

Design and Analysis of a Fuselage Using Helical Longerons

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ABSTRACT

The objective of this paper is to design and analyze a fuselage using helical longerons. The conceptual design of fuselage structure for very light jet aircraft by using CAD and CATIA V5 software as the design tool. Specific size and performance, the number of competing designs and the commonality of features with existing light jet aircraft are factors need to be considered in the design process. This conceptual design develops the first general size and configuration for a new light jet aircraft fuselage structure.

The model of the fuselage structure is then undergoing engineering simulation programmed which is based on the finite element method. In this analysis, problems with multiple components are modeled by associating the geometry defining each component with the appropriate material model and specifying component interaction. Besides that, the load increments and convergence tolerance are continually adjusted to ensure an accurate solution is obtained. The multidisciplinary process relies on the integrated CAD software CATIA V5 for the generation of the parametric-associative geometrical and structural models.

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 resist 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 achieve aircraft stability and maneuverability, 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.

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. 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 such as Skin, Bulkheads, Stringers, Floor beams etc are called the airframe. The airframe is what remains if all equipment and systems are stripped away. Old aircrafts had skin made from impregnated linen that could hardly transmit any force at all. In most modern aircrafts, the skin plays an important role in carrying loads. Sheet metals can usually only support tension. But if the sheet is folded, it has the ability to carry compressive loads. Modern aircrafts such as Airbus A350 use skin made of composite materials such as CFRP – carbon fiber reinforced plastic.

COMPOSITE MATERIALS

Composite materials that emerged in the middle of the 20th century as a promising class of engineering materials providing new prospects for modern technology. Generally speaking any material consisting of two or more components with different properties and distinct boundaries between the components can be referred to as a composite material. Composite materials consisting of stiff and strong fibers (glass, carbon, boron etc) embedded in compatible matrix (polymer, metal, and ceramic) have emerged as engineering materials of the future in aerospace.

Due to their heterogeneous, anisotropic characteristics and non linear or inelastic behavior, engineering analysis of composite parts/structures/products demand the applications of FEM. composite materials that is under study are called “reinforced materials”. The basic components of these materials (sometimes referred to as “advanced composites”) are long and thin fibers possessing high strength and stiffness.



Fig 1.1: Conventional Composite material

Continuous fibers (the first type of fibers used in advanced composites) are made by pulling molten liquid form of fiber through 0.8-3.0 mm diameter dies and further high-speed stretching to a diameter of 3-19 μm. Usually carbon fibers have solid circular cross sections. However there exist fibers with rectangular (square or plane), triangular, and hexagonal cross sections, as well as hollow circular fibers. The mechanical characteristics and density of fibers differ for different cross section.

Overall, the properties of the composite are determined by:

- i. The properties of the fiber
- ii. The properties of the resin or matrix
- iii. The ratio of fiber to resin in the composite (Fiber Volume Fraction)
- iv. The geometry and orientation of the fiber in the composite

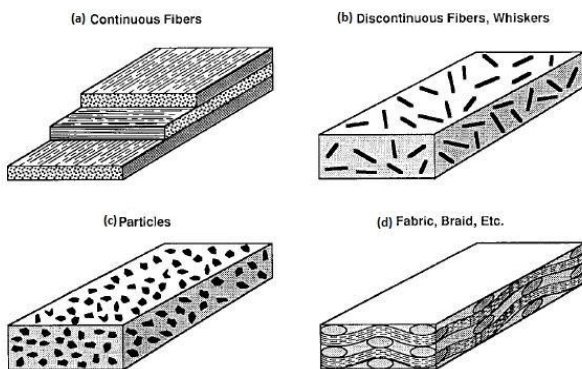


Fig 1.2: Reinforcement forms (or) Fiber orientations

DESIGN OF FUSELAGE AND MODELING DESIGN SPECIFICATIONS:

	DIMENSIONS
LENGTH OF FUSELAGE	2885 mm
DIAMETER OF FUSELAGE	1600 mm
LONGERON THICKNESS	70 mm
SKIN THICKNESS INTERNAL AND EXTERNAL	25 mm
AREA OF LONGERON	70 x70 mm

MODELLING:

ABOUT CATIA-V5 TOOL:

CATIA is one of the world’s leading high end CAD/CAM/CAE software packages. CATIA (Computer Aided Three-dimensional Interactive Application) is a multi-platform PLM/CAD/CAM/CAE commercial software suite developed by DASSAULT SYSTEMS and marketed worldwide by IBM. CATIA is written in C++ programming language.

Profile toolbar:

The commands located in this toolbar allow us to create simple geometries (rectangle, circle, line, etc...) and more complex geometries (profile, spline, etc...).



Fig. 3.1 Profile toolbar

The Profile toolbar contains many sub-toolbars. Most of these sub tool bars contain different options for creating the same geometry. For example, we can create a simple line, a line defined by two tangent points, or a line that is perpendicular to a surface.

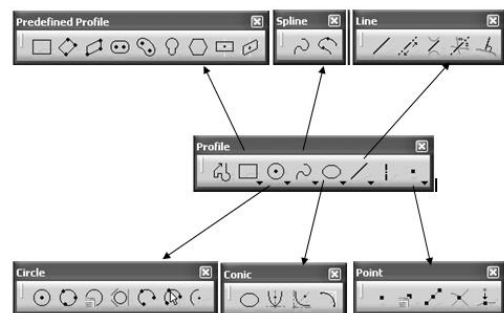


Fig. 3.2 Sub toolbars of profile toolbar

Reading from left to right, the Profile toolbar contains the following commands.

Profile:

This command allows us to create a continuous set of lines and arcs connected together.

Rectangle / Predefined Profile toolbar:

The default top command is rectangle. Stacked underneath are several different commands used to create predefined geometries.

Circle / Circle toolbar:

The default top command is circle. Stacked underneath are several different options for creating circles and arcs.

Spline / Spline toolbar:

The default top command is spline which is a curved line created by connecting a series of points.

Ellipse / Conic toolbar:

The default top command is ellipse. Stacked underneath are commands to create different conic shapes such as a hyperbola.

Line / Line toolbar:

The default top command is line. Stacked underneath are several different options for creating lines.

Axis:

An axis is used in conjunction with commands like mirror and shaft (revolve). It defines symmetry. It is a construction element so it does not become a physical part of your feature.

Point / Point toolbar:

The default top command is point. Stacked underneath are several different options for creating points..

Constraint toolbar:

Constraints can either be dimensional or geometrical. Dimensional constraints are used to constrain the length of an element, the radius or diameter of an arc or circle, and the distance or angle between elements. Geometrical constraints are used to constrain the orientation of one element relative to another. For example, two elements may be constrained to be perpendicular to each other. Other common

geometrical constraints include parallel, tangent, coincident, concentric, etc... Reading from left to right:



Fig no 3.3 Constraint toolbar

Constraints Defined in Dialog Box:

Creates geometrical and dimensional constraints between two elements.

Constraint:

Creates dimensional constraints.

Contact Constraint:

Creates a contact constraint between two elements.

Fix Together:

The fix together command groups individual entities together.

Auto Constraint:

Automatically creates dimensional constraints.

Animate Constraint:

Animates a dimensional constraint between to limits.

Edit Multi-Constraint:

This command allows you to edit all our sketch constraints in a single window.

RESULTS & DISCUSSIONS

STATIC ANALYSIS

Static analysis is used to determine displacements, stresses, etc., under static loading conditions. Both linear and nonlinear static analyses. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper-elasticity, contact surfaces, and creep.

DEFORMATION:

When a sufficient load is applied to a metal or other structural material, it will cause the material to change shape. This change in shape is called deformation. A temporary shape change that is self-reversing after the force is removed, so that the object returns to its original shape, is called elastic deformation. In other words, elastic deformation is a change in shape of a material at low stress that is recoverable after the stress is removed. This type of deformation involves

stretching of the bonds, but the atoms do not slip past each other. When the stress is sufficient to permanently deform the metal, it is called plastic deformation.

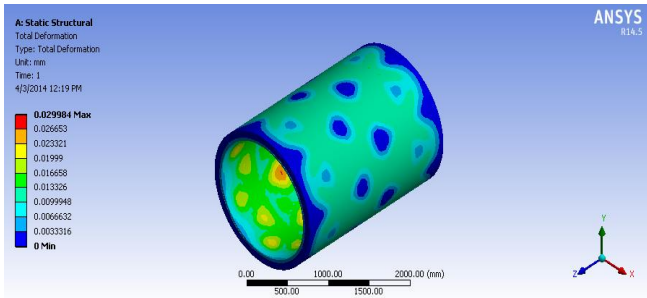


Fig. 5.1 Screenshot of Total Deformation of the fuselage

The figure shows the total deformation on the fuselage. By seeing the result we can come to an conclusion that the fuselage is successfully withstanding the default pressure load of 1 atm., which is applied inside the fuselage.

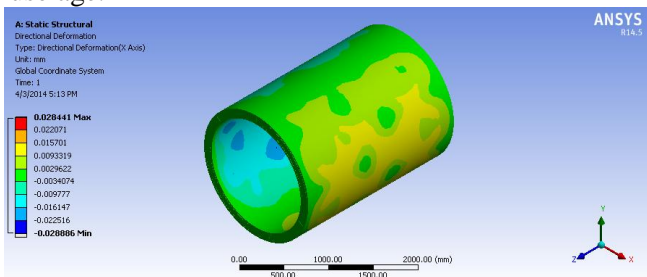


Fig. 5.2 Screenshot of Total Deformation of the fuselage(X-direction)

After applying the pressure force the deformation or the reaction force of the fuselage is shown in the above and below figures and it is clearly seen the figures that the deformation that is occurring in the each end of the direction is very minute and negotiable

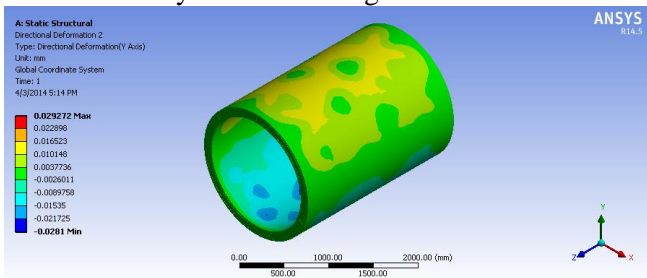


Fig. 5.3 Screenshot of Total Deformation of the fuselage(Y-direction)

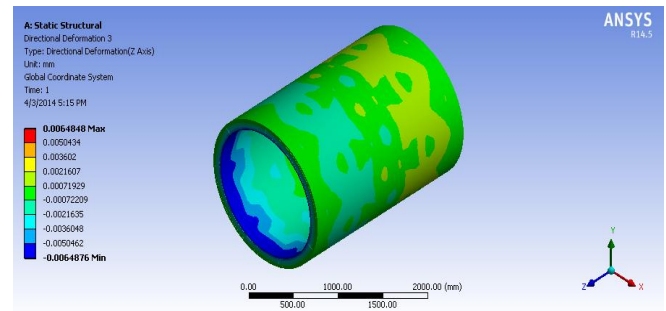


Fig. 5.4 Screenshot of Total Deformation of the fuselage(Z-direction)

At the inner skin surface the pressure force of about 1 mpa is given as it is the standard pressure of amount that should be maintained in the general airplane so that the passengers could have a easy breath as well to maintain the pressurized structure inside and after this considerations and all the time comes for the stress development on the outside of the skin ,here the skin inside is easily able to withstand the internal pressures that are applied and giving the minimal reaction forces as the deformation is very low,now lets see the topic about the stresses that are general induced since fuselage is like a pressurized capsule when ever operated the surface skin of the fuselage is stressed skin and leads to high deformations that are e to be eliminated Lets see about the stress in the next views

STRESS:

Pressure is defined as force applied on some cross sectional area. Stress is the reaction force developed inside the body because of the applied pressure. There are 2 different types of stress, shear stress and normal stress. The normal stress " σ " acts perpendicular to the selected plane. The shear stress " τ " acts parallel to the selected plane.

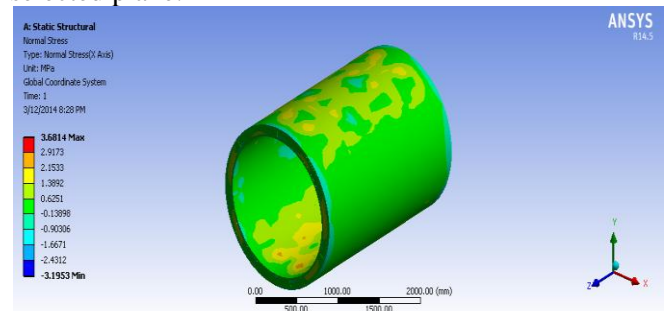


Fig. 5.5 Screenshot of NORMAL STRESS of the fuselage

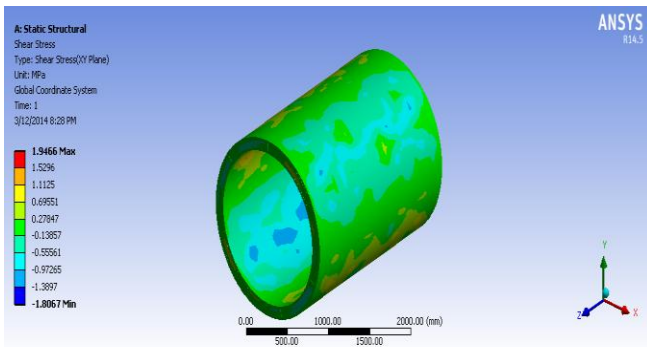


Fig. 5.6 Screenshot of SHEAR STRESS of the fuselage

observed clearly that the fuselage is having the maximum stiffness given to that the red color indicates the max stressed area and blue color indicates the minimum stressed area, here we can clearly see that the fuselage structure is stiff enough to withstand the stress on the outer surface of the skin and also will be able to control the deformations

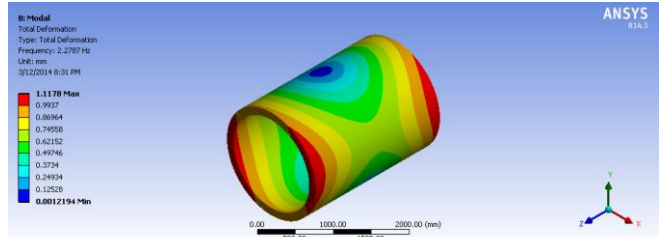


Fig. 5.9 Screenshot of DEFORMATION at the 5th MODESHAPE

MODAL ANALYSIS

Modal analysis is used to calculate the natural frequencies and mode shapes of a structure. Several mode-extraction methods are available.

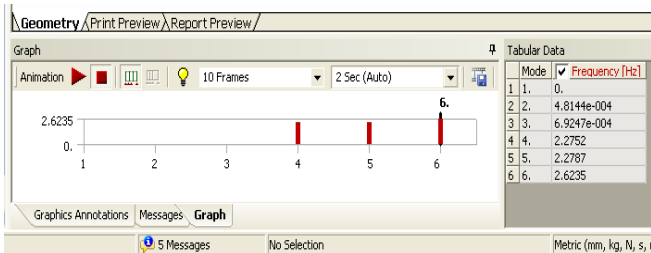


Fig. 5.7

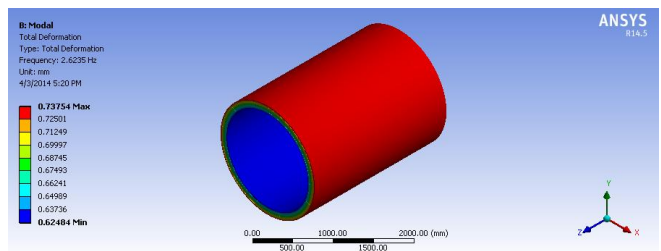


Fig. 5.10 Screenshot of DEFORMATION at the 6th MODESHAPE

The mode shapes that are shown above are attained with the natural free vibrations so the values are small and are negligible compared to all the other fuselage models

Now here in the above figure indicated the frequencies that are induced in the fuselage at static position are attained by the model analysis in ANSYS workbench and according to the results file the frequencies that are developed are very minute and very much small in such a way that they could hardly deform the fuselage in any of the manner

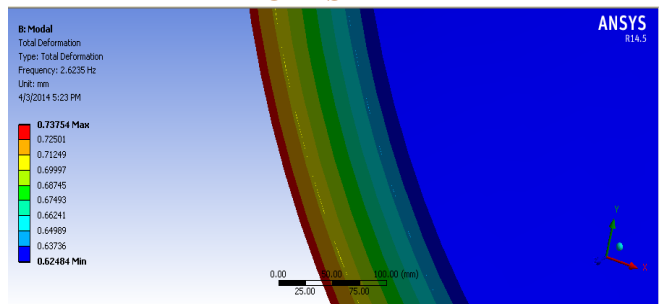


Fig. 5.11 Screenshot of DEFORMATION Along the total structure

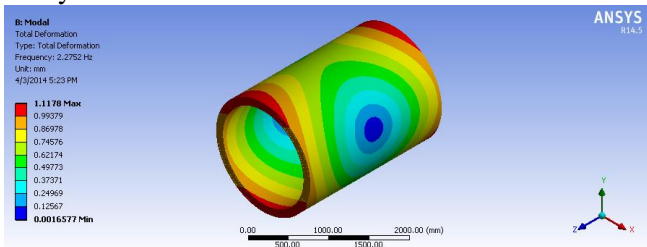


Fig. 5.8 Screenshot of DEFORMATION at the 4th MODESHAPE

Above figures indicate the stresses that are induced due to the pressure that is applied from inside, here we

In the above 2 figures the total deflections of the structure are given, now we can see to it that the pressure applied from inside to transformed to the longirons type of the panels that are arranged in between the both skins, it can be clearly said that the pressure applied on the skin from inside first transfers to the longirons that are placed inside and they in turn gets stressed and ring type of structure also are induced to escape the max stress production and to attain min deflections which will give a very high stiffness factor to the structure

CONCLUSION:

In any of the general fuselage structure the longerons would be in the longitudinal direction i.e. straight in direction, but here we have twisted those longerons in as of the helical spring type both clockwise and counter clockwise so that the use of the stiffeners, ribs and other type of the structures would be eliminated

Other thing that we have observed is the uses of this type of the fuselage structures are able with stand all basic required criteria.

The future scope of this structure is to model all the setup as on the other structures as windows, doors and etc, and will continue with the analysis part to observe that how will it react.

By removing the ring type of structures, by placing on the helical longerons we will try to develop a new type of the fuselage structure that will come into the real world from the conceptual stage.

This type of the structures will reduce the amount of weight that will be added to the whole structure with a high strength i.e a high weight to strength ratio is attained.

FUTURE SCOPE:

The structure can be so designed that frames can be eliminated. The longerons which could withstand the stresses, deformation will bear all kinds of loads. Further work can be done where cutouts for windows and doors can be made and structural analysis can be done. We will try to make the structure as strong as possible with lowest weight.

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