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# Static and Model Analysis of A Twin Seater Aircraft Fuselage

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*Abstract*

***The fuselage is an aircraft's main body section that holds crew and passengers or cargo. In single-engine aircraft it will usually contain an engine, although in some amphibious aircraft the single engine is mounted on a pylon attached to the fuselage which in turn is used as a floating hull. The fuselage also serves to position control and stabilization surfaces in specific relationships to lifting surfaces, required for aircraft stability and maneuverability.***

***Aircraft is a complex mechanical structure and must be designed with a very high structural safety. Aircraft designer needs to ensure the structural integrity of the airframe without compromising on the safety of the structure. In current study a center fuselage structure of a transport aircraft is considered for the evaluation. The linear static and buckling analysis of center fuselage is carried out through FEM approach. Semimonocoque type fuselage structure is modeled using CATIA modeling tool.***

***This type of fuselage structure consists of frame assemblies, bulkheads, and formers as used in the monocoque type fuselage but the skin is reinforced by longitudinal members called longerons. Longerons usually extend across several frame members and help the skin support primary bending loads. They are typically made of aluminum alloy either of a single piece or a built-up construction. Stringers are also used in the semimonocoque fuselage. These longitudinal members are typically more numerous and lighter in weight than the longerons. They come in a variety of shapes and are usually made from single piece aluminum alloy Stringers have some rigidity but are chiefly used for giving shape and for attachment of the skin. Stringers and longerons together prevent tension and compression from bending the fuselage. Fuselage will encounter fundamentally the inertia and pressurization loads. The present study is concerned with compression buckling of center fuselage structure when it is subjected to axial loading along the flight direction of the fuselage also a linear static analysis of center fuselage structure with a circulated air load following up on it.***

## INTRODUCTION

### Fuselage:

The fuselage should carry the payload, and is the main body to which all parts are connected. It must be able to resist bending moments (caused by weight and lift from the tail), torsional loads (caused by fin and rudder) and cabin pressurization. The structural strength and stiffness of the fuselage must be high enough to withstand these loads At the same time, the structural weight must be kept to a minimum.

In transport aircraft, the majority of the fuselage is cylindrical or near-cylindrical, with tapered nose and tail sections. The semi-monocoque construction, which is virtually standard in all modern aircraft, consists of a stressed skin with added stringers to prevent buckling, attached to hoop-shaped frames.

The fuselage also has members perpendicular to the skin, that support it and help keep its shape. These supports are called frames if they are open or ring-shaped or bulkheads if they are closed.

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## Types of fuselage:

There are mainly two types of fuselage

- Monocoque
- Semi Monocoque

## Monocoque

Monocoque fuselage design relies on the strength of the skin to carry the various loads. True monocoque construction does not use formers, frame assemblies, or bulkheads to give shape to the fuselage. Instead, the skin carries all fuselage stresses. Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. Thus, the biggest challenge in monocoque design is maintaining enough strength while keeping the weight within allowable limits. The advantage of a monocoque design is that it is relatively easy to manufacture. Despite this advantage, the weight penalty makes it impractical and inefficient to use monocoque construction except in relatively small areas of the fuselage that carry only limited loads. To overcome the strength-to-weight problem of monocoque design, a modification called semi monocoque design was developed.

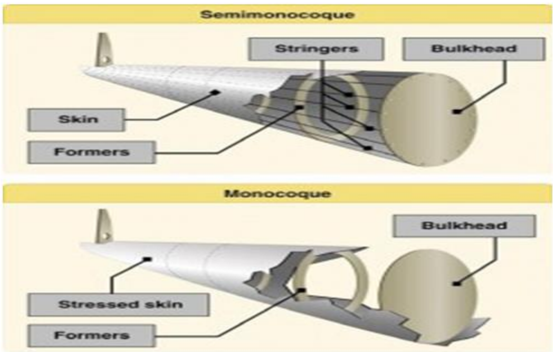


Figure1.1: Fuselage types

## Semi-monocoque

This is the preferred method of constructing an all-aluminium fuselage. First, a series of frames in the shape of the fuselage cross sections are held in position on a rigid fixture, or jig. These frames are then joined with lightweight longitudinal elements called stringers. These are in turn covered with a skin of sheet aluminium, attached by riveting or by bonding with special adhesives. The fixture is then disassembled and removed from the completed fuselage shell, which is then fitted out with wiring, controls, and interior equipment such as seats and luggage bins. Most modern large aircraft are built using this technique, but use several large sections constructed in this fashion which are then joined with fasteners to form the complete fuselage. As the accuracy of the final product is determined largely by the costly fixture, this form is suitable for series production, where a large number of identical aircraft are to be produced. Early examples of this type include the Douglas Aircraft DC-2 and DC-3 civil aircraft and the Boeing B-17 Flying Fortress. Most metal light aircraft are constructed using this process.

Both monocoque and semi-monocoque are referred to as "stressed skin" structures as all or a portion of the external load (i.e. from wings and empennage, and from discrete masses such as the engine) is taken by the surface covering. In addition, all the load from internal pressurization is carried by the external skin.

Figure1.2: fuselage structure

The semi monocoque fuselage is constructed primarily of aluminium alloy; however, on newer aircraft graphite epoxy composite material is often used. Steel and titanium are found in areas subject to high temperatures. Primary bending loads are absorbed by the "longerons," which usually extend across several points of support. The longerons are supplemented by other longitudinal members, called "stringers." Stringers are lighter in weight and are used more extensively than longerons. The vertical structural members are referred to as "bulkheads, frames, and formers." These vertical members are grouped at intervals to carry concentrated loads and at points where fittings are used to attach other units, such as the wings, engines, and stabilizers.

**Introduction to analysis:**

**Static Analysis:**

A static analysis calculates the effects of steady loading conditions on a structure, while ignoring inertia and damping effects, such as those caused by time-varying loads. A static analysis can, however, include steady inertia loads (such as gravity and rotational velocity), and time-varying loads that can be approximated as static equivalent loads (such as the static equivalent wind and seismic loads commonly defined in many building codes).

**Modal analysis:**

Modal analysis is the study of the dynamic properties of structures under vibrational excitation. Modal analysis is the field of measuring and analysing the dynamic response of structures or fluids when excited by an input.

In structural engineering, modal analysis uses a structure's overall mass and stiffness to find Although modal analysis is usually carried out by computers, it is possible to hand-calculate the period of vibration of any high-rise building by idealizing it as a fixed-ended cantilever with lumped masses. the various periods that it will naturally resonate at.

**Problem definition:**

In this project we are going to do static and modal analysis of twin seater fuselage. Static Analysis:
Static analysis is used to determine displacements, stresses, etc. under static loading conditions. in static analysis we are going to calculate the displacement and stresses by using ANSYS.

**Modal Analysis:**

Modal analysis used to calculate the natural frequencies and mode shapes of a structure.
We are doing this static and modal analysis of twin seater fuselage.

Figure1.4: Fuselage

**Dimensions of fuselage:**

Fuselage length : 2 meters
Skin thickness: 1.2 mm or 0.0012 meters
Longerons cross sectional area: 120mm

**Material properties:**

Youngs modulus: 70×109
Poisons ratio: 0.3
Density: 2700 kg/mt3
With this dimensions create the fuselage in ansys. And then mesh the fuselage. Then apply boundary conditions on the fuselage and plot the results and deform shapes

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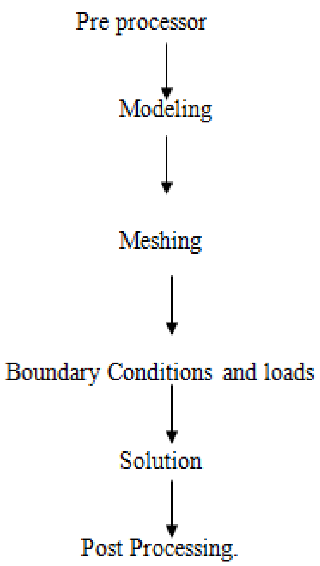
## Introduction to ANSYS

ANSYS, Inc. is an engineering simulation software provider founded by software engineer john swanson. It develops general purpose finite element analysis and computational fluid dynamics software. While ANSYS has a developed a range of computer aided engineering(CAE) products, it is perhaps best known for its ANSYS Mechanical and ANSYS Multi physics products.

ANSYS Mechanical and ANSYS Multi physics software are non exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non- linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

## ANSYS Simulation Process:




## 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 aluminum 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 i.e. hermetic.

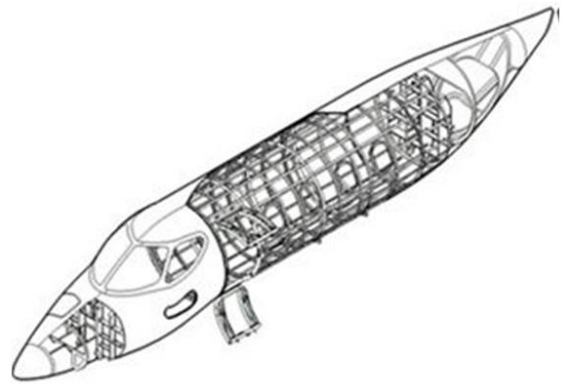


Figure2.1: fuselage structure

## Semi monocoque construction

Semi monocoque fuselage design usually uses combination of longerons, 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 longerons which are supplemented by other longitudinal members known as stringers. Stringers are smaller and lighter than longerons. They provide rigidity to the fuselage in order to give shape and attachment to the skin. Stringer and longerons 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,

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such as those at wing, landing gear, and tail surface attach points. Frames are used primarily to maintain the shape of Latest Trends on Theoretical and Applied Mechanics, Fluid Mechanics and Heat & Mass Transfer 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.

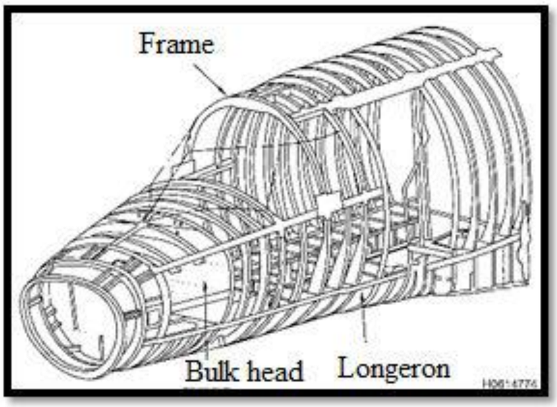


Figure 2.2: Semi-monocoque construction

### Discrete skin thicknesses

Aluminum sheet is normally supplied from their rolling mill to the airframer in particular thickness gauges To allow for this type of construction in the absence of machining, the design variables are updated in discrete values. Using this method, the "optimal" value for the skin thickness may actually exist somewhere between the discrete values supplied by the designer. This presents a problem for convergence as the solution can flip-flop

### Longeron design

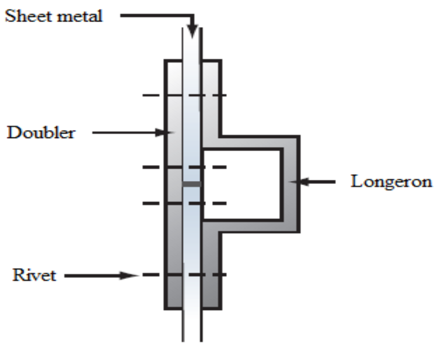


Figure2.3: longeron

In aircraft construction, a longeron or stringer or stiffener is a thin strip of material, to which the skin of the aircraft is fastened. In the fuselage, stringers are attached to frames and run the longitudinal direction of the aircraft. They are primarily responsible for transferring the aerodynamic loads acting on the skin onto the frames

Sometimes the terms "longeron" and "stringer" are used interchangeably. Historically, though, there is a subtle difference between the two terms. If the longitudinal members in a fuselage are few in number and run all along the fuselage length, then they are called "longerons". The longeron system also requires that the fuselage frames be closely spaced. Three methods for stringer design have been devised.

## METHODOLOGY

### Static analysis:

### Pre processor:

### Fuselage properties:

Fuselage dimensions
Fuselage length: 2 meters
Skin thickness: 1.2 mm or 0.0012 meters
Longerons cross sectional area: 120mm

### Material properties

Young's modulus: 70×109 n/m2 .
Poisons ratio: 0.3
Density: 2700 kg/m3

### Load

1000N
To check the strength of the fuselage and conclude the better model we have to apply some load and survey about 3 models so we have selected 1000N

### Set Preferences in ANSYS:

### Main Menu > Preferences

In the Preferences for GUI Filtering dialog box, click on the box next to "Structural" so that a tick mark appears in the box. From now on, only the menu options valid for structural problems will be made

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available. We are selected structural because the static analysis and modal analysis are subjected to structural problem

**Element type**
**SHELL: SHELL63l**

SHELL63 has both bending and membrane capabilities. Both in-plane and normal loads are permitted. The element has six degrees of freedom at each node: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z-axes. Stress stiffening and large deflection capabilities are included. A consistent tangent stiffness matrix option is available for use in large deflection analyses.

**Modeling:**

To model fuselage with Skin thickness 1.2 mm or 0.0012 meters, Longerons cross sectional area 120mm, Fuselage length 2 meters go to modeling> create> key pionts> an active CS give key points (0,0,0), (0,0,2) ok. Then go to modeling> create> lines>lines>straight lines select key points click ok. Then go to modeling> create> lines>arcs>full circle> click at(0,0,0) point and give radius as 0.3click ok. Then to create cross sectional areas of longerons go to modeling> create> areas>circle>solid circle and give wp x =0.2938196128, wp y = 0, radius = 0.006180387232, click ok. One cross sectional area has been created. Then to create cross sectional areas of 2nd longeron go to modeling> create> areas>circle>solid circle and give wp x = -0.2938196128, wp y = 0, radius = 0.006180387232, click ok. Cross sectional area of 2nd longeron has been created.

Then extrude the full circle and solid circle with 2 meters length in Z- direction. To extrude circle modeling> operate> extrude>lines>lines along lines select circle lines click ok then select 2meters extrude lines click ok. Then to extrude stringer area go to modeling> operate> extrude>by xyz offset select stringer cross sectional areas click apply give z offset as 2 click ok. Then merge key points, to merge key points write “nummrg,all” in ansys command prompt and enter. The solid model is shown in figure 3.1.1


Figure 3.1.1: solid model

**Meshing:**

After completing modeling we have to mesh the surface and stringers. because to solve this problem To mesh surface go to meshing> mesh tool, select smart size click course set it as 8 click close. Then go to meshing> mesh> areas> free, select surface click ok. Then go to meshing> mesh> volumes> free, select stringers click ok. meshed model is shown in figure:3.2

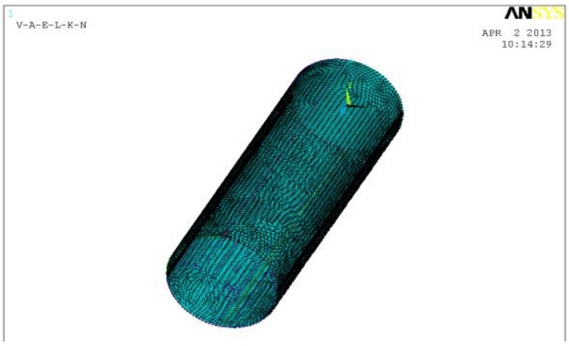


Figure3.1.2: meshed fuselage model

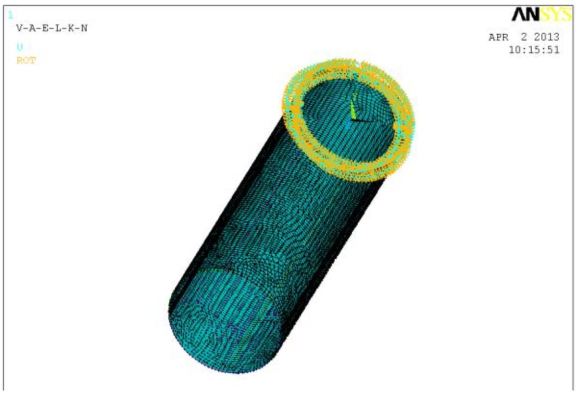


Figure3.1.3: loads

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## RESULTS

### Static analysis results:

Here we are applied the 1000N m load on fuselage in three cases that is fuselage with 2 longerons and 4 longerons and 8 longerons

- Structural displacement of fuselage with 2 longerons by applying the 1000N m load: 0.013853mt
- Structural displacement of fuselage with 2 longerons by applying the 1000N m load: 0.010651
- Structural displacement of fuselage with 2 longerons by applying the 1000N m load: 0.006223mt

When compare with number of stringers the displacement of fuselage with 4 longerons is less than the fuselage with 2 longerons. And the displacement of fuselage with 8 longerons is less than the fuselage with 4 longerons.

### Deflection to weight ratio

By comparing the deflection and weight of the fuselage we can conclude that which is the better modal from fuselage with 2longerons and 4longerons and 8longerons.

Weight of the fuselage= volume of fuselage ×density.

Volume of fuselage= cross sectional area ×length.

Fuselage cross sectional area with 2 stringers =2×3.1459×0.3×0.0012+0.00012×2=2.505048×10-3

Length of the fuselage=2

Volume of the fuselage=5.010096×10-3m3

weight of the fuselage=volume ×density=5.010096×10-3×2700=13.52kg

deflection of the fuselage=0.013853mt

Deflection to weight ratio for 2 longerons=0.013853/13.52kg=1.024630×10-3

Deflection to weight ratio for 4 longerons=0.7183×10-3

Deflection to weight ratio for 8 longerons=0.3573303×10-3

By observing above values we can say that the deflection to weight ratio has been decreased when we increase the longerons.

### Modal analysis results:

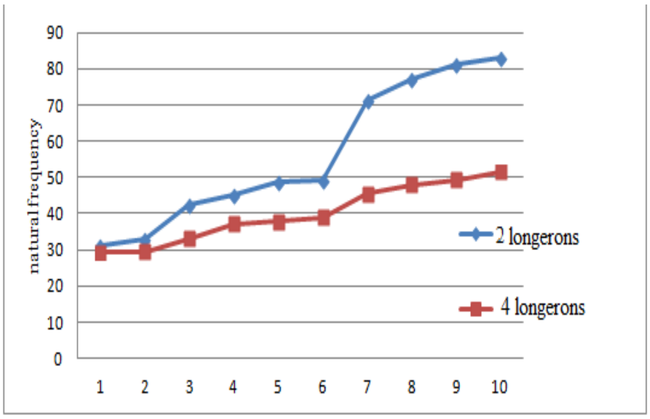
Here we found 10 mode shapes and frequencies for fuselage with 2longerons and 4longerons.

### Frequencies of fuselages

| s. no. | Natural frequencies of 2 longeron fuselage | Natural frequencies of 4 longeron fuselage |
|---|---|---|
| 1 | 31.109 | 29.315 |
| 2 | 32.896 | 29.522 |
| 3 | 42.555 | 33.144 |
| 4 | 45.373 | 37.094 |
| 5 | 48.934 | 37.947 |
| 6 | 49.199 | 38.991 |
| 7 | 71.171 | 45.614 |
| 8 | 77.227 | 47.955 |
| 9 | 81.453 | 49.306 |
| 10 | 82.884 | 51.483 |

table4.1: natural frequencies

By comparing above results, the natural frequency of fuselage with 4 longerons is less than the natural frequency of fuselage with 2 longerons.




Graph4.1: natural frequency

By observing the above graph we can say that the natural frequencies of fuselage with 4longerons is less than the natural frequencies of fuselage with 8longerons.

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## CONCLUSION

The static analysis of fuselage with 2 longerons and 4 longerons and 8 longerons are taking place. Model analysis of fuselage with 2 longerons and 4 longerons are done.

It is observed that in static analysis deflection in y-direction more than the other direction. In the deflection to weight ratio the ratio of the 4 longerons is less than compare to 2 longerons and also observed that 8 longerons deflection ratio is less than the 4 longerons.

It is also observed that the deflection to weight ratio of the fuselage with 4longerons is less than compare to fuselage with 2longerons and also observed the deflection to weight ratio of the fuselage with 8longerons is less than the fuselage with 4 longerons.

By observing this deflection and the weight to deflection ratio we can conclude that the fuselage with 8 longerons is better than other 2 models which are having 2and 4 longerons because in this fuselage we increased number of longerons from 4 to 8, but the weight has been increased less but deflection has been decreased very much.

In the modal analysis the natural frequencies of the fuselage with 4longerons is less compare to the natural frequencies of the fuselage with 2longerons

Frequencies are more in 2 longerons compare to 4 longerons.

And by observing the natural frequencies of fuselage the natural frequency is increasing to each from 1st set to 10th set of frequencies.

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