Stress Analysis of Wing-Fuselage Lug Attachment Bracket of a Transport Aircraft

B.K. Sriranga, Dr.C.N. Chandrappa, R. Kumar and Dr.P.K. Dash

Abstract--- *Civil transport aircraft is used for carrying passengers from one place to another. Aircraft is a highly complex flying structure. Generally transport aircraft undergoes nominal maneuring 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 caused 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 the attachment joints.

In this project bending load transfer joint is considered for the analysis. First one needs to ensure the static load carrying capability of the wing-fuselage attachment bracket. Stress analysis will be carried out for the given geometry of the wing-fuselage attachment bracket. Finite element method is used for the stress analysis.

Rarely an aircraft will fail due to a static overload during its service life. For the 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.

Keywords--- *Transport Aircraft, Lift Load, Bending Moment, Wing-Fuselage Attachment, Stress Concentration, Stress Ratio*

I. INTRODUCTION

1.1 Introduction to Lug Attachment Joints

LUGS are the primary structural elements in airframe structure that are widely used in connecting different components of the airframe. For ex. aircraft engine-pylon support fittings, wing fuselage attachment, and landing gear links are some of the typical applications where attachment lugs of various configurations can be found. [1]

Failure of lug may lead to the catastrophic failure of the whole structure. Finite element analysis studies and experimental data help the designer to safeguard the structure from catastrophic failure. Attachment lugs can be some of the most fracture critical components in aircraft structure, and the consequences of structural lug failure can be very severe (disastrous) (it is so severe (disastrous) 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 the damage tolerance of aircraft attachment lugs. [4]

II. GEOMETRICAL CONFIGURATION

The wing fuselage attachment bracket considered for the study is shown in figure 2.1. The attachment bracket consists of a lug and a portion of the spar connected to each other by several bolts. The lug consists of two pin holes along with an integrated top flange and bottom flange which will be connected to the spar. The geometric dimensions of the lug attachment bracket are shown in the figure below. Three views of wing fuselage lug

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attachment bracket are shown in the Figure 2.1. A three dimensional view of the lug attachment bracket is shown in the figure 2.2.

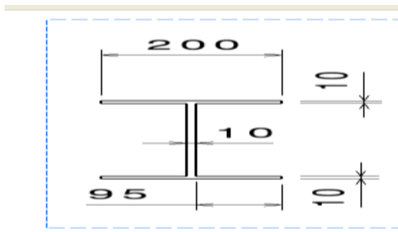

Figure a

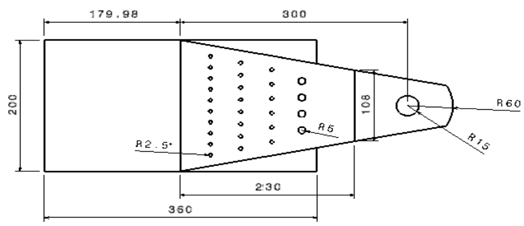

Figure b

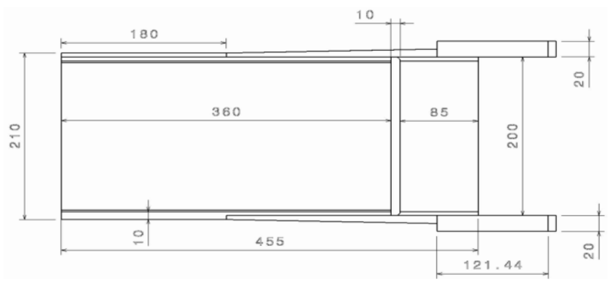

Figure 2.1 a, b, c, Shows Three Views of Wing Fuselage Lug Attachment Bracket.

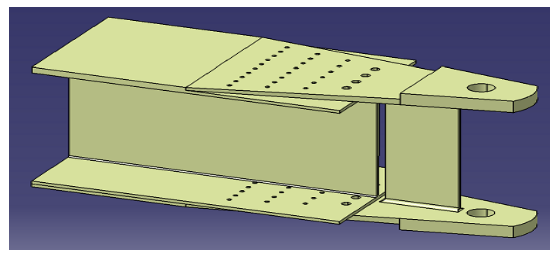

Figure 2.2: Isometric View of the Lug Attachment Bracket

III. MATERIAL SPECIFICATION

Selection of aircraft materials depends on any considerations, which can in general be categorized as cost and structural performance. Cost includes initial material cost, manufacturing cost and maintenance cost. The key material properties that are pertinent to maintenance cost and structural performance are

- Density (weight)
- Stiffness (young's modulus)
- Strength (ultimate and yield strengths)
- Durability (fatigue)
- Damage tolerance (fracture toughness and crack growth)
- Corrosion

Seldom is a single material able to deliver all desired properties in all components of the aircraft structure. A combination of various materials is often necessary.

3.1 Alloy Steel, Heat Treated AISI-4340

The material considered for the lug part of the structure is steel alloy AISI4340.

The following properties.

1. Young's Modulus, E = 201105N/mm^2
2. Poison's Ratio, μ = 0.3
3. Ultimate Strength, $б_u$ = 1530N/mm^2

3.2 Aluminum Alloy – 2024-T351

The material considered for the I-spar and rivets of the structure is aluminum alloy-2024T351.

The following properties.

1. Young's Modulus, E = 7000N/mm^2
2. Poison's Ratio, μ = 0.3
3. Ultimate Strength, $б_u$ = 485N/mm^2

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IV. Loads on the Wing Fuselage LUG Attachment Bracket

Most of the wing bending is carried by the spars in the wing structure. The maximum bending moment occurs at the root of the spar where wing and fuselage components will be attached to each other. The load calculation for the wing fuselage lug attachment bracket is described in the next section.

4.1 Load Calculation for the Wing Fuselage Lug Attachment

- *Bracket*

1. Aircraft category=medium size of fighter aircraft
2. Total weight of the aircraft=**6500**kg=63765 N
3. Load factor considered in design=**3**g.
4. Design limit load on the structure=3*63765=1.9129*E5N
5. Design ultimate load=1.9129*E5*1.5=2.8694*E5N
6. Distribution of lift load on fuselage and wing= 20% and 80%.
7. Total Load acting on the Wings=2.8694*E5N*0.8=229.554*E3N
8. Load acting on the each Wing= (229.554*E3)/2=114.777*E3 N
9. Number of spar in the wing=3
10. Load sharing by spars is
    a. spar 1=15%
    b. Spar 2=40%
    c. Spar 3=45%
11. The wing fuselage attachment considered for the current analysis is at spare.

Therefore, load acting on the spare 3=114.777*E3 *0.15=17.216*E3 N.

Total bending momentum acting at the root of the beam = 17.216*E3 N *750mm=12.912*E6 N/mm2

To simulate the equivalent bending moment by applying the load at a distance of 12mm which is free end of the beam considered in the analysis is=(12.912*E6 N/mm2))/480=26.9*E3 N

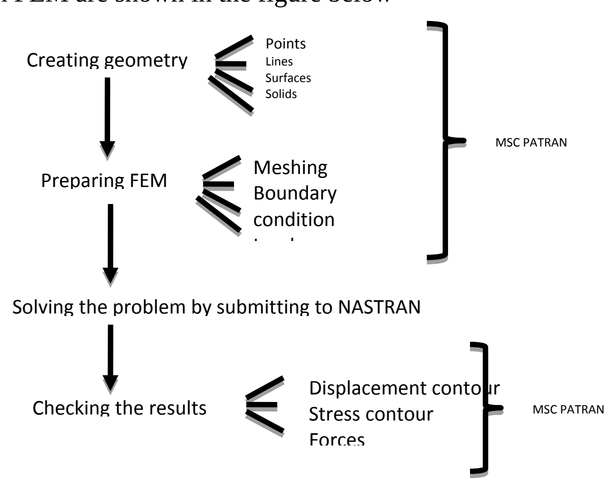
V. Finite Element Analysis

5.1 Introduction to FEA Approach

The finite element method (FEM) is a numerical technique for solving problems which are described by partial differential equations or can be formulated as functional minimization. A domain of interest is represented as an assembly of finite elements. Approximating functions in finite elements are determined in terms of nodal values of a physical field which is sought. A continuous physical problem is transformed into a discretized finite element problem with unknown nodal values. For a linear problem, a system of linear algebraic equations should be solved. Values inside finite elements can be recovered using nodal values.

5.2 The Different Stages of Finite Element Analysis

The software used for the analysis of the Landing gear lug attachment joint in an airframe is MSC Patran & MSC Nastran. The stages involved in FEM are shown in the figure below



VI. Finite Element Model of the Wing Fuselage LUG Attachment Bracket

As per the design calculations from the previous section the dimensions of the lug at the pin hole are used in the actual model of the lug attachment bracket. All other dimensions of the complete assembly of the structure are as per the description provided in the previous section in the problem definition chapter. A finite element model is the complete idealization of the entire structural problem including the node location, the element, physical and material properties, loads and boundary conditions. The purpose the finite element model is to make a model that behaves mathematically as being modelled and creates appropriate input files for the different finite element solvers. In Finite Elements libraries, selected 4 Nodded QUARDRILATERAL Shell Element (QUAD4). In this Geometrical model for available surface area, chosen for formulation of FE Model, reason was flow of displacement and stiffness.

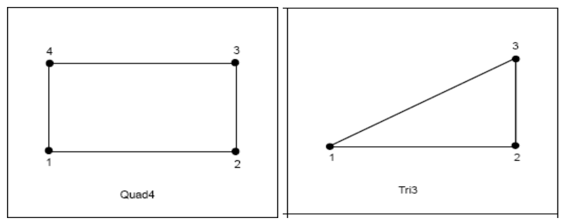


Figure 6.1: 3Noded TRIA Shell Element and 4Noded Quadrilateral Shell Element.

FE model of the wing fuselage Lug attachment bracket is as shown in Figure 5.4 Meshing is carried out by using CQUAD4 and CTRIA3 shell elements. Triangular elements are used for the transition between the coarser mesh to finer mesh.

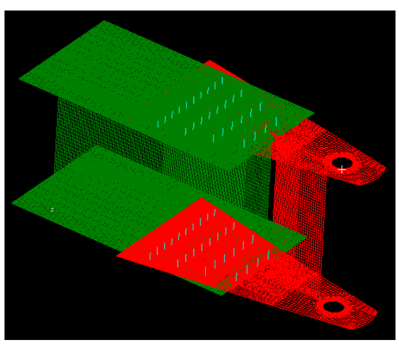


Figure 6.1 Finite Element (FE) Model of the Wing Fuselage Lug Attachment Bracket

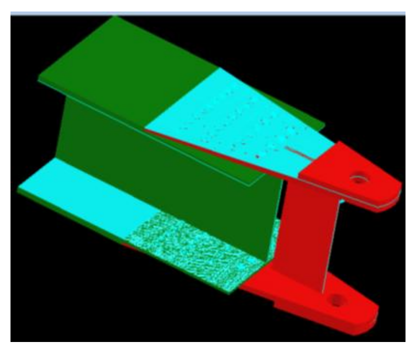


Figure 6.2 The 2-D Mesh Display in 3-D form to Visualize the Thickness of the Members in the Model.

6.1 Different Structural Members of the Wing Fuselage Lug Attachment Bracket are

- Lug
- I-spar
- Top and bottom flanges of the lug attachment bracket
- Rivets

The corresponding mesh generated for each of the above mentioned members are shown in the figure below.

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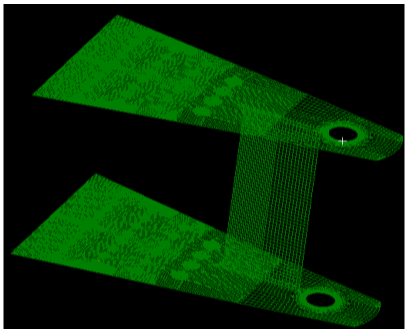

Figure 6.3 Finite Element (FE) Model of the Lug

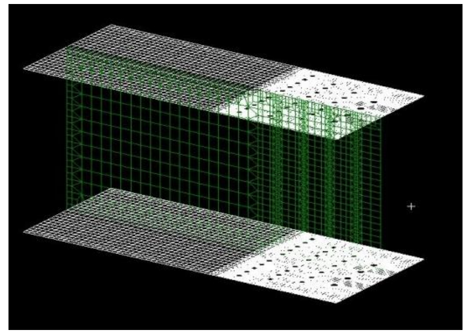

Figure 6.4 Finite Element (FE) Model Of The I-Spar.

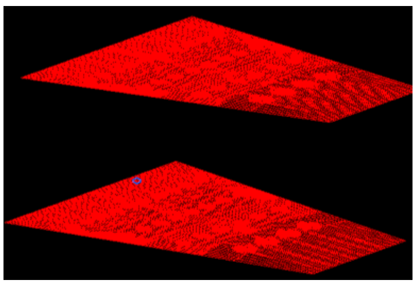

Figure 6.5: Finite Element (FE) Model of the Variable Thickness Plate.

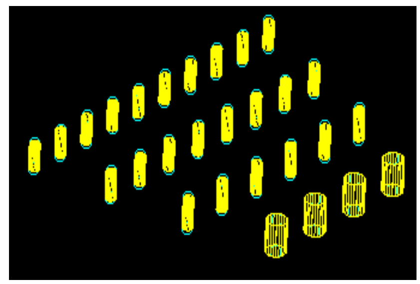

Figure 6.6: FEA Model of the Rivets

VII. Loads and Boundary Conditions

The loads and boundary conditions along with the finite element model are shown in the figure 5.10. A load 90.677*E3 N of is introduced at one end of the spar beam. This load will essentially create the required bending moment at the root.

The top and bottom lug holes of the wing fuselage Lug attachment bracket are constrained with all six degrees of freedom at the semicircular circumferential region.

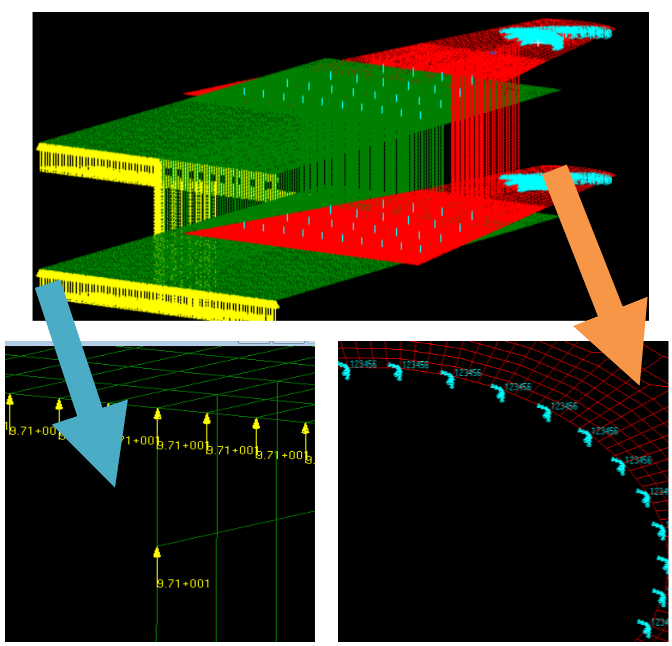

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Figure 7.1: Load and Boundary Conditions applied to the Wing Fuselage Lug Attachment Bracket.

VIII. Finite Element Modelling and Stress Analysis in Wing Fuselage Attachment Bracket

The stress values at the lug hole and the displacement contours are shown in the figures 8.1. A maximum stress of 919N/mm2 is observed at the midpoint of the hole section. A maximum displacement of 2.64mm at the free end of the cantilever structure can be observed from the displacement contour in the figure 8.1. The maximum stress value obtained from the analysis is used as the input for the fatigue calculations.

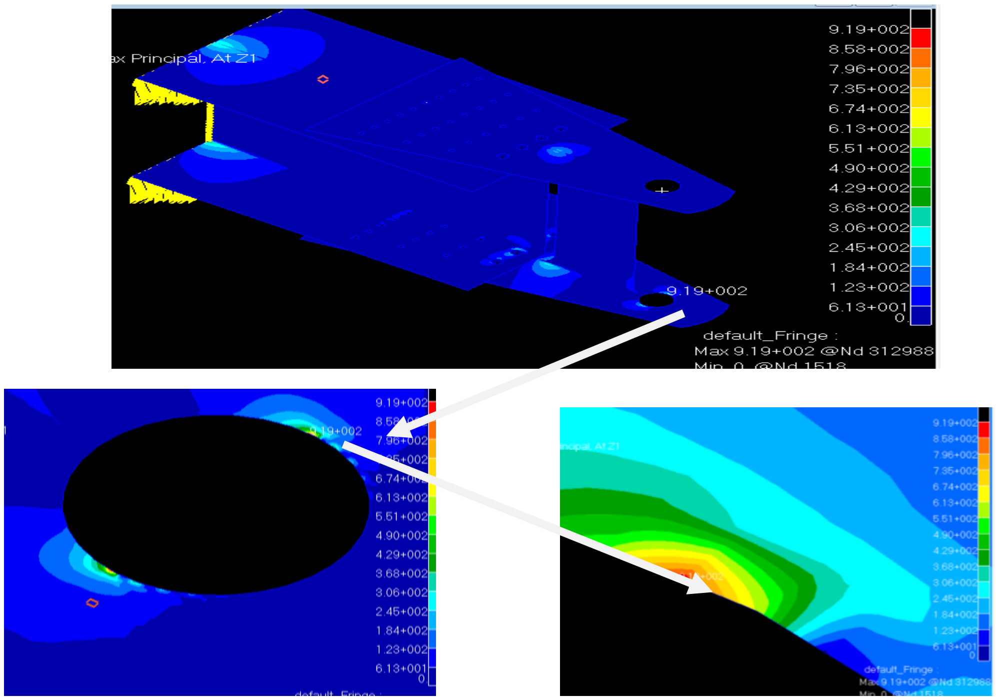

Fig 8.1: Figure Showing Maximum Stresses of Wing Fuselage Lug Attachment Bracket

Table 8.1: Convergence Requirements

NO. iterations	σ_{max} (N/mm2)
0	0
1	390.7
2	546.4
3	918.51
4	919
5	919

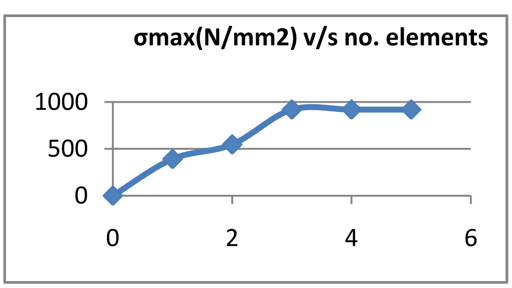

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Figure 8.2: Max Stress (N/Mm2) V/S No. Elements

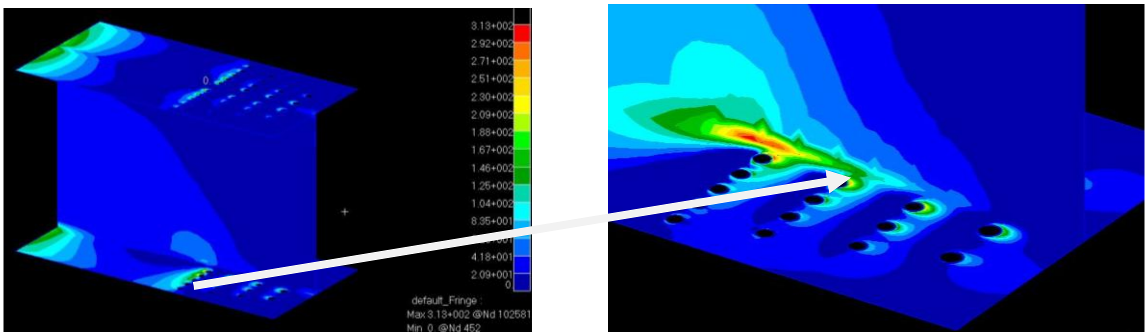

Figure 8.3: Max Stress in I-Sectional Spar Z1=3.13*E2n/Mm2

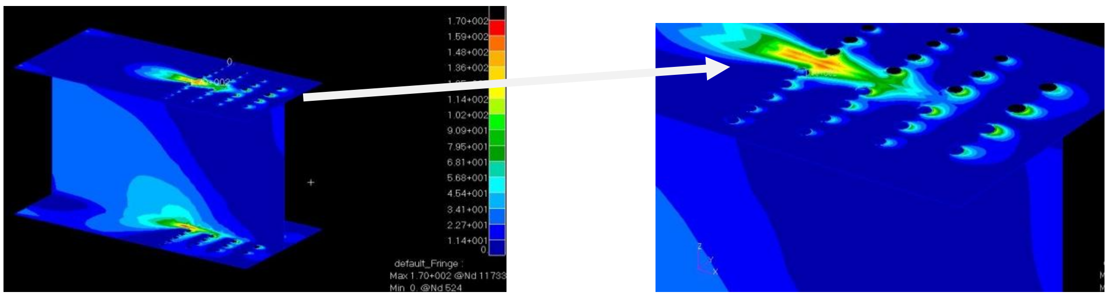

Figure 8.4: Max Stress I-Sectional Spar Z2=1.7*E2n/Mm2

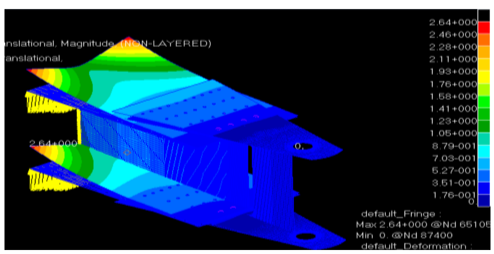

Figure 8.4: Displacement Contour of Wing fuselage Lug Attachment Bracket.

IX. RESULTS AND DISCUSSIONS

Material	Bending moment load (KN)	Maximum displacement(mm)Average	Tensile strength(MPA)	Density (kg/m3)
ALLUMINIUM 2024 T351(SPAR)	26.9	2.64	290	2800
ALLOY STEEL (AISI 4340) LUG JOINTS	26.9	2.64	919	7800

X. CONCLUSIONS

- Stress analysis of the wing fuselage lug attachment bracket is carried out and maximum tensile stress is identified at one of the lug-holes.
- FEM approach is followed for the stress analysis of the wing fuselage lug attachment bracket.) A validation for FEM approach is carried out by considering a plate with a circular hole.
- Maximum tensile stress of 919N/mm^2 is observed in the lug.

- Several iterations are carried out to obtain a mesh independent value for the maximum stress.
- A fatigue crack normally initiates from the location maximum tensile stress in the structure.

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