Modelling and Analysis of Fuselage

G. Raju¹*, V. Suresh¹, T. Ramesh¹, V. Hathiram¹

¹Asst Professor, Dept of Mech Engg, HolyMary Institute of Engineering and Tecnology and Science, Hyderabad
*Corresponding author E-Mail ID: raju.guduri@gmail.com.

ABSTRACT

Aircraft is a complex structure, but a very efficient man made flying machine. The fuselage is the main body of the machine, customarily streamlined in form. It usually contains control equipment, and space for passengers and cargo. In this project we mentioned how the present design of fuselage has evolved from truss and monocoque structures. We also mentioned the advantages and disadvantages of truss and monocoque type fuselages. The main objective of this project is to arrive at an optimum design of a semi-monocoque fuselage. In this semi-monocoque structure we used different structural elements and uses of all these elements are mentioned. We are attempting to present an insight into the design aspects involved in the modeling of a fuselage structure. Step by step procedure involved in modeling and analyzing the fuselage is mentioned. The modeling is done with the aid of software package CATIA V5 to generate solid model. CATIA is most advanced tool for the modeling of aerospace components. By this tool any complex designs can be generated easily. Stress analysis is done using ANSYS Mechanical APDL. ANSYS is advanced CAD/CAM software that deals with the industrial concepts of Structures, Mechanics & CFD.

Keywords: AIRCRAFT, CATIA V5, ANSYS, CAD/CAM.

1. INTRODUCTION

The function of the fuselage of an aircraft is to transmit and resist the applied loads provide an aerodynamic shape and to protect the payload and systems of the aircraft. The fuselage supports major concentrated loads such as wing and tail plane reactions, undercarriage reactions and inertia forces. It is the role of the designer to manage these loads whilst considering the impact of the design on aspects such as weight. Weight optimization of the fuselage structure is an important phase of the design process as it impacts the performance of the aircraft. By optimizing the specific rigidity of the fuselage, weight can be reduced and thus payload or fuel volume may increase.

The fuselage is the component of an aircraft that provides the payload containment and the structural connection for the wing and the empennage (tail assembly). The fuselage is the mounting structure for the wing and tail surfaces that provides stability as well as the means of introducing pitch and yaw control to the aircraft. For some aircraft like fighter aircrafts, the fuselage houses the engine or engines. The nose or tail gear and the main landing gear are often attached to the fuselage structure

1.1 Fuselage

The fuselage (pronounced from the French fuselé "spindle-shaped") 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.

Fuselages are split into three separate segments (front, mid, and rear). Total fuselage length is the sum of the parameters front-fuse-length, mid-fuse-length, and rear-fuse-length. This is shown in the fig 1.1

![Fig 1. Fuselage Segments](image)

The mid-segment is defined as a parallel tube of constant cross-section (not necessarily circular). It has an external width given by fuse-width, and its external depth is the product of fuse-depth/width (default value = 1) and fuse-width. Several choices for the shape of the cross-section are provided by the parameter fuse-x-section-type.

Arbitrary shapes can be assigned to the front and rear fuselage segments. These are the shapes seen in plan and elevation in 3-view drawings. Whenever you change the dimensions of a fuselage segment, the corresponding shapes are automatically scaled ('rubberized') to match the new length, width, or depth.

Each segment of fuselage has several segments like stringers, chord, skin, longerons etc, as shown in the fig 1.2. Stringers are thin strip of material to which the skin of aircraft is fastened. In the fig 1.2, stringers are spaced six to seven inches apart, span the length of each section. Chords are fastened to the stringers. Thirty nine to sixty six aluminum ribs are spaced nearly 20 inches apart from the nose of plane to tail and form the cylindrical skeleton of the fuselage. Main frame connects one section to the other.
The fuselage 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 supports it and helps keep its shape. These supports are called frames if they are open or ring shaped, or bulkheads if they are closed.

Disturbances in the perfect cylindrical shell, such as doors and windows, are called cutouts. They are usually unsuitable to carry many of the loads that are present on the surrounding structure. The direct load paths are interrupted and as a result the structure around the cut-out must be reinforced to maintain the required strength.

2. FEM

The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements. The simple equations that model these finite elements are then assembled into a larger system of equations that models the entire problem. FEM then
uses variational methods from the calculus of variations to approximate a solution by minimizing an associated error function.

3. CREATING THE MODEL

The model is drawn in 1D, 2D or 3D space in the appropriate units (M, mm, in, etc.). The model maybe created in the pre-processor, or it can be imported from another CAD drafting package via a neutral file format (IGES, STEP, ACIS, Para solid, DXF, etc.). If model is drawn in mm for example and the material properties are defined in SI units, then the results will be out of scale by factors of The same units should be applied in all directions, otherwise results will be difficult to interpret, or in extreme cases the results will not show up mistakes made during the loading and restraining of the model.

![Fig 3. Model assembly of the fuselage using ANSYS](image)

3.1 Assigning Properties

Material properties (Young’s modulus, Poisson’s ratio, the density, & if applicable, coefficients of expansion, friction, thermal conductivity, damping effect, specific heat etc.) will have to be defined. In addition element properties may need to be set. If 2D elements are being used, the thickness property is required. 1D-beam elements require area. We are take two materials for doing the analysis on fuselage .they are titanium and aluminium .

<table>
<thead>
<tr>
<th>Structural</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Young's Modulus</td>
<td>7.1e+010 pa</td>
</tr>
<tr>
<td>Poisson's Ratio</td>
<td>0.33</td>
</tr>
<tr>
<td>Density</td>
<td>2770 kg m^-3</td>
</tr>
<tr>
<td>Thermal Expansion</td>
<td>2.3e-005 C^-1</td>
</tr>
</tbody>
</table>
3.2 Applying a Mesh

Mesh generation is the process of dividing the analysis continuum into a number of discrete parts or finite elements. The finer the mesh, the better are the results, but longer is the analysis time. Therefore, compromise between accuracy & solution speed is usually made. The mesh may be created manually, as the one on the right, or generated automatically like the one below. In the manually created mesh, you will notice that the elements are smaller at the joint. This is known as mesh refinement, and it enables the stresses to be captured at the geometric discontinuity (the junction). Any mesh is usually applied to the model by simply selecting the mesh command on the pre-processor list of the GUI.

![Mesh of the fuselage structure using ANSYS model](image-url)
3.3 Apply Loads

Some type of load is usually applied to the analysis model. The loading may be in the form of a point load, a pressure or a displacement in a stress (displacement) analysis. The loads may be applied to a point, an edge, a surface or an even a complete body. The loads should be in the same units as the model geometry & material properties specified.

![Figure8.3: loading conditions in ansys](image)

**Solution**

The FE solver can be logically divided into three main parts, the presolver. The mathematical-engine & the post-solver. The pre-solver reads in the model created by the pre-processor and formulates the mathematical representation of the model. All parameters defined in the pre-processing stage are used to do this, so if you left something out, chances are the presolver will complain & cancel the call to the mathematical engine. If the model is correct the solver proceeds to form the element-stiffness matrix for the problem & calls the mathematical-engine which calculates the result (displacement, temperatures, pressures, etc.) The results are returned to the solver & the post-solver to calculate strains, stresses, heat fluxes, velocities, etc. for each node within the component or continuum. All these results are sent to a result file.

4. ANALYSIS PROCEDURE

Here the results of the analysis are read & interpreted. They can be presented in the form of a table, contour plot, deformed shape of the component or the mode shapes and natural frequencies if frequency analysis is involved. Other results are available for fluids, thermal and electrical analysis types. Most post-processors provide an animation service, which produces animation & brings your model to life.

All postprocessors now include the calculation of stress & strains in any of the x, y or z directions, or indeed in direction at an angle to the coordinate axes. The principal stresses and strains may also be plotted, or if required the yield stresses and strains according to the main theories of failure (Von-misses, St.Venant, Tresca etc.). Other information such as the strain energy, plastic strain and creep strain may be obtained for certain types of analyses. In the analysis we find out the total deformation, equivalent stress, and maximum shear stress.
Fig 5. Total deformation condition on the fuselage structure - ANSYS

Fig 6. Maximum shear stress condition on the fuselage - ANSYS

Fig 7. Equivalent Stress condition on fuselage using ANSYS
5. RESULTS AND DISCUSSIONS

<table>
<thead>
<tr>
<th></th>
<th>For Aluminium</th>
<th>For Titanium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total deformation</td>
<td>0.68139</td>
<td>0.23157</td>
</tr>
<tr>
<td>Maximum shear stress</td>
<td>0.2929e7</td>
<td>2.2846e7</td>
</tr>
<tr>
<td>Equivalent stress</td>
<td>4.515e7</td>
<td>4.5443e7</td>
</tr>
</tbody>
</table>

Table:1. Results And Analysis

The main objective of our projects to deal with the design and analysis of fuselage The designing is done in 3D modeling by CATIA software and analysis by applying various loads upon at by using analysis. In the analysis of fuselage we are taking two materials they are aluminium and titanium the analysis of these two materials the aluminium shows best results that’s why we can suggest aluminium is better to use, because the titanium also can be used but cast is more than three time of aluimium.

6. CONCLUSION

1) The basic fuselage structure is essentially a single cell thin-walled tube with many transverse frames (or rings or bulkheads) and longitudinal stringers to provide a combined structure which can absorb and transmit the concentrated and distributed loads safely and efficiently.
2) The fuselage of an aircraft must be heated, ventilated and pressurized to provide the necessary safety to the passengers.
3) Modeling of the fuselage with structural arrangements is done by using CATIA V5 R20.
4) CATIA is a powerful tool to learn in depth designing of aerospace interior and exterior components and analyze aero structural parts.
5) In fuselages, the skin in curved. The curves sheet panels have a higher critical compressive buckling stress than flat panels of the same size and thickness.
6) Because of high-altitude flight, the fuselage must withstand cabin pressurization loads. To handle these internal pressures efficiently, requires a circular cross-section fuselage or a combination of circular elements
7) Total deformation, stress and Strain analysis are done using ANSYS WORK BENCH.
8) The fuselage is subjected to large concentrated forces such as the wing reactions, landing gear reactions, empennage reactions, et

REFERENCES