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Static and Buckling Analysis of Center Fuselage Structure of a Transport Aircraft through FEA Approach

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Abstract - *Safety is the most important aspect in the aircraft design. So the designer has to take care of safety of the aircraft structure, to prove safety of structure the designer has to understand the behavior of the structure and load. Aircraft design is a separate discipline of aeronautical engineering and it is different from the analytical disciplines such as aerodynamics, structures, controls and propulsion. Fuselage of an aircraft structure can be divided into front fuselage, center fuselage and rare fuselage. A center Fuselage is a part, which houses the passengers and cargo on account of a common transport air ship. Fuselage structure usually made up of stiffened panels which include longitudinal stringers, transvers frames (bulkheads) and cover skin of lightweight material. Fuselage will encounter fundamentally the inertia and pressurization loads. The present study is concerned with design of center fuselage structure of a transport aircraft and analysis of compression buckling of center fuselage structure when it is subjected to compression loading at certain altitude and a linear static analysis of center fuselage structure to determine the critical stress reasons in panels.*

***Key Words*: Centre Fuselage, Compression Buckling, Static analysis, Buckling load factor, Structural Integrity,**

1.INTRODUCTION

Aircraft design is a complex and multi-disciplinary process that involves a large number of disciplines and expertise in aerodynamics, structures, propulsion, flight controls and systems amongst others. During the initial conceptual phase of an aircraft design process, a large number of alternative aircraft configurations are studied and analyzed. The main body structure is the fuselage to which all other components are attached. The fuselage contains the cockpit or flight deck, passenger compartment and cargo compartment. While wings produce most of the lift, the fuselage also produces a little lift. A bulky fuselage can also produce a lot of drag. For this reason, a fuselage is streamlined to decrease the drag. The fuselage of an aircraft consists of sheet panels, stringers, and stiffeners held together by riveted lap joints. Although different joining techniques exist, the skin panels are typically fastened together with rivets. Numerous rivets are required to join the skin completely.

1.1 Buckling

There are two major categories leading to the sudden failure of a mechanical component: material failure and structural instability, which is often called buckling. For material failures you need to consider the yield stress for ductile materials and the ultimate stress for brittle materials. The load at which buckling occurs depends on the stiffness of a component, not upon the strength of its materials. Buckling refers to the loss of stability of a component and is usually independent of material strength. This loss of stability usually occurs within the elastic range of the material.

1.2 Buckling Load Factor

The buckling load factor (BLF) is an indicator of the factor of safety against buckling or the ratio of the buckling to the currently applied loads. In buckling analysis value of Buckling Load Factor determines the safety of the component. If buckling load factor is less than or equal to 1, then structure loses its stability.

Table -1: Buckling Load Factor (BLF)

Buckling Load Factor		
SL NO	Buckling Factor	Remarks
1	<1	Failure
2	=1	Needs Modification
3	>1	Safe

2. PROBLEM DESCRIPTION

A center fuselage structure of a transport aircraft is analyzed when it is flying 10,000 fts above the ground at a velocity of 250 km/h. Here we are analyzing center fuselage structure by compression buckling method to check whether center fuselage structure will buckle or not. Since it is an indeterminate structure and it is difficult to calculate buckling factor by mathematical calculations. For this we are using FEA method to understand the buckling and critical stress reasons of the center fuselage structure.

2.1 Methodology

- Creation of CAD Model for the fuselage section of the transport aircraft using CATIA v5.
- Generation of FE Model based on the CAD model generated by using Hyper Mesh 13.
- Assigning Materials and properties for the generated FE model.
- Application of Loads and Boundary conditions based on the flight condition chosen.
- Analysis of the FE Model with Loads and BCs using NASTRAN.
- Extraction of results after completion of analysis and documentation using Hyper View.

2.2 CAD Modelling

In this section, modeling of Center Fuselage structure has been done using CATIA v5 modelling software. The center fuselage structure is modelled with its stringers, bulkheads and skin with reference to standard dimensions. For model simplification, all fillets and chamfers below 3mm are neglected. The skin is divided into different section to allow for thermal expansion. The total length of fuselage is 3600mm and the diameter of fuselage is 1900mm.

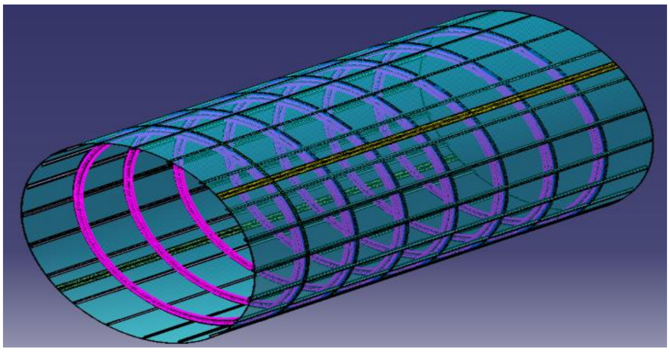

Fig -1: Geometric model of center fuselage structure.

2.2 FE Model

Finite Element model generated for the geometric model of the fuselage structure using 2D Quad elements. These elements are selected because the large size of the structure and one of the dimensions of all the components are comparatively less than the other two dimensions. Each component is considered as a separate entity and then joined using 1D rigid element which replaces the rivets that are used to connect all the components in the actual model.

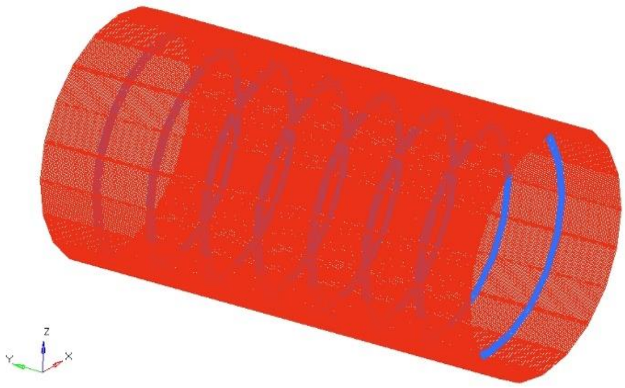

Fig -2: Finite element model of center fuselage structure.

2.3 Material Properties

Table 2 gives the material properties applied to the model. The material is aluminum alloy Al 7075 and its properties are given below. The material properties required for the current analysis are Young's' Modulus, Poisson's ratio, density and ultimate strength. This is because the analysis is of structural nature and other properties are not considered in the analysis.

Table -2: Material Properties

Material Name: Aluminum Alloy Al 7075		
Property	Units	Value
Young's' Modulus	GPa	71.7
Poisson's Ratio	-	0.33
Density	Kg/m^3	2820
Ultimate Strength	Mpa	572
Yield Strength	Mpa	503

2.4 Load Calculation

The load calculations are as given below.

Air density at the height of 3000m = 0.905 kg/m3

Speed of the aircraft = 250 km/h = 69.44 m/s

Air Pressure acting on the center fuselage is given by

$$P_d = \frac{1}{2}\rho v^2$$

Where,

ρ = Density of the air (kg/m^3)

v = Velocity of the aircraft (m/s)

Therefore,

P_d = 0.5 * 0.905 * (69.44)2

P_d = 2181.91 Pa = 4.82 kPa

P_d is the total pressure applied on the skin of the center fuselage for the analysis.

Design load factor considered = 3g

No. of passengers on the aircraft = 4 Nos.

Average load of each passenger = 75kg

Total passenger load = 75 X 4 = 300kg

Mass of other equipment on the aircraft = 300kg

Total load distributed on all bulk heads = (Design load factor) *(Total passenger load) * (Total equipment load)

= 3*300*300

= 1800 kg

Total weight applied = 1800 X 9.81

= 17658N

The total weight calculated above is applied on the bulkheads equally distributing the load among them.

2.5 Boundary Conditions

For the analysis, the ends of the center fuselage are fixed and pressure load is applied to simulate the air pressure acting on it when the airplane is moving at a speed of 250 km/h and at a height of 3000 m (10,000 ft.).

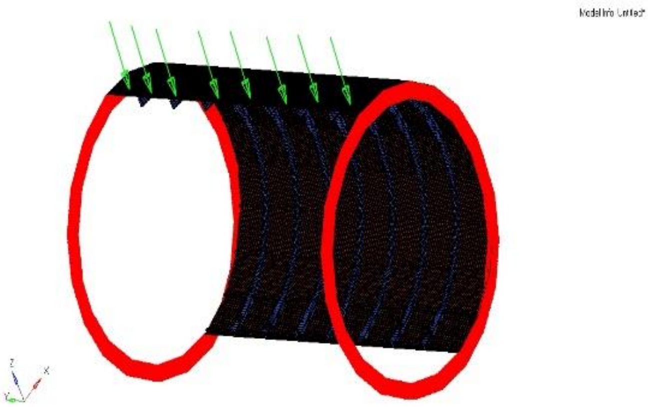

Fig -3: Application of load and Boundary Condition

3. RESULTS AND DISCUSSION

The analysis was run for the above mentioned FE Model with the loads and boundary conditions attached to it. The following figures give the results obtained from both the static analysis (Displacement and Stresses) and buckling analysis (Buckling mode).

3.1 Buckling Analysis results

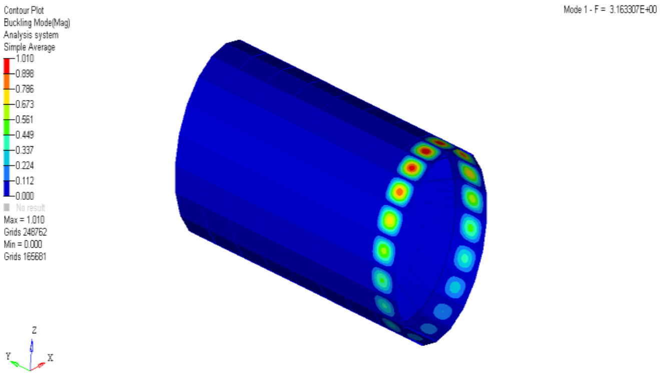

Fig -4: Buckling Mode Plot

Figure 4 shows the buckling mode plot of the fuselage structure for the applied loads. It is observed that the buckling factor is 3.6 which means that the fuselage structure designed can withstand loads as high as 3.6 times the load applied under the above mentioned conditions. In buckling analysis, the value of buckling factor determines the safety of the component.

3.2 Liner Static Analysis results

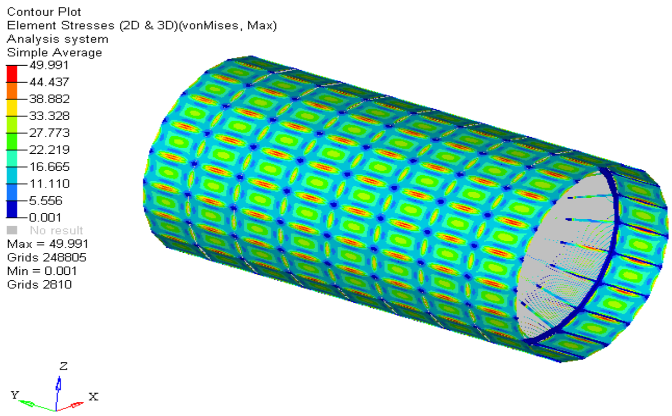

Fig -5: Stress plot for static analysis

Figure 5 shows the Von Mises stress plot for the fuselage structure under the loads applied. It is clear from the above figure that the maximum stress is seen where the skin of the aircraft is joined to the stringers with rivets at a value of 49.99 MPa. This value is very much less than the yield strength of the material and hence it can be said that the center fuselage structure is safe under the applied load because the value of the stress developed is well within the maximum allowable stress level of 572 MPa and the factor of safety calculated is of the order of 11.44.

4. CONCLUSIONS

In this work, a center fuselage structure was considered for analysis. The fuselage structure considered was modelled, discretized and analyzed to determine its static and buckling strength due to the applied air load, passenger and equipment loads. It can be concluded, based on the results presented in this work, that

- The displacement occurring in the fuselage structure is minimum and does not affect the strength or performance of the structure for the applied loads.
- The linear static analysis shows that the stress generated in the model due to the applied load is well within the value of the ultimate strength of the material.
- The buckling analysis of the structure revealed that the buckling factor was greater than 1 and hence can be said that the structure can withstand the applied buckling load.

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