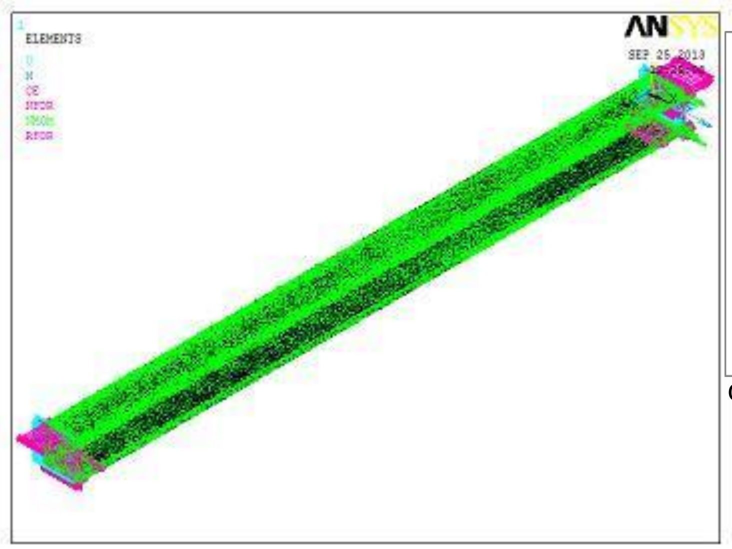


Fig Undeformed shape with load applications of channel with variables

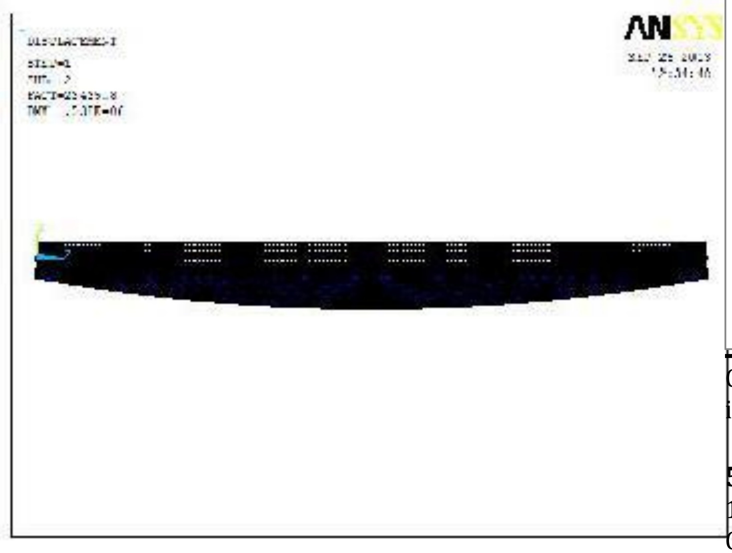


Fig Deformed shape

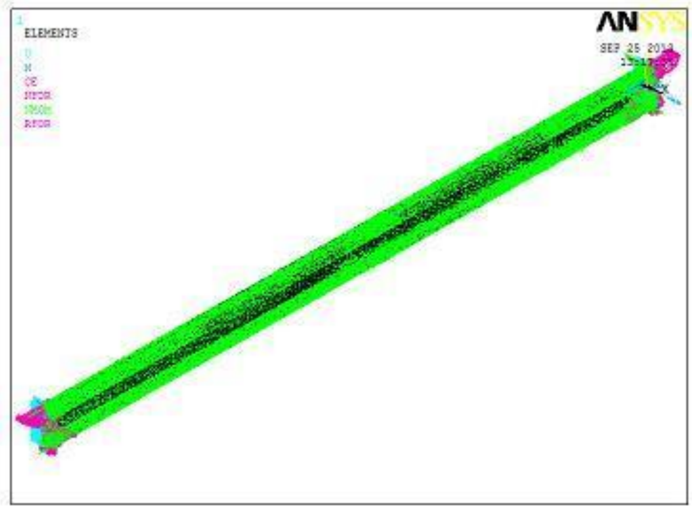
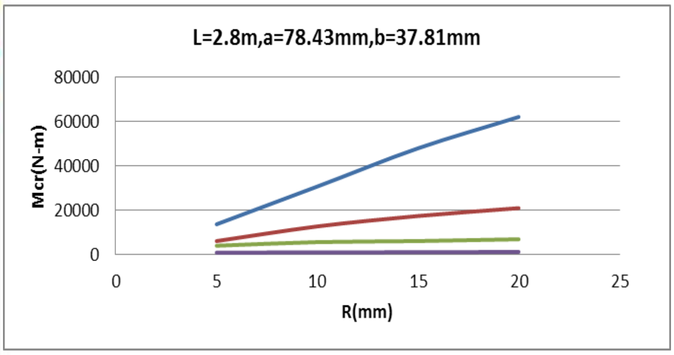
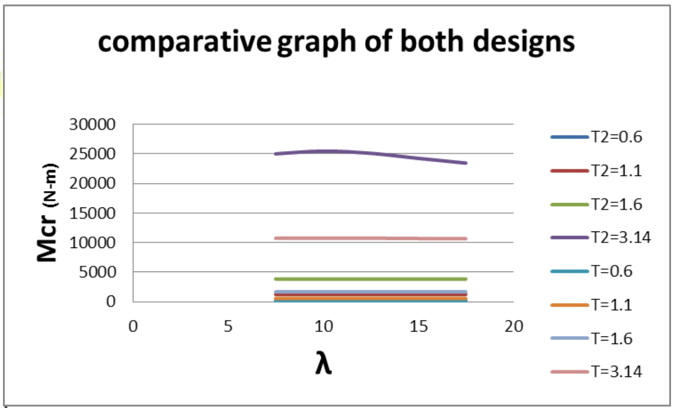


Fig Undeformed shape with load applications of channel with variables



Graph showing change in critical moment Mcr with change in radius and thickness



Graph showing change in critical moment Mcr with change in λ and thickness

5. CONCLUSIONS

1. Thin walled C channel sections with elongated open Circular end and closed Circular end are analyzed.
2. Firstly it was concluded that the more the thickness of the material the more is the maximum critical moment of the channel section.
3. Whereas the maximum critical moment of the channel is more when b/a ratio is around 0.5 to 1.
4. The effect of change in radii of the ends was concluded as the radii of the Circular ends also decided the maximum critical moment in way such that the higher was the value of radius the higher is the maximum critical moment.
5. It was also concluded that the effect of change in length can be neglected since there is negligible change in the value of maximum critical moment when compared to the other variables
6. It is concluded that the open section c channel with Circular ends has more strength when compared with open section c channel with elongated open circular ends.

ACKNOWLEDGEMENT

The authors would like to graciously thank Dr.P.Bhaskar Reddy, Principal and Dr. S. Satyanarayana Gupta, Head of the Department MLRIT, Hyderabad, for their extended support in project. Finally I would like to thank K.S.Naidu, Assistant professor, MLRIT Hyderabad, who has provided me with the best knowledge about the project.

REFERENCES

1. Marcello Pignataro Angelo Luongo and Nicola Rizzi "On The Effect Of The Local Overall Interaction On The Postbuckling Of Uniformly Compressed Channels" 01/1985; DOI: 10.1016/0263-8231(85)90009-6
2. M.A.M and O Huges "Lateral distortional buckling of monosymmetric I-beams under distributed vertical load" Thin-Walled Structures ISSN 0263-82311996, vol. 26, n2, pp. 123-145.
3. G.J. Hancock, K.J.R. Rasmussen"Recent Research On Thin-Walled Beam-Columns"Thin-Walled Structures Volume 32, Issues 1–3, September 1998, Pages 3–18 Doi: 10.1016/S0263-8231(98)00025-1
4. K Magnucki, E Magnucka-Blandzi "Variational design of open cross-section thin-walled beam under stability constraints"Thin-Walled Structures (Impact Factor: 1.23). 01/1999; 35(3):185-191. DOI: 10.1016/S0263-8231(99)00031-2
5. Krzysztof Magnucki,Tomasz Monczak,Optimum Shape Of The Open Cross-Section Of A Thin-Walled Beam"Engineering Optimization+A35 01/2000; 32:335-351. Doi: 10.1080/03052150008941303
6. B. W. Schafer "Local, Distortional, And Euler Buckling Of Thin-Walled Columns" Journal Of Structural Engineering / March 2002 / 289
7. Nuno Silvestre And Dinar Camotim "GBT-Based Distortional Buckling Formulae For Thin-Walled Channel Columns And Beams" Sixteenth International Specialty Conference On Cold-Formed Steel Structures Orlando, Florida USA, October 17-18, 2002
8. Xiao-ting Chu, Roger Kettle, Long-yuan Li. "Lateral-torsion buckling analysis of partial-laterally restrained thin-walled channel-section beams."Journal of Constructional Steel Research 60 (2004) 1159-1175.
9. N.S Trahair,G.J Hancoock "Steel member strength by inelastic lateral Buckling"Journal Of Structural Engineering, Vol. 130.No. 1 January 2004,pp.64-69,ASCE 0733-9445(2004)130:1(64)
10. Cheng Yu, B W. Schafer "Simulation of cold-formed steel beams in local and distortional buckling with applications to the direct strength method" Journal of Constructional Steel Research Volume 63, Issue 5,pages 581-590 DOI: 10.1016/j.jcsr.2006.07.008.