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Design and Static Stress Analysis of Fuselage Structure for a Military Transport Aircraft

Ms.Srilaxmi
Assistant Professor,
Dept. of Aeronautical Engineering
MLRIT, Hyderbad.

Olem Prashanth Rao
M.Tech Student,
Dept. of Aeronautical Engineering
MLRIT, Hyderbad.

Dr. M Satyanarayana Gupta
Professor & HoD,
Dept. of Aeronautical Engineering
MLRIT, Hyderbad.

ABSTRACT

This project deals with the Design and static stress analysis of fuselage structure for a military transport aircraft. The aim of this project work is to design and analyze the stringers, longerons, frames and bulkheads of a transport aircraft for the stresses and displacements due to the applied loads. For this project work deals with the comparative study on particular transport aircraft.

The optimum design parameters for a transport aircraft are suitably selected based on the fuselage modal was design using the CATIA-V5 R19 software, which is developed by Dassault systems and is very famous for its 3D modeling capabilities.

The major fuselage design parameters were explained in detail and the fuselage configuration has been described. Different types of loads acting on the aircrafts fuselage are determined and the moments, displacements, etc., are also determined. The fuselage structure was also explained and functions of each component and their arrangement are also studied. The methodology of finite element method and the detailed description about various FEM tools have been studied and implemented in this work. The procedure of finite element method was followed to analyze the model. The analyzing part of this project is done using the NASTRAN-PATRAN package and the results were discussed.

Keywords: ***fuselage structures, FE modeling, linear static analysis, Catia V5 R 19, MSC Nastran Patran.***

Introduction

A fuselage is the body of an aircraft which houses passengers, cargo, and usually the pilots of the craft as well. Fuselages vary widely in shape, size, and style, depending on the purpose of the aircraft that they are attached to. They are hollowed out to reduce the overall weight of the craft, and they provide the structural framework to which the wings, tail, and other features are attached. If you have ever flown in an aircraft, chances are that you have been inside a fuselage.

The word comes from the French fuselé, which means “spindle shaped” a reference to the classic cylindrical fuselage used to produce commercial aircraft like the Boeing Company’s 7-series. Construction of a fuselage starts with assembling a framework which accounts for specific needs in the plane design, and then covering the framework with a lightweight metallic skin. The plane may be insulated to help control the temperature inside, and then the inside of the fuselage is fitted out in accordance with the plane's purpose.

In a passenger plane, for example, the fuselage is divided into a cargo section and a passenger section. The passenger section is fitted with seats, temperature control devices, and other equipment needed to make the flight more comfortable, such as bathrooms and kitchens for preparing meals. On a cargo plane, the inside is usually less finished, since the plane is only used for packages, not for living organisms.

The aerodynamics of a fuselage can vary. For example, on a fighter jet, the fuselage is made extremely sleek, to allow the plane to fly more quickly. Smaller personal planes might have less sleek fuselages since speed is not as important. Some commercial aircraft have very bulky fuselages with projections to accommodate the pilots and first class passengers, while others are more streamlined since they are designed for quick commutes.

Figure1.1 FUSELAGE

When designing an aircraft, it's all about finding the optimal proportion of the weight of the vehicle and payload. It needs to be strong and stiff enough to withstand the exceptional circumstances in which it has to operate. Durability is an important factor. Also, if a part fails, it doesn't necessarily result in failure of the whole aircraft.

The main sections of an aircraft, the fuselage, tail and wing, determine its external shape. The load bearing members of these main sections, those subjected to major forces, are called the airframe. The airframe is what remains if all equipment and systems are stripped away.

Sheet metals can usually only support tension. But if the sheet is folded, it suddenly does have the ability to carry compressive loads. Stiffeners are used for that. A section of skin, combined with stiffeners, called stringers, is termed a thin-walled structure. A very good way of using sheet metal skin is in a thin-walled cylinder, called a monocoque structure. A cylinder with holes, for doors and such, is called a "Semi-monocoque structure".

An extruded stiffener is manufactured by squeezing hot, viscous material through an opening of a certain shape. It can usually be recognized by the fact that the thickness is not consistent, especially in the corners.

This is relatively expensive, compared to stiffeners made from sheet metal. From sheet metal it is not possible to make complicated stiffeners. Thin sheet metal can be rolled or drawn.

Usually stiffeners are attached to the skin. In an integral structure, the skin and stiffeners have been manufactured from one solid block of material. It is also possible to make some kind of a sandwich structure, in which the skin has a high stiffness due to its special structure.

FUSELAGE CONFIGURATION:

The fuselage is the main structure, or body, of the aircraft. It provides space for personnel, cargo, controls, and most of the accessories. The power plant, wings, stabilizers, and landing gear are attached to it There are two general types of fuselage construction they are

1. Welded steel truss and
2. Monocoque designs.

Truss Type

A truss is a rigid framework made up of members, such as beams, struts, and bars to resist deformation by applied loads. The truss-framed fuselage is generally covered with fabric. The truss-type fuselage frame is usually constructed of steel tubing welded together in such a manner that all members of the truss can carry both tension and compression loads. In some aircraft, principally the light, single engine models, truss fuselage frames may be constructed of aluminum alloy and may be riveted or bolted into one piece, with cross-bracing achieved by using solid rods or tubes.
The welded steel truss was used in smaller Navy aircraft, and it is still being used in some helicopters.

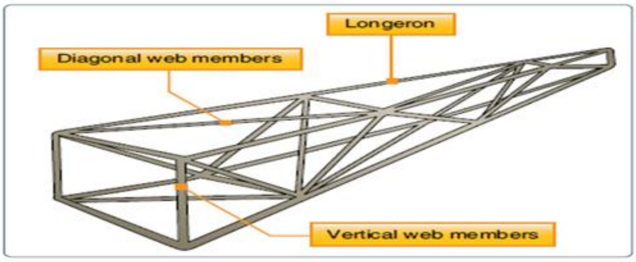

Figure 2.1 Truss element

Monocoque Type

The monocoque design relies largely on the strength of the skin, or covering, to carry various loads. The monocoque design may be divided into three classes:
a. True monocoque,
b. Semi-monocoque,
c. Reinforced shell

True monocoque

The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. However, the skin carries the primary stresses. Since no bracing members are present, the skin must be strong enough to keep the fuselage rigid. The biggest problem in monocoque construction is maintaining enough strength while keeping the weight within limits.

Different portions of the same fuselage may belong to either of the two classes, but most modern aircraft are considered to be of Semi-monocoque type construction. The true monocoque construction uses formers, frame assemblies, and bulkheads to give shape to the fuselage. The heaviest of these structural members are located at intervals to carry concentrated loads and at points where fittings are used to attach other units such as wings, power plants, and stabilizers. Since no other bracing members are present, the skin must carry the primary stresses and keep the fuselage rigid. Thus, the biggest problem involved in monocoque construction is maintaining enough strength while keeping the weight within allowable limits.

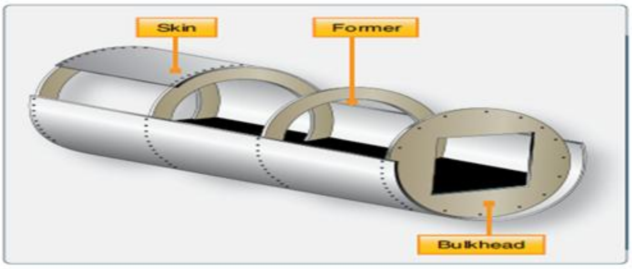

Figure 2.1.(b) Monocoque structure

Semi-monocoque Type:

Semi-monocoque design overcomes the strength-to-weight problem of monocoque construction. In addition to having formers, frame assemblies, and bulkheads, the Semi-monocoque construction has the skin reinforced by longitudinal members.

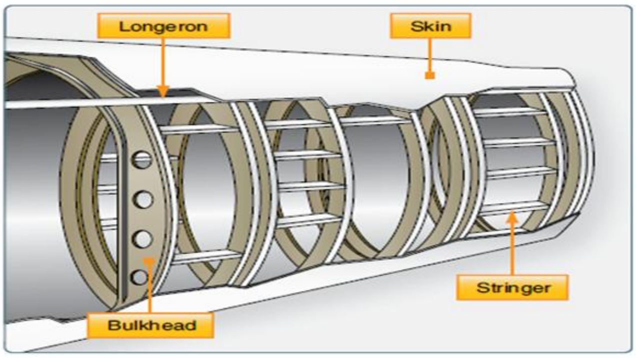

Figure2.1(c): Semi-Monocoque structure

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 Semi-monocoque 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 extrusions or formed aluminum. 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

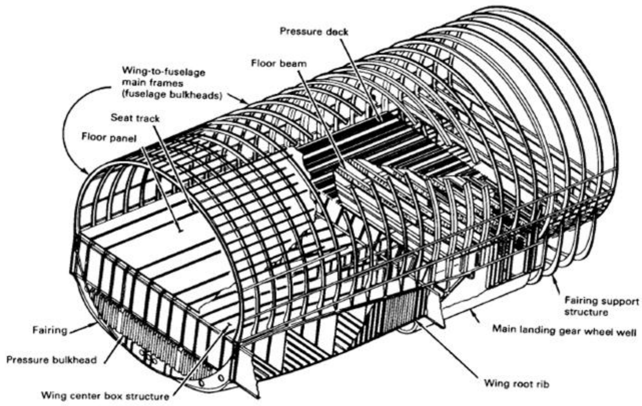

Figure 2.1.(d). Simple semi-monocoque structures

The reinforced shell type:

The reinforced shell has the skin reinforced by a complete framework of structural members. Different portions of the same fuselage may belong to any one of the three classes. Most are considered to be of Semi-monocoque-type construction.

The Semi-monocoque fuselage is constructed primarily of aluminum alloy, although steel and titanium are found in high-temperature areas. Primary bending loads are taken by the longerons, which usually extend across several points of support. The longerons are supplemented by other longitudinal Members known as stringers, stringers are more numerous and lightweight than longerons. The vertical structural members are referred to as bulkheads, frames, and formers.

The heavier vertical members are located at intervals to allow for concentrated loads. These members are also found at points where fittings are used to attach other units, such as the wings and stabilizers. The stringers are smaller and lighter than longerons and serve as fill-ins. They have some rigidity but are chiefly used for giving shape and for attachment of skin. The strong, heavy longerons hold the bulkheads and formers. The bulkheads and formers hold the stringers. All of these joined together to form a rigid fuselage framework. Stringers and longerons prevent tension and compression stresses from bending the fuselage. The skin is attached to the longerons, bulkheads, and other structural members and carries part of the load.

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The fuselage skin thickness varies with the load carried and the stresses sustained at particular location.

There are a number of advantages in using the Semi-monocoque fuselage.

The bulkhead, frames, stringers, and longerons aid in the design and construction of a streamlined fuselage. They add to the strength and rigidity of the structure. The main advantage of the Semimonocoque construction is that it depends on many structural members for strength and rigidity. Because of its stressed skin construction, a Semimonocoque fuselage can withstand damage and still be strong enough to hold together.

FUSELAGE STRUCTURAL MEMBERS

Airframe

The skin of aircraft can also be made from a variety of materials, ranging from impregnated fabric to plywood, aluminum, or composites. Under the skin and attached to the structural fuselage are the many components that support airframe function.

Stringers

Stringers are also used in the semi monocoque 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 extrusions or formed aluminum. 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.

Longerons

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.

Bulkheads:

Bulkheads are provides at point of introduction of concentrated forces such as those from the wings tail surface and landing gear. The bulkheads structure is quite substantial and serves to distribute the applied load into the fuselage skin.

Figure 4.1: Forward bulkhead

Frames:

Fuselage frames perform many diverse functions such as, support shell (fuselage skin stringer panel) ,distribute concentrated loads ,fail-safe(crack stoppers).frames also acts as a circumferential tear strips to ensure fail-safe design against skin crack propagation.

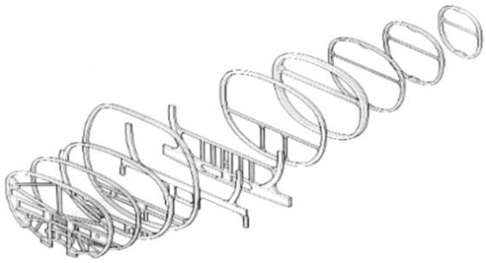

Figure 4.2: Frames

LOADS ACTING ON FUSELAGE COMPONENTS

Aircraft structural members are designed to carry a load or to resist stress. In designing an aircraft, every square inch of wing and fuselage, every rib, spar, and even each metal fitting must be considered in relation to the physical characteristics of the material of which it is made. Every part of the aircraft must be planned to carry the load to be imposed upon it.

The determination of such loads is called stress analysis. Although planning the design is not the function of the aircraft technician, it is, nevertheless, important that the technician understand and appreciate the stresses involved in order to avoid changes in the original design through improper repairs.

The term “stress” is often used interchangeably with the word “strain.” While related, they are not the same thing. External loads or forces cause stress. Stress is a material’s internal resistance, or counterforce, that opposes deformation.

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The degree of deformation of a material is strain. When a material is subjected to a load or force, that material is deformed, regardless of how strong the material is or how light the load is.

There are five major stresses to which all aircraft are subjected:

- Tension
- Compression
- Torsion
- Shear
- Bending

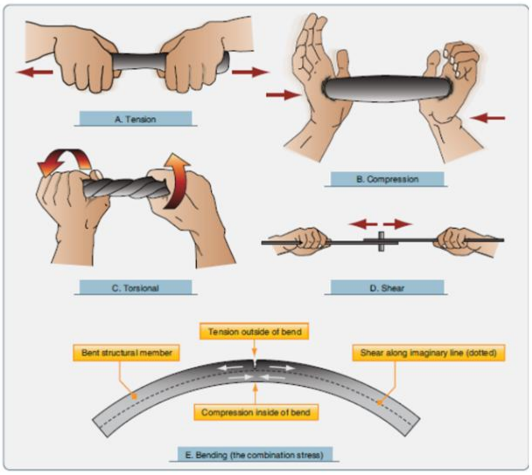

Figure5.1. Stress acting on an Aircraft

During flight, any maneuver that causes acceleration or deceleration increases the forces and stresses on the wings and fuselage.

FINITE ELEMENT METHOD

FE ANALYSIS OF THE CUTOUT SECTION

For analysis NASTRAN and PATRAN software are used. These softwares were well known as Finite Element Analysis. The finite element method is a numerical technique for solving engineering problems. It is most powerful analysis tool used to solve simple to complicated problems.

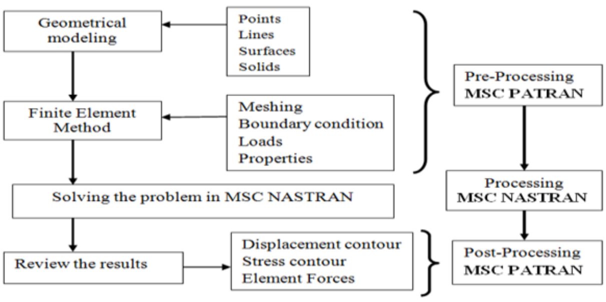

figure 7.1Steps involved in Finite Element Analysis

The pre-processing stage involves the preparation of nodal co-ordinates & its connectivity, meshing the model, load & boundary conditions and material information for finite element models carried in MSC PATRAN described in the figure above.

Applications of Finite Element tools:

1.Static Analysis: deflections, stress, strains, forces and energies.
2.Dynamic Analysis: frequencies, deflections, stress, strain, forces and energies.
3.Heat Transfer Analysis: Temperature, heat fluxes, thermal gradients and heat flow from convection.
4.Fluid Analysis: Pressure, gas temperature, convection coefficients and velocities
5.Other than these electromagnetic analysis and electric current analysis can also be easily carried out.
6.In the aerospace industry the following types of finite element analysis is common: static analysis, dynamic analysis, aerodynamics, transient dynamics, heat transfer, fracture mechanics, creep and plasticity analysis, composite materials, aero elasticity.
7.In the automobile industry; static analysis, dynamic analysis, heat transfer mechanics, fracture mechanics etc is carried out.

Advantages and Disadvantages of finite element tools:

Advantages:

1.Complex geometry can be analyzed very easily using the finite element method
2.Complex analysis such as vibrations, non linear, heat transfer and fluid Analysis can easily be conducted.
3.Complex boundary conditions can easily be represented.
4.By using the finite element method it is easy to analyse non homogeneous structures.
5.Material properties such as plasticity creep and swelling can easily be accounted for.
6.Geometric effects such as large displacements, large rotations and contact conditions can also be represented
7.It has a very systematic approach that lends it to be very easily programmed on the computer
8.It is more flexible and responsive information based development process, enabling the modification of designs at later stages of development.
9.Faster return on investment due to reduced development time.

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Disadvantages:

1.Computers can only carry a limited amount of significant digits. Due to this round off errors and error accumulation are common. The method is very sensitive to the choice of finite elements.
2.It is only an appropriate technique to model a large technique with series of interconnected smaller ones.
3.Extensive data input required
4.Each element represents a strain value, which may or may not match really
5.Secondary unknowns (stress), which are calculated from primary unknowns.
6.Many resources such as disk space time are required.

RESULTS:

PARTS	MATERIAL	SECTION	THIKNESS	VON MISES	DISPLACEMENT
BULKHEADS AND FREAMES	Al 7075-T6	C-sec	3.5*8*0.5*0.5	234	362
SKIN	Al 2024-T3	Pipe	1.5	361	368
STRINGER	Al 7075-T6	Z-section	2*0.80*2*3	308	366

CONCLUSION

The primary goal of this research work to identify the action initiatives that make up and the implementation of existing fuselage design and the initiation of overall fuselage design and procedures. The aim of this project is to design an advanced for future fuselage design. Whereas in this static analysis, we can take output where ever we needed. If the proposal gets admitted surely this method will be more reliable for fuselage design as well as aircraft structural design. In the occasion of this work reported to future fuselage developments. Using different objective functions it was shown that the design of a fuselage section is sensitive to requirements from different disciplines. Optimization of fuselage structure, with the aim to be finds the optimum number of static parameters.

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