

Compression Buckling Analysis of Vertical Tail Stiffened Panels.

Shaikh.Md.Furkhan¹ Mr.Ambadas.Kadam²

¹P.G Student ²Assistant Professor

^{1,2}Department of Machine Design

^{1,2}Visvsevaraya Technological University Regional Center, Kalaburagi

Abstract— Thin structural members are susceptible to buckling under compression loading. Aircraft skin is always thin irrespective of the size of the aircraft. Therefore, when the skin undergoes compression, it is likely to buckle. Vertical tail of the aircraft experiences bending, whenever the rudder is deflected to achieve the yawing motion of the aircraft. Side load will cause the bending of the vertical tail, which introduces tension and compression stress field in the two side skins respectively. This project includes the linear static analysis of the vertical tail box structure and buckling analysis of the stiffened panels undergoing compression. A linear static buckling analysis of the vertical tail box structure will be carried out to identify the most critical panel. After that the critical panel is taken for buckling analysis.

Key words: Vertical load, Stiffeners, Flight loads, Compressive stress, tensile stress, Ribs, Stringers and Buckling

thickness of skin and ribs are 2mm and 3mm respectively. Rivets have a diameter of 5mm.

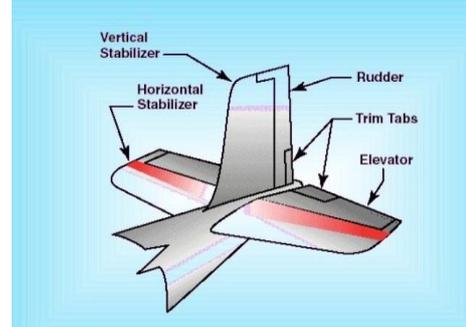


Fig. 1: Basic parts of the vertical tail.

- 1) VERTICAL TAIL
Length of the tail - 3662 mm.
Sweep angle - 30 degree.
Material used – aluminum 7075-T6.
- 2) RIBS
Cross section – NACA 0012 aerofoil.
Thickness – 5 mm.
- 3) SPARS
Cross section – I section.
Thickness – 3 mm.
- 4) STRINGERS
Cross Section - Z section.
Thickness - 2mm

I. INTRODUCTION

The airplane we are designing needs to have the required strength and toughness to resist the extreme conditions. The design must be such that if in a case one of the parts of the airplane fails, the entire airplane shouldn't fail. The important parts of the airplane are the fuselage, the empennage and the wings. The airframe is the load bearing member of the parts which are subjected to forces. In the case of old airplanes the skin is made from impregnated linen which is not capable of transmitting any forces. In modern day aircrafts we are using hollow parts instead of solid sections because of the simple reason of weight reduction. But in the process we are losing out stiffness. For that purpose stiffeners are used. Skin and stringers act as stiffeners. Stiffeners are attached to the skin. Stringers are the stiffening members that come in various cross sections and serve various purposes. Sheet metals are used in preparing the skin and are cheaper than other types of stringers. But complicated stiffeners cannot be made using the sheet metal. Stiffened panel is a panel used for the buckling analysis of the structure at the local level.

II. OBJECTIVE OF THE WORK

“The buckling analysis is done for the vertical tail to examine whether the tail buckles or not at the maximum load. Further the buckling analysis is done for the stiffened panels also”.

III. GEOMETRICAL SPECIFICATIONS OF VERTICAL TAIL

The aircraft considered in this project is the Cessna 206 Stationair which has seating capacity of 6 persons and the load acting on the vertical of the aircraft is 3264 kgs. Spars used here are of I section and thickness of 3mm, stringers used here are of Z section and thickness of 2mm. The

Material	Young's modulus E in (Gpa)	Poisson's ratio γ	Tensile ultimate stress σ_t in MPa	Tensile yield stress σ_y in Mpa	Density ρ in kg/m ³
Aluminum 7075-T6	71.7	0.33	572	503	2780

Table 1: Mechanical Properties of Aluminum 7075-T6

Component	Al	Cr	Cu	Fe	Mg	Mn	Si	Ti	Zn
Weight %	87.1-91.4	0.18-0.28	1.2-2	Max 0.5	2.1-2.9	Max 0.3	Max 0.4	Max 0.2	5.1-6.1

Table 2: Composition of Aluminum 7075-T6.

IV. MESHING OF RIBS, SPARS, STRINGERS & RIVETS

Ribs, Spars, Stringers are extracted and meshed separately and all the quality parameters are checked. Rivets are made to connect these parts with the skin. All the parts are now posted and the completely meshed vertical tail before analysis looks as below:

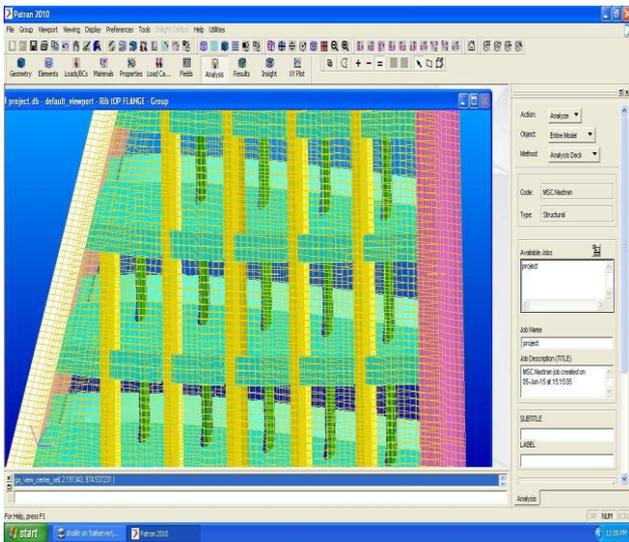


Fig. 2: Complete of Meshed Mail.

V. STRESS ANALYSIS OF VERTICAL TAIL (GLOBAL ANALYSIS)

1) Length of each rib calculated from base to center of the rib is as:

- L1= 90.7 mm
- L2= 333.23 mm
- L3= 675.7 mm
- L4= 1063.7 mm
- L5= 1395.6 mm
- L6= 1775.16 mm
- L7= 2117.83 mm
- L8= 2488.05 mm
- L9= 2840.1 mm
- L10= 3221.46 mm
- L11= 3617.34 mm
- Total length = 3662.2 mm

2) Load factor is calculated by dividing the corresponding lift value from the chart to the sum of all lift values and multiplied with total weight of the aircraft tail.

Load factor = (lift value) / (sum of lift) x weight of the aircraft tail.

Load factor for 1st rib = (0.6)/(7.5) x 3264 = 261.12

Load factor for 2nd rib = (0.8)/(7.5) x 3264 = 348.16

Load factor for 3rd rib = (1.25)/(7.5) x 3264 = 544

Load factor for 4th rib = (1.5)/(7.5) x 3264 = 652.8

Load factor for 5th rib = (1.7)/(7.5) x 3264 = 739.84

Load factor for 6th rib = (1.8)/(7.5) x 3264 = 783.36

Load factor for 7th rib = (1.9)/(7.5) x 3264 = 826.88

Load factor for 8th rib = (1.8)/(7.5) x 3264 = 783.36

Load factor for 9th rib = (1.6)/(7.5) x 3264 = 696.32

Load factor for 10th rib = (1.25)/(7.5) x 3264 = 544

Load factor for 11th rib = (0)/(7.5) x 3264 = 0

3) Bending moment is calculated is as follows:

$$BM = \sum (\text{load factor} \times \text{length})$$

$$BM = (261.12 \times 90.7) + (348.16 \times 333.23) + (544 \times 675.7) + (652.8 \times 1062.7) + (739.84 \times 1395.6) + (783.86 \times 1775.16) + (826.88 \times 2117.83) + (783.36 \times 2488.05) + (696.32 \times 2840.1)$$

$$+ (544 \times 3221.46)$$

$$BM = 11055097.93 \text{ kgmm.}$$

$$BM = 1.1 \times 10^7 \text{ kgmm.}$$

One end of the tail is fixed and the other end is free, so the vertical tail acts as a cantilever beam. The bottom end of the tail is fixed and the load is distributed throughout the length of the vertical tail. Now do the linear static analysis to get the stresses and deformation. In analysis and in solution types check for linear static analysis and run the software to get the stresses and deformations. The average stress obtained 10- 15kg/mm² which is less than the ultimate strength (35). Then we have to find the buckling factor. For that change the solution type to buckling and do the buckling analysis and get the buckling factor. Buckling factor obtained was 0.08, which means that the tail will buckle as the buckling factor is less than one. To achieve that purpose rivets are added at the spar and then the buckling analysis is done and now the buckling factor obtained was 0.28547 which is still to be increased. Design modification has to be carried out.

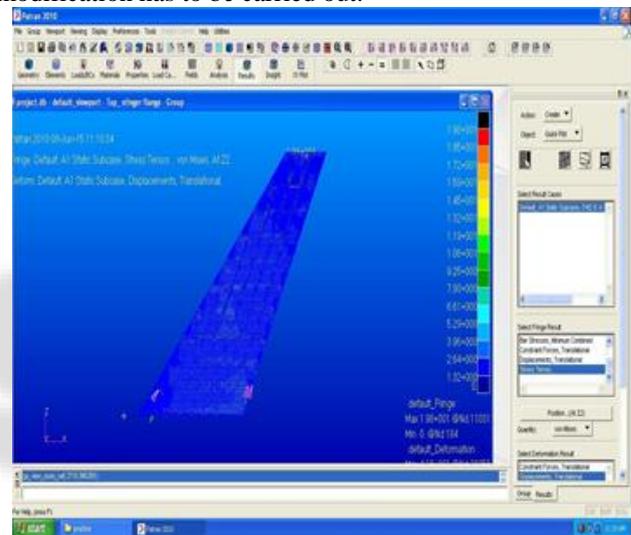


Fig. 3: Stress Analysis of Vertical Tail.

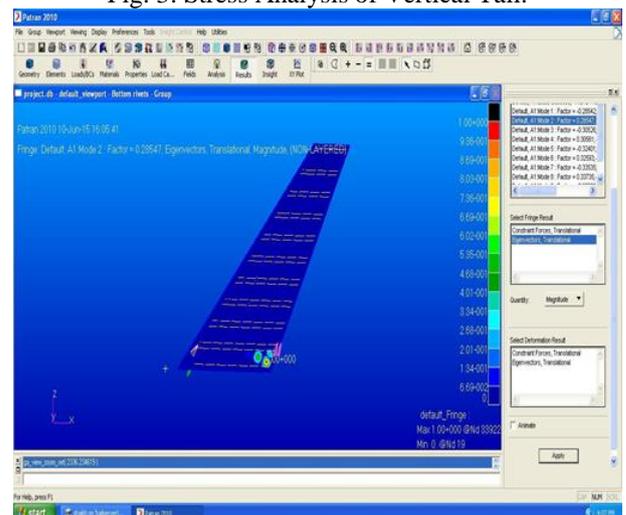


Fig. 4: Buckling Analysis Of Vertical Tail

VI. DESIGN MODIFICATIONS TO WITHSTAND COMPRESSION BUCKLING

A. Local Analysis (Stiffened Panels):

Buckling factor for global analysis was less than 1, therefore above mentioned modification has to be done i.e. decrease the applied load (P_{applied}) or make the structure more stiffer by increasing the thickness of the load bearing members. In other words increasing the thickness of the skin and ribs. Now we will concentrate on the buckling analysis of stiffened panels. The stiffened panel comprises of skin and stingers and did not include ribs because ribs functions more as support to the structure. Top skin and stingers were posted up to 4th rib from bottom and the loads were applied. The root end is fixed and the load is applied on the top end. Loads are calculated using the marker stresses. Marker stresses are obtained as, in results go to create and then marker and select stress tensor. In target entity select elements. In display attributes change label style to fixed. In plot options change it to global and apply.

1) Marker Stresses for Skin:

1.2 + 1.1 + 1.1 + 1.2 + 1.4 + 1.6 + 2 + 3 + 1.3 + 5.2 + 2.5 + 4.4 + 2.7 + 4.4 + 2.7 + 2.1 + 1.6 + 1.4 + 1.2 + 1.1 + 1.1 + 1.4 + 2.1 + 1.5 + 1.9 + 2.6 + 1.8 + 1.4 + 1.6 + 1.7 + 1.7 + 1.7 + 1.6 + 1.5 + 1.1 + 1.6 + 1.9 + 2.6 + 2.4 + 2.2 + 2.5 + 2.5 + 2.5 + 2.4 + 2.2 + 2 + 1.4 + 1.6 + 1.6 + 2.4 + 2.5 + 2.5 + 2.9 + 2.9 + 2.8 + 2.6 + 2.5 + 2.4 + 2.5 + 3.3 + 55 + 23 = 197.5 kg/mm².

Average stresses for skin = 197.5 / 60 = 3.292 kg/mm²

Area = (width) x (thickness)

= 1133.6678 x 3

= 3401 mm²

Load = (stress) x (area)

= 3.292 x 3401

= 11196.09 kg

Marker stresses for stingers: 0.09 + 0.16 + 0.08 + 0.05

= 0.38 kg/mm².

Average stress for stingers = 0.38 / 4

= 0.095 kg/mm²

Area = (width) x (thickness)

= 917.3 x 3 = 1834.6 mm²

Load = (stress) x (area)

= 0.095 x 1834.6

= 174.287 kg

Load of 11196.09 kg and 174.287 kg has to be applied at the skin and stingers of the stiffened panel respectively. Linear static analysis is done and the results are obtained. The stresses are well within the ultimate stress and hence the structure is considered to be safe.

VII. RESULTS AND DISCUSSIONS

In order to increase the buckling factor and to make sure that the tail doesn't buckle under maximum applied load we shall now consider the flat stiffened panels. The thickness of the rib was increased from 3 mm to 5mm and the buckling analysis done. The buckling factor obtained was 0.99. As ribs act as support providing structure and in the stiffened panels we have consider only skin and stingers and simulate the ribs in this condition. For that the three sides of the skin were simply supported and same loads were applied to the skin and stingers with the root end being fixed. Linear static analysis was carried out and the stress value was less than

the ultimate stress. Similarly buckling analysis was carried out and the buckling factor obtained was 1.3596. Hence this buckling factor was more than 1 and the stiffened panel is safe under the given maximum applied loads and given conditions.

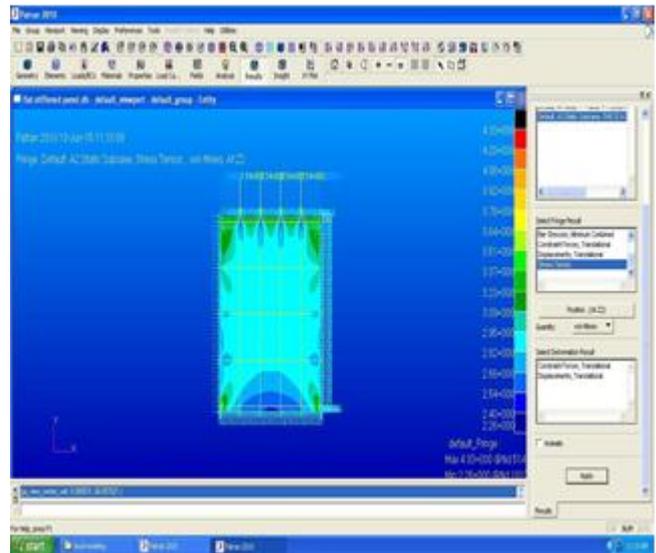


Fig. 5: Stress Analysis of Stiffened Panels

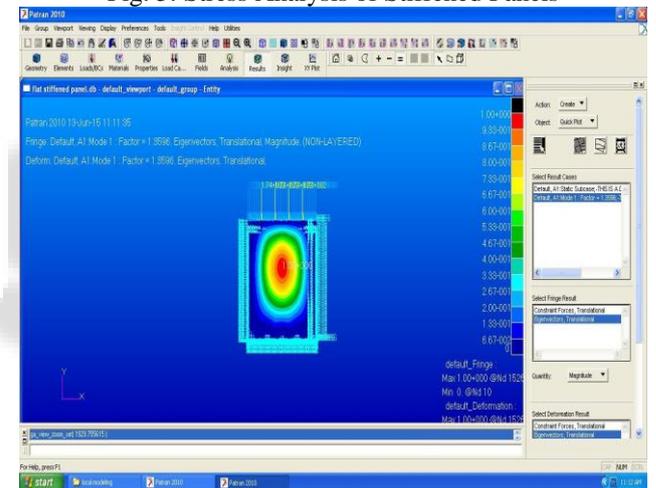


Fig. 6: Buckling Analysis of Stiffened Panels.

VIII. CONCLUSION

As the buckling factor for global analysis was found to be less than one, some modifications are to be done like decreasing the load, increasing the thickness of ribs and skin to make the structure stiffer and increasing the rivets diameter etc. The modifications were suggested and the concentration was on stiffened panels. In the stiffened panels the section of the tail is considered with only skin and stingers. The loads acting on the skin and stingers at these sections have to be calculated. For that marker stresses are found and then multiplying these stresses with the area, the loads are found out. They are applied and the three sides of the stiffened panels are simply supported to simulate the support provided by the ribs. The linear static analysis and buckling analysis were carried out and the buckling factor was found out to be 1.3596. Hence we conclude that the vertical tail is safe and will not buckle at the maximum applied loads. Further analysis can be done for the linear static and buckling analysis of complete model i.e. global analysis. Also the effect of loads due to the moment of the

rudder on the joints between vertical tail and other parts which are connected to it can be carried as future work.

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