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Static Structural Linear Analysis of Fuselage Lug Joint Bracket for a Transport Aircraft with Mid Wing Configuration

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Abstract: *Civil transport aircraft, a highly complex flying structure is used for carrying passengers from one place to another. Generally transport aircraft undergoes nominal maneuvering flights. During the flight when the maximum lift is generated, the wings of the aircraft will undergo highest bending moment. The bending moment will be maximum at the root of the wing which causes highest stress at this location. Wings are attached to the fuselage structure through wing-fuselage attachment brackets. The bending moment and shear loads from the wing are transferred to the fuselage through these attachment brackets. In this study, bending load transfer joint is considered for the analysis. Firstly it needs to ensure the static load carrying capability of the wing-fuselage attachment bracket. Stress analysis has been be carried out for the given geometry of the wing-fuselage attachment bracket by varying its materials.*

Key Words: *Aircraft, wings, fuselage, Stress Analysis, Bending*

1. INTRODUCTION

The primary structural elements in airframe structure that are widely used in connecting different components of the airframe viz., are aircraft engine-pylon support fittings, wing fuselage attachment and landing gear links. These are some of the typical applications where attachment lugs of various configurations can be found. Failure of lug may lead to a catastrophic failure of the whole structure. Finite element analysis studies help the designer to safeguard the structure from catastrophic failure. Attachment lugs can be the most fracture critical component in an aircraft structure, with a very severe consequence of structural lug failure (disastrous). It is so severe that quite a few times the fuselage and wings of an aircraft gets separated.

Therefore, it is important to establish design criteria and analysis methods to ensure that the damage tolerance of aircraft attachment lugs are the primary structural elements in airframe structure widely used in connecting different components. E.g., aircraft engine-pylon support fittings, wing fuselage attachment and landing gear links where attachment lugs of various configurations can be found. The occurring catastrophic failure may lead to separation of lug joint bracket of the aircraft structure. Therefore, Finite element analysis (static) and experimental (numerical) data helps the designer to determine life of the structure before catastrophic failure.

Stress analysis was carried out on the given geometry of the wing-fuselage attachment bracket of a transport airframe structure. Finite element method is used for the stress analysis [1]. Aircraft failing due to a static overload during its entire service life is a rarity [2]. The combination of high level of acceleration and complicated maneuvers will introduce high magnitude of loads on the wings [3]. The bending moment will be maximum at the root of the wing which causes highest stress at that location [4]. Wings are attached to the fuselage structure using wing-fuselage attachment brackets. The bending moment and shear loads from the wing are transferred to the fuselage through these attachment joints [5]. In this work the bending load on the transfer joint is considered for the analysis. First we need to consider the static load carrying capability of the wing-fuselage attachment bracket. For continued airworthiness of an aircraft during its entire economic service life; fatigue and damage tolerance design, analysis, testing and service experience correlation play a pivotal role.

Considering a transport aircraft with mid wing configuration, different loads acting on the aircraft and its transfer from wing to fuselage is found. So different loads acting on the rivets due to the shear force and bending moment caused by the pressure load on the wing also have been calculated. All the three materials viz., steel, aluminium, titanium and their alloys are considered for the analysis.

1.1 Geometric Configuration

The following geometric configuration has been used for analysis;

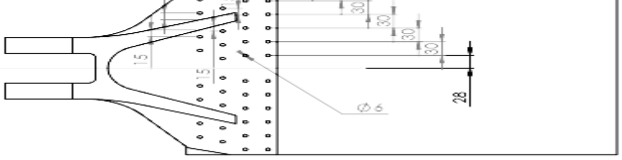

Fig-1 Top view of wing fuselage lug joint bracket

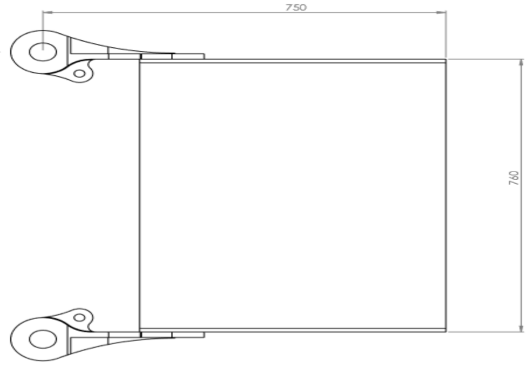

Fig-2 Front view of wing fuselage lug Joint bracket

1.2 Material and Mechanical Properties

The metals used in the aircraft wing fuselage attachment manufacturing industry include Aluminium alloy, Titanium alloy and Carbon Fibre Reinforced Polymer. Aluminium alloys are characterised by having lower density values compared to steel alloys (around one third), with good corrosion resistance properties. Titanium is also used in the design of aircraft structures as it is lightweight, strong and corrosion resistant metal.

In addition to metals, composite materials are also used within the aircraft industry due to their strength, relatively low weight and corrosion resistance. They can be made of fibrous materials embedded within a resin matrix. In general, fibres oriented in a specific direction are laminated with fibres characterised by a different orientation in order to obtain the required strength and stiffness. In the present study the material used are Aluminium 2024T351, Titanium Alloy and Carbon Fibre Reinforced Polymer (CFRP).

The mechanical properties are as shown in Table-1.

Table -1: Mechanical properties of the materials

Material	Young's modulus N/mm^2	Poisson's ratio	Density kg/mm^3	Yield Strength N/mm^2
Aluminum alloy-2024T351	70000	0.3	2800	378
Titanium Alloy	100000	0.21	4420	910
Carbon Fibre Reinforced Polymer	1500	0.28	1500	200

2. MODELLING AND ANALYSIS OF LUG JOINT BRACKET

The 3D modelling and meshing of lug joint bracket has been carried out using ANSYS software according to geometric configuration.

Hex Dominant Meshing Method, where a free hex dominant mesh is created. This option is recommended for bodies that cannot be swept.

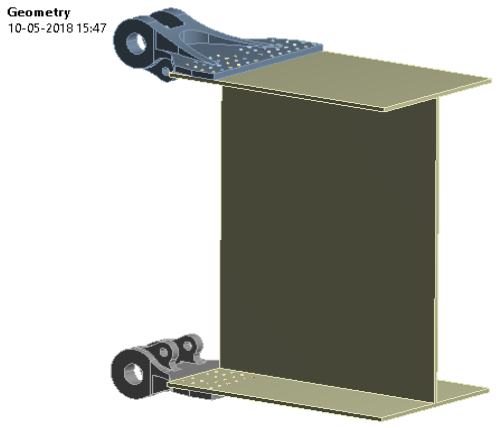

Fig-3 Isometric view of the lug joint bracket

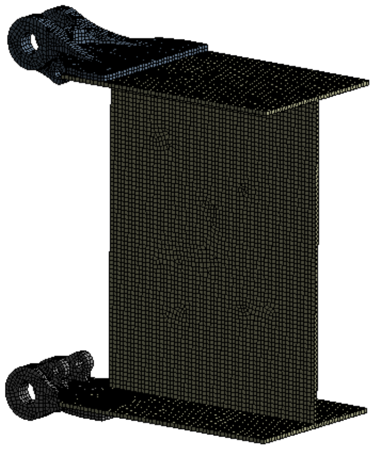

Fig-4 Hex Dominant Meshing

The mesh contains a combination of tet and pyramid cells with majority of cell being of hex type. Hex dominant meshing reduced element count.

A mesh well suited for a specific analysis can be generated with a single mouse click for all parts in a model. Full controls over the options used to generate the mesh are available for the expert user who wants to fine-tune it. The power of parallel processing is automatically used to reduce the time you have to wait for mesh generation. Number of elements is 76285 and nodes is 42520.

2.1 Boundary condition

Loading on the wing fuselage lug attachment bracket of the aircraft wing, bending moment by the spars in the wing structure resulted in the maximum bending moment occurring at the root of the spar where wing and fuselage components are attached to each other. The load calculation for the wing fuselage lug attachment bracket has been carried out by applying tension load 233085.6N on wing fuselage attachment fitting.

The loads and boundary conditions along with the finite element model are shown in the figure 5.

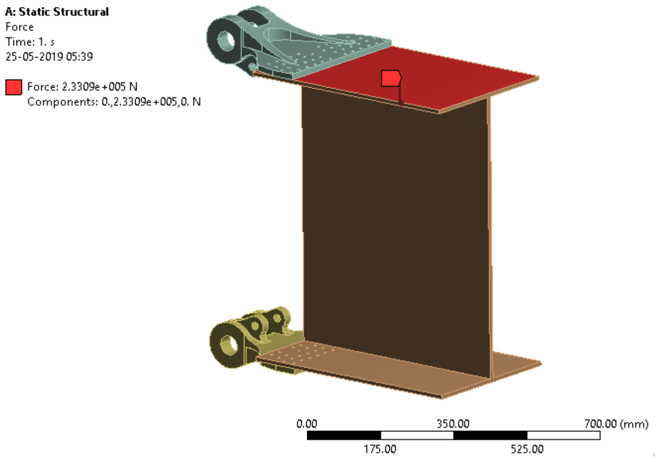

Fig-5 Applying tension load 233085.6N on wing fuselage attachment fitting on the surface of the I section

A load 233085.6N is applied at one end of the I section spar beam. This load will essentially create the required bending moment at the root section.

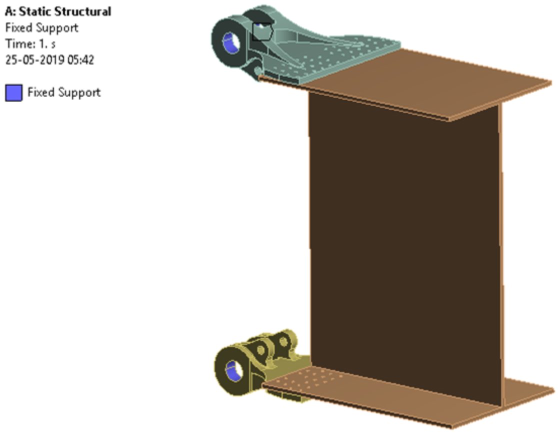

Fig-6 Fixed support on wing fuselage attachment fitting

Fixed support on wing fuselage attachment fitting and the top and bottom lug holes of the wing fuselage lug attachment bracket are constrained with all six degrees of freedom at the semi-circular circumferential region.

3. RESULTS AND OBSERVATION

The results obtained after the static analysis has been discussed here.

3.1 Titanium Alloy

The stress values at the root section of the lug hole and the displacement contours occurring are shown in the Figure 7. A maximum stress of 209N/mm^2 is observed at the midpoint of the root section.

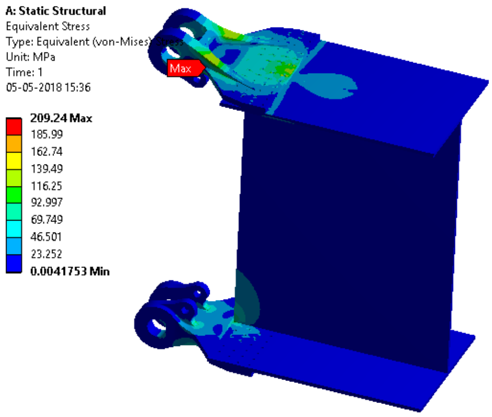

Fig-7 Maximum equivalent stress is 209.24MPa for the applied load and max stress observed in mid region of I section

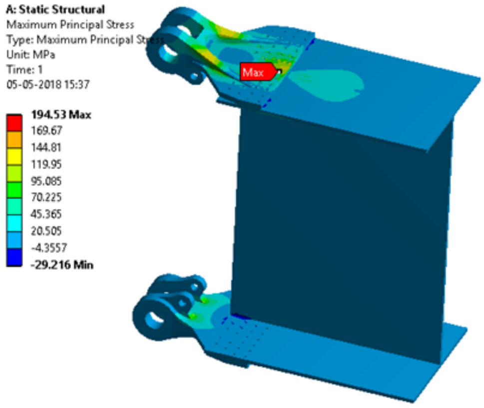

Fig-8, Maximum principal stress is 194.56MPa for the applied load and maximum stress observed in middle region of I section

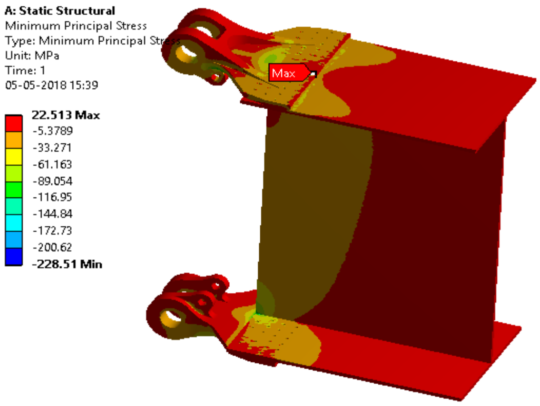

Fig-8 Minimum principal stress is 22.513MPa for the applied load

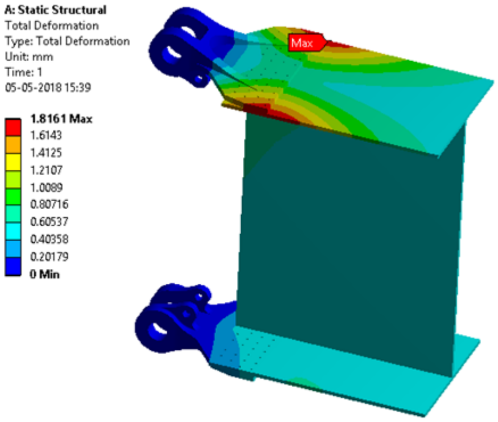

Fig-9 Maximum total deformation 1.816 mm and maximum stress observed in edge region of I section.

3.2 Aluminum Alloy

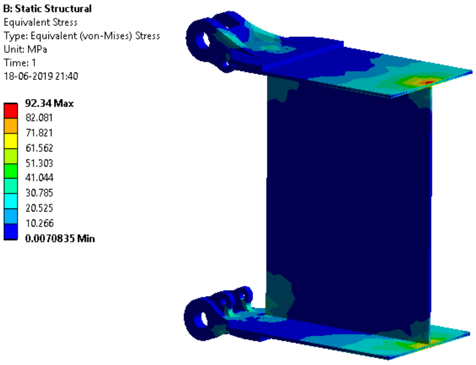

Fig-10 Maximum equivalent stress is 92.34MPa for the applied load condition and maximum stress observed in middle region of I section

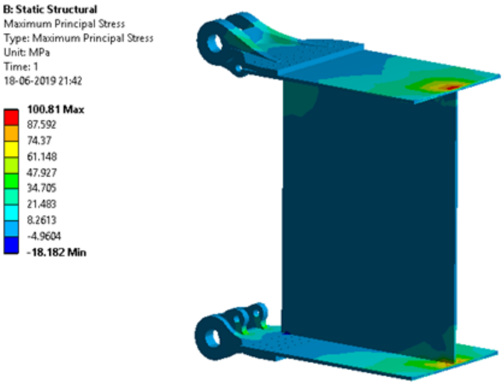

Fig-11 Maximum principal stress is 100.81MPa for the applied load condition and maximum stress observed in middle region of I section

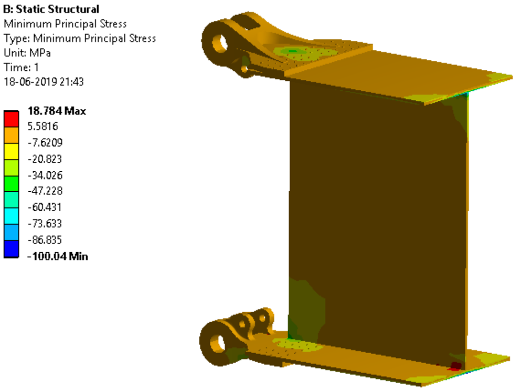

Fig-12 Minimum principal stress is 18.784MPa for the applied load and maximum stress observed in mid of the I section

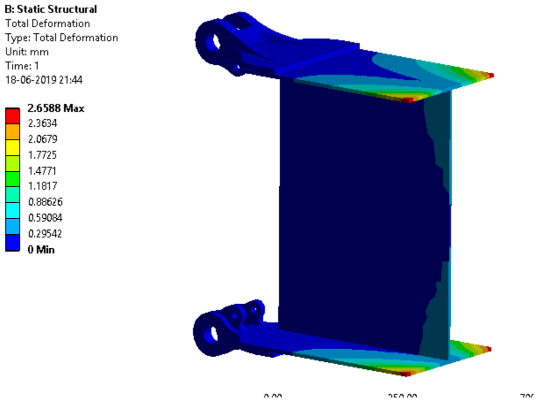

Fig-13, Total deformation is 2.6588mm for the applied load condition and maximum stress observe in edge of the I section

3.3 Carbon Fibre Reinforced Polymer (CFRP)

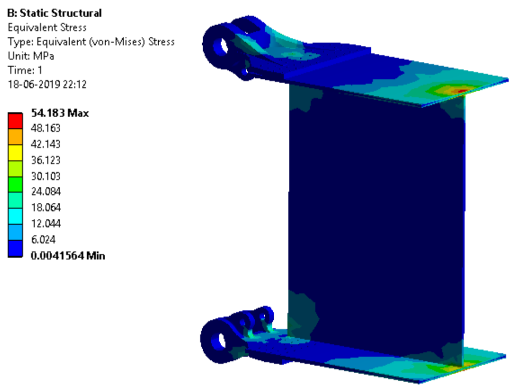

Fig-13 Maximum equivalent stress is 54.183 MPa for the applied load and stress values at the lug hole and the displacement contours

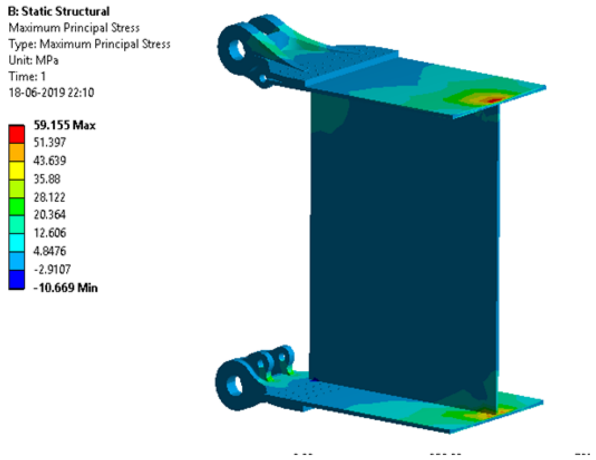

Fig-14 Maximum principal stress is 59.155MPa for the applied load and a maximum stress of 59.183 is observed at the midpoint of the I section.

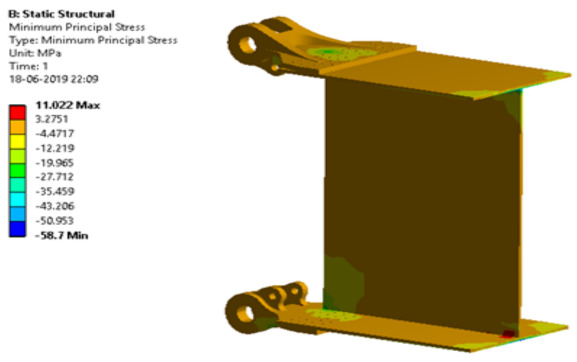

Fig-15 Minimum principal stress is 11.022MPa for the applied load condition and maximum stress observer in middle of the I section region

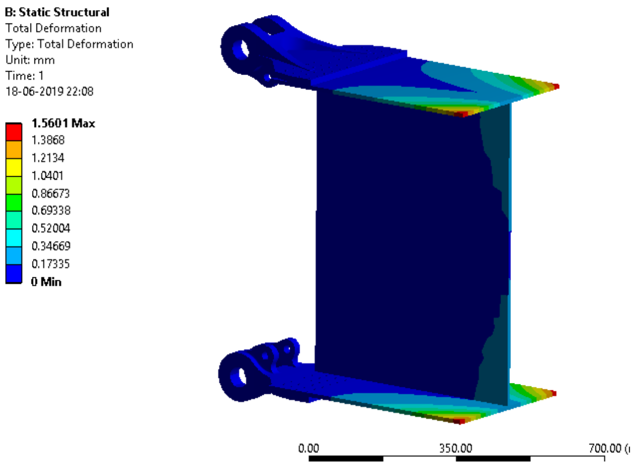

Fig-16 Maximum displacement of 1.56mm at the free end of the cantilever structure observed from the displacement contour

Table -2: Comparison between materials like Aluminum alloy, Titanium alloy and CFRP materials and comparison between weights of the different materials

Materials	**Equivalent stress (MPa)**	**Max principal stress (MPa)**	**Mini principal stress (MPa)**	**Total deformation (mm)**	**Weight (Kg)**
Aluminum alloy	92.34	100.81	18.78	1.81	35.6
Titanium alloy	209.24	194.53	22.15	2.61	41.12
Carbon Fibre Reinforced Polymer	54.18	59.15	11.02	1.50	28.12

4. CONCLUSIONS

Damage tolerance design philosophy is generally used in the aircraft structural design to reduce the weight of the structure. Stress analysis of the wing fuselage lug attachment bracket had been carried out and maximum tensile stress is identified at one of the lug-holes. FEM approach was followed for the stress analysis of the wing fuselage lug attachment bracket. Maximum equivalent stress for the aluminum alloy, titanium alloy and Carbon Fibre Reinforced Polymer are safe because the maximum stress is less than the yield stress. Carbon Fibre Reinforced Polymer wing-fuselage attachment material weight is very less compare with aluminum and titanium alloys. Several iterations were carried out to obtain a mesh independent value for the maximum stress.

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