Structural Analysis Of Fuselage With Lattice Structure

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Abstract

The design of a fuselage structure for any aircraft is very essential. The fuselage structure for business jet aircraft carries stringers, frames, floor beam and outer skin. The fuselage structure for heavy passenger aircraft carries a wide numerous structural parts such as bulkheads, longerons, frames, stringers, flat plate, outer skin etc. Nowadays, stiffened shell structure was used in fuselage structure. The lattice structure is a complex design which carries a individual structural components of actual fuselage structure seen. In this project, the lattice structure was adapted to the aircraft instead of stiffened shell structure. The design of the lattice structure is carried out in CATIA and the static structural analysis is carried out in ANSYS to find the stress and deformation due to the load.

Keywords— *stringers, lattice, fuselage structure, finite element analysis.*

1. Introduction

The word fuselage is based on the French word fuseler, which means "to streamline". The fuselage must be strong and streamlined since it must withstand the forces that are created in flight. Fuselage is an aircraft's main body section that holds crew and passengers. The functions of an aircraft fuselage include all of the following; support structure for wings and tail, structure that contains the cockpit for the pilot and structure that allow aircraft to carry cargo, passengers, and equipment. It must be able to resists bending moments (caused by weight and lift from the tail), torsional load (caused by fin and rudder) and cabin pressurization. The majority of the fuselage in transport aircraft is cylindrical or near cylindrical with tapered nose and tail section. In order to achieved aircraft stability and manoeuvrability, aircraft fuselage plays an important role in position control and stabilization surfaces in specific relationships to lifting surfaces. The fuselage can be class into three basic sections which are engine section, cabin section and sheet-metal tail cone section.

2. Fuselage Pressurization

The fuselage structure which consists primarily of frames, stringer and external skin is basically designed to resist, in an efficient manner, the shears and bending moments resulting from air loads and inertial loads. Upon internal pressurization, however, this type of structure becomes an inefficient pressure vessel due to primarily to stringer and frame bending. The principal structure implication of fuselage pressurization can be classified in the following manner. The primary structural effect of pressurization is the inducement of longitudinal and circumferential stresses in the skin panels bounded by adjacent stringers and frames. Since the stringers are adjacent to the outer skin panels and are supported internally by the frames, a portion of the pressure loading is carried by these members into frames. The second important effect is, therefore, the stresses induced in the stringer by the outer skin panels .Because the frames can be non-circular and with variable cross-sectional structural properties, shears are transmitted to these members resulting in frame warpage and outward deflections.

Another important effect is the influence of cut outs, floors and splices, i.e. any of the smaller components effects, upon the stresses induced in the primary load carrying components (frames, stringers and outer skin). The final effect concerns the stresses induced by a closing bulkhead, or the nose or tail section of the airplane. These entire principal effects when combined with the stresses induced by air loads result in the overall fuselage stress system. Since, in general, the pressure loading on a panel is held in equilibrium by a non-linear interaction of the deflection and the stresses, the combined structural effects of fuselage pressurization and the inertial and air loads are not a simple superposition of the individual effects. Some portion of the structure may be stabilized by internal pressurization.

3. Construction of Fuselage

Basically, the purpose of aircraft structure is to transmit and resists all loads applied to it. Furthermore, it also acts as a cover to maintain the aerodynamic shape and protects its content. Fuselage construction can be separate into two types which are welded steel truss and monocoque designs. However, most aircraft used monocoque design in their structure in order to carry various loads. The monocoque design can be categorized into three classes which are monocoque, semi monocoque and reinforced shell. Standard aluminium fuselage of a big passenger airplane is a semi monocoque construction with shell, stringers and frames. The fuselage contains a cockpit and passenger compartment, both sections experiencing surplus internal pressure.

3.1 Semi-monocoque structure

Semi monocoque fuselage design usually uses combination of stringers, bulkheads, and frames to reinforce the skin and maintain the cross sectional shape of the fuselage. The skin of the fuselage is fastened to all this members in order to resists shear load and together with the longitudinal members, the tension and bending load. In this design structure, fuselage bending load are taken by stringers. They provide rigidity to the fuselage in order to give shape and attachment to the skin. Stringer and frames are essential to prevent tension and compression stress from bending the fuselage.

The fuselage skin thickness varies with the load carried and the stresses sustain at particular location. Moreover, bulkheads are used where concentrated loads are introduced into the fuselage, such as those at wing, landing gear, and tail surface attach points. Frames are used primarily to maintain the shape of the fuselage and improve the stability of the stringers in compression. The benefits of semi monocoque design is it overcome the strength to weight problem occurred in monocoque construction.

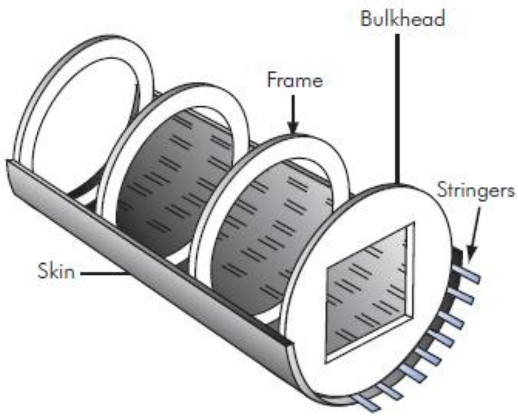

Figure 1: Stiffened structure

4. Lattice structure

Lattice structure is made of a number of helical and circumferential ribs. Lattice structures provide a great potential to replace conventional metal structures by offering higher strength to weight ratio. Aircraft fuselage and launch vehicle fuel tanks are some of the many applications of these structures in aerospace and aircraft industries. These structures are characterized by a shell structure (or skin) supported by a lattice pattern (or grid) of stiffeners either on the inner, outer or both sides of the shell. Cylindrical shells are subjected to any combination of in plane, out of plane and shear loads during application. Due to the geometry of these structures, stress analysis is also one of the most important failure criteria.

Figure 2: Lattice structure

5. AIRCRAFT LOADS

Aircraft loads are those forces and moments, or loadings, applied to the airplane structural components (the wing, horizontal tail and the fuselage, for instance) to establish the required strength level of the complete airplane. These loadings may be caused by air pressure (lift), inertia (mass, weight) forces or ground reactions during take offs and landings. The determination of design loads involves a full aircraft analysis of the air pressure and inertia forces during certain prescribed manoeuvres, either in the air or on the ground.

5.1 Fuselage Loads

Usually fuselage is considered as a beam supported by main wing-fuselage joints. The main sources of fuselage loads are as follows:

- Reaction of other components of an aeroplane which are mounted to the fuselage, especially: horizontal and vertical tail, landing gear, reaction of point mass, payload, devices, etc.
- Aerodynamic loads
- Load due to pressurization of cabin.
- Engines and other power units assembled with the fuselage

Fuselage loads involved of distributed and concentrated load. The concentrated loads are loads that transferred from the fixing bolts on the wing, tail stabilizers, and the landing gear. These forces are the main force acting on the fuselage Contrast to the loads above, aerodynamic load and dynamic pressure of the fuselage are classes as distributed loads. These forces subject the fuselage to bear shearing force, bending moment and twisting moment. Furthermore, the weight of fuselage structure and payload will cause the fuselage to bend downwards from its support at the wing. Consequently, the top part of the fuselage will experience tension while the bottom part in compression.

5.2 Pressurization Loads

The pressure cabin has been the source of some spectacular disasters directly attributed to fatigue in aircraft. The contribution to the failure of the fuselage shells are:

- Cut-outs in shell structures, which create high local stresses;
- Cut countersink rivets adjacent to the edge of the cut-out compounds the stress concentration effects;
- Aluminium materials with high yield to ultimate strength ratios are PRONE to rapid tearing at low stress levels.

The airplane structure must be strong enough to withstand the flight loads combined with pressure differentials loads from zero up to the maximum relief valve setting. This relieving valve works as a safety device that enables a decrease in the cabin pressure whenever the pressure difference between the fuselage's outer and inner skins exceeds a given admissible threshold for a particular fuselage. In the case of a pressurized cabin landing, these must be combined with the landing loads. The aeroplane must be capable of withstanding pressure differential loads corresponding to the maximum relief valve setting multiplied by a factor of 1.33, not accounting for other loads. The critical loading conditions arise when no pressure difference is felt or when the maximum admissible pressure difference is reached, which corresponds to the relief valve setting.

5.3 Boundary conditions for lattice structure

Condition	**Value**
End condition	Both end fixed
Internal pressure load	1 atm
Solver type	Mechanical APDL
Result type	Total deformation
material	aluminium alloy

Table 1.Inlet Boundary Condition

6. FINITE ELEMENT ANALYSIS

In the fuselage lattice structure, the helical ribs and circumferential ribs are stiffening elements.
In this paper, the skin with stringers and floor beam at first are modelled and analysed separately in order to see the stress working over every node on them. Then the analysis of combination of them is done. All of them are drawn by using softwares CATIA V5R20 and analysed using ANSYS for finite element analysis.
Basically fuselage structure can be divided into three sections which are cockpit section, tail section and the cabin section. For this study, the design is focusing on the cabin structure of the fuselage with lattice concept. Lattice structure consists of helical and circumferential ribs. The diameter and length of the fuselage is 1600mm and 2885mm

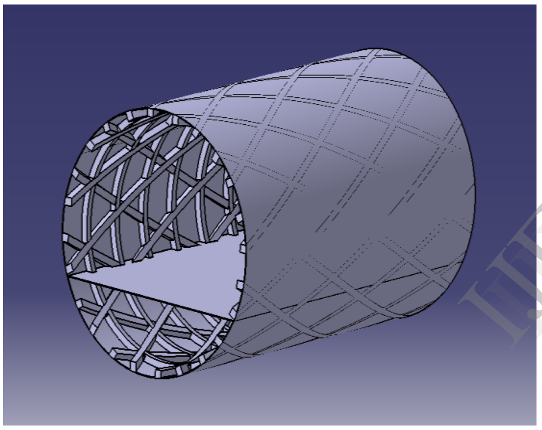

Figure 3: Lattice Design Structure

7. RESULT AND DISCUSSION

In this Paper, the results desired are the stresses modes, which are deduced from the program, built in ANSYS. The equivalent stresses (von Misses) deduced by the static analyses of the structure give us a good estimation of the stress distributions in the structure and show us where the maximum stress is obtained. In this paper the linear stress analysis in ANSYS finite elements software is performed. In the first step a static solution to the structure is obtained. In this analysis the stress occurrence of the structure is calculated. From the finite element analysis model results show that the design structure is rigid and safe. It can be shown in three kind of result of the analysis. The first result is the fuselage skin with the stringers which is loaded by the internal pressure of 1 atm.

In the first condition, both end of the fuselage structure is fixed and internal pressure load is applied inside the fuselage stringers alone. The material used is aluminium alloy. The maximum stress value occur is 3.0896 MPa. The stress value is far below the yield strength of the material.

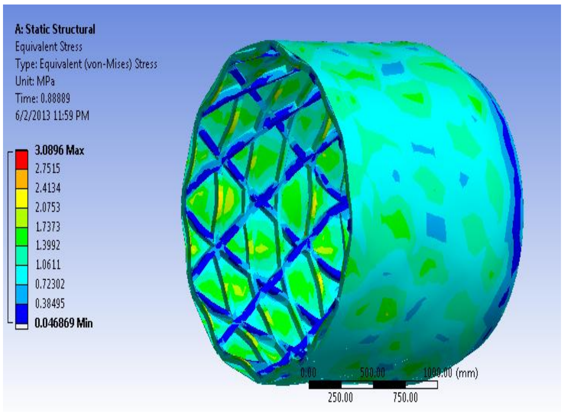

Figure 4: Stress Distribution on Stringers

In the second condition, both end of the fuselage structure is fixed and internal pressure load is applied inside the fuselage. The material used is aluminium alloy. The maximum stress value occur is 11.8 MPa. The stress value is far below the yield strength of the material.

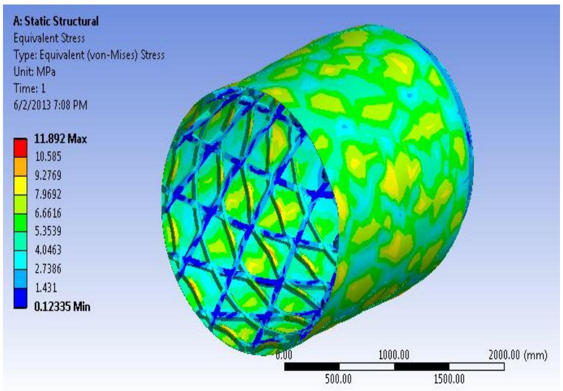

Figure:5 Stress Distribution with Skin and Stringers

The third condition is the fuselage structure skin with the stringers and floor beam which loaded by the internal pressure as 1 atm. The maximum stress value occur is 18.9 MPa. The stress value is far below the yield strength of the material.

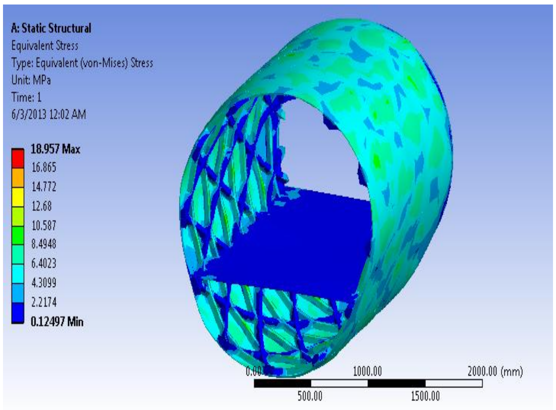

Figure 6: Stress Distribution with Stringers and Floor

8. CONCLUSION

The structural analysis of fuselage with lattice structure of light jet aircraft has been presented. The result shows that the fuselage lattice structure is rigid and safe according to the failure theory analysis, which means the working stress is far below the yield strength of the materials. The result at this stage is satisfied higher than the stiffened shell structure but it needs more attention to the critical area of the structure since the fuselage is not as one body but consist of assembly parts constructed it. The critical area carried under study also includes the kinds of joins which assembled the whole parts. In turn, the design needs validation by experimental test and analysis with static and dynamic loads in order to get the good and safety result before producing the aircraft.

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