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DESIGN AND ANALYSIS OF A TRUSS TYPE FUSELAGE USING FEM

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ABSTRACT

This paper elucidate the CFD analysis of truss type fuselage. The fuselage is made up of welded tubular steel frame construction. In this paper fuselage geometry has been designed using a CATIA design software and analyzed using ANSYS Mechanical ADPL. The main dimensions were assumed using 2-D drawings, due to lack of original dimensions. The dimensions were extracted experimentally from an original aircraft. Computational fluid dynamic program for the horizontal tail were used for aerodynamic loads finite element method (FEM) has been used for Static structural analysis by fastened connection property among the frames. The results were found at the front part of the engine mount, next on the mid-section which offers cantilever support for the wing and landing gear and the rear section supports the horizontal and vertical stabilizers;. The displacements, Von Mises stresses, and principal stresses were found in the three sections and found satisfactory except for a small area near the connection between fuselage and wing.

1. INTRODUCTION

The name fuselage is derived from the word fuseler, which means “to streamline”. The fuselage should be streamlined and strong so that it can withstand the forces that are created in aircraft. Fuselage is an airplane main body part that supports crew and passengers. The functions of an aircraft fuselage include all of the following; holds the structure for wings and tail, structure that contains the cockpit for the pilot and structure that allow aircraft to carry cargo, passengers, and equipment.

Fuselage must be able to resists bending moments (caused due to the weight and lift from the stabilizers), torsional load (caused by control surfaces) and cabin pressurization. The popular shape of the fuselage in commercial aircraft is circular or near circular with tapered nose and tail section. Therefore to achieved airplane stability and maneuverability, airplane fuselage plays an vital role in positioning the control surfaces and stabilization surfaces in precise to produce lifting. The fuselage can be class into three basic sections which are pilot cabin, engine and tail section

Fuselage Pressurization

Fuselage constitutes the shell containing the payload which must be carried a certain distance at a specified speed. It must permit rapid loading before the flight and rapid unloading after it. The fuselage structure also offers protection against climatic factors (cold, low pressure, a very high wind velocity) and against external noise, provided suitable measures have been taken. The fuselage may be regarded as the central structural member to which the other main parts are joined (wings, tail unit and in some cases the engines) on the on~ hand, and as the link between the payload and the aircraft on the other.

In some aircraft a number of these duties are assigned to tail booms. d. Most of the aircraft systems are generally housed in the fuselage, which sometimes also carries the engines, fuel and/or the retractable undercarriage.

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.

Construction of Fuselage

The main purpose of aircraft fuselage 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.

Though, larger airplane uses 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 steel fuselage of a small passenger and aerobatic airplane is a truss type construction. The fuselage contains a pilot cabin and passenger cabin, both sections experiencing excess internal pressure.

Truss type structure

The fuselage is of welded steel tubes or composite fabric-covered construction. The fuselage consists of 109 tubes with lengths from (65-4950) mm, outer diameter (15-30) mm and thickness (2-5) mm.

The pilot's compartment are closed with transparent plastic sheets on the top and sides. The fixed split-v type landing gear incorporates individually sprung, hydraulic brake equipped wheels. The wheels are mounted by low-pressure 8.00× 4.00 [inch] tires. The steerable 8.00 × 3.00 tail wheel is mounted on steel spring leaves.

Tail surfaces are of conventional type, with a manually-controlled adjustment provided for the stabilizer, the basic dimension and data is illustrated in Table 1 [2]

Table 1: Dimensions and data of the aircraft

Gross Weight	700 kg
Wing Span	10.62 m
Total Length	7.1 m
Stall Speed	50 km/hr
Maximum Speed	180 km/hr
Wing Airfoil	USA 35B modified
Fuel Tank Capacity	120 liter
Engine Horse-Power	150 hp
Rate of Climb	2 m/sec
Range	1120 km
Service Ceiling	3 km
Take off distance	50 m

2. 3D Modeling

The 3-D model of the fuselage has been performed using 3-view drawings from the maintenance manual of the aircraft, and the missing dimensions were measured off an actual model of the aircraft. The fuselage skeleton has been drawn as lines first in the software, to ensure the centers of the tubes are in the accurate positions. Second step was configuring the tubes as surfaces; the benefit of these surfaces is to simplify the difficulty of joining the tubes together. Finally the intended shape was completed as an assemblage by drawing every tube as a separate part; the segmentation facilitates the manufacturing processes by drafting each part and supplying it to manufacturer or directly feeding the drawing to CNC machineFig. 1 unveils the complete drawing of SAFAT 01 truss

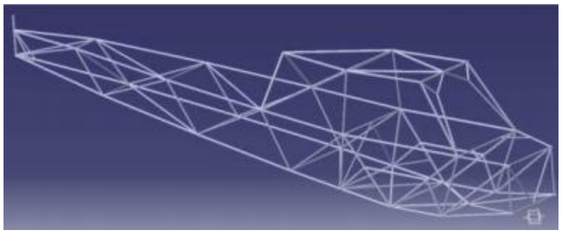

Fig. 1. Truss 3D drawing

Structural Analysis

Analysis of the assemblage needs the definition of the connections between the assembled parts. In this paper, fastened connection property was chosen. Fastened connection is the link between two bodies which are fastened together at their common boundary and will behave as if they are a single body. From a finite element model view point, this is equivalent to the situation where the corresponding nodes of two compatible meshes are merged together. However, since bodies can be meshed independently, the fastened connection is designed to handle incompatible meshes, and its relation take into account the elastic deformability of the interfaces. Parabolic octra tetrahedron element has been selected for this solid model.

The size of the mesh elements was made different from one part to another, in order to reduce unnecessary consumption of computer resources

Fuselage Loads

Fuselage are considered as a beam joint by main wing. The main causes of fuselage loads are as follows: • Reaction of components of an airplane which are attached to the fuselage, especially: tail structures, landing gear, point mass, payload, etc. • Aerodynamic loads • Load due to cabin pressurization • Engines and other power plants attached with the fuselage. Fuselage loads involved of concentrated and distributed load. The loads transferred from fixing bolts to the main wing, stabilizers, and the landing gear are known as concentrated loads. Those are the main forces acting on the fuselage body. Disparity to the above loads, distributed loads are classified as aerodynamic load and dynamic pressure of the fuselage. These forces subject the fuselage to bear, bending moment, twisting moment and shearing force. Furthermore, the weight of payload and fuselage structure will cause the fuselage to curve downwards from its support at the wing. Therefore, the upper surface of the fuselage will experience tension and the bottom surface in compression.

Boundary conditions for truss structure

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

3. Results

The maximum displacement has been found as 6.12 mm at the tip of the vertical tube where the vertical stabilizer is attached to the fuselage as in Fig.3. Although this value isreasonable compared to the tube size, experimental validation is still needed. The magnitude of Von Mises stress as illustrated in Fig. 3 indicates that the values of stresses for most of fuselage are less than (128 MPa), which is acceptable compared to the yield strength of the material (517.1 MPa). The maximum stress was (1400 MPa) as shown in Fig. 4, which is more than the yield stress. Principal stresses range from 874 MPa to -677 MPa as illustrated in Fig. 4. This high stress value has been observed in a very small region in the fuselage which is the area of the attachment of the strut and the main landing gear as shown in Fig. 4. The areas of attachment between fuselage and wing were subjected to some changes.

Accordingly, the fuselage was reanalyzed and the maximum value of Von Mises stress became (199 MPa), which is less than the yield strength of the material.

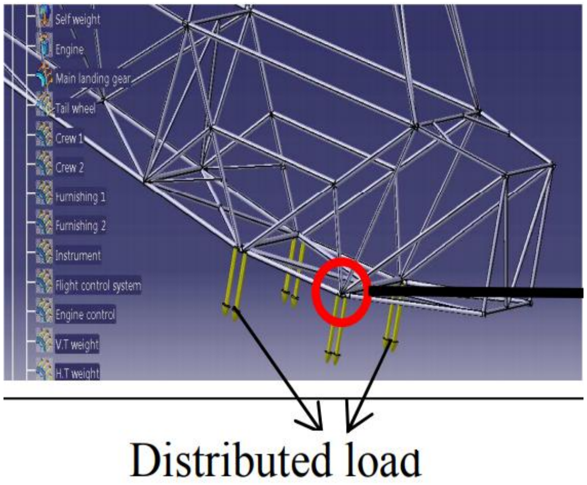

Figure: 2 Various load distributed over fuselage

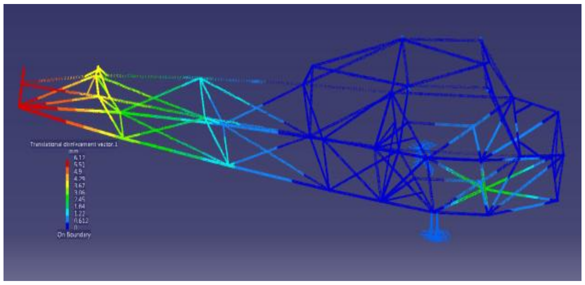

Figure:3 Maximum displacement

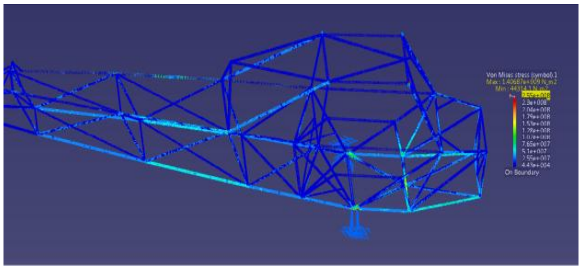

Figure: 4:- Von misses stress

4. Conclusion

Modeling of the truss fuselage as 3D was done accurately using CATIA. 4130N steel was selected as the model material and a fastened connection property was defined between all the parts of the assembly. Then octree tetrahedron mesh solid elements were created. The restraints were defined and inertial loads were taken from the equipment and structural parts, which are attached and fixed to the fuselage. The stress and displacement results has been obtained from the model. It is recommended to design new attachment fittings between the fuselage and the wing to increase the areas for the attachment as illustrated.

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