"Parametric Study of Stress and Fatigue Analysis of Aircraft Attachment Lug Subjected to Cyclic Loads"

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***Abstract*— In this paper failure analysis of wing-fuselage lug attachment is considered. Aircraft undergoes variable loading condition during its takeoff and landing so maximum lift generated. Wing is subjected to 20% of total load of aircraft and it will cause bending moment and it is high at the root of the wing. Hence it is required to know the static load carrying capacity of wing fuselage attachment lug. Load and bending moment acting on wing is transferred to this lug-joint, so this lug-joint play an critical role in complex aircraft structure.**

Finite element method is utilized to determine the stress state under operating condition. Development of Material Science cause new concepts in structural design, material selection, production technique and load spectra may lead to fatigue damage problems are increased significantly. So prediction and analysis of fatigue life is much more important. Maximum tensile stress will cause fatigue crack in that location hence fatigue analysis for variable loading condition using constant S-N amplitude for different stress cycles. CATIA VS5 is used for modeling, MSC/PATRAN used as preprocessor for meshing, MSC/NASTRAN as solver.

Keywords — Wing-Fuselage Lug attachment, Stress, Fatigue, Bending moment

I. INTRODUCTION

Lugs are commonly used in aircraft as structural application means to connecting different components of aircraft. Lug joint usually connected to the fork by pin or single bolt. Typical examples of lug are wing fuselage connection, landing gear to fuselage. Advantages of lug simple in geometry and they can easily mounting and dismounting. [1]

Wing is connected to fuselage through lug attachment so wing load transferred through lug joint hence lug joint high stress and bending moment. Failure of lug attachment may separates wing-fuselage so it is required to establish design criteria and analysis methods to ensure the damage tolerance of aircraft attachment lugs.

II.GEOMETRICAL CONFIGURATION

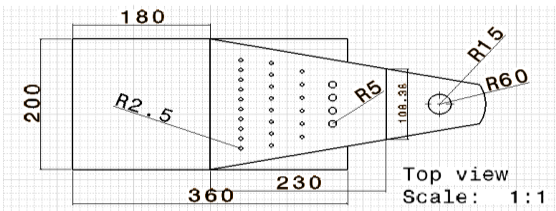


Figure 2.1 a: Top view of lug attachment

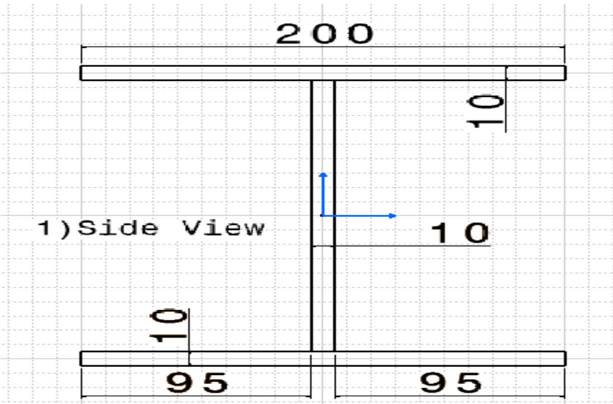


Figure 2.1 b: Side view of lug attachment

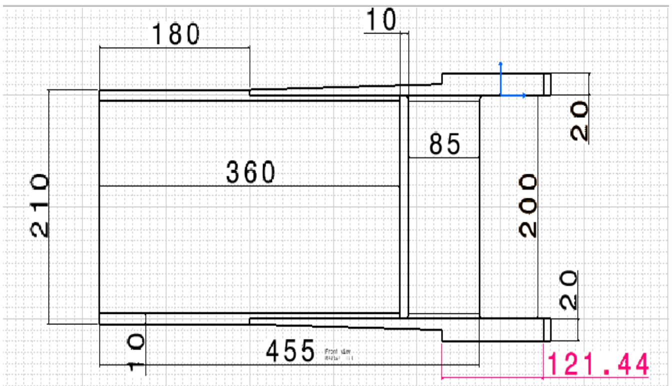


Figure 2.1 a, b, c shows the three views of attachment.

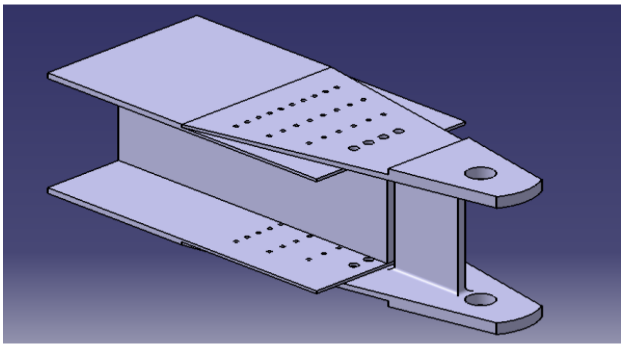


Figure 2.2: Isometric view of lug joint

The wing fuselage lug attachment is considered for parametric study as shown in above figures. Three views of wing fuselage lug attachment bracket are shown in the Figure 2.1. A isometric view of the lug attachment bracket is shown in the figure2.2. Lug is having 2 pin holes and variable thickness flange this mate with wing spar through rivets.

III.MATERIAL SPECIFICATION

Wing carries 20% of total load of aircraft this load is transferred fuselage through wing spar it creates highest bending moment at lug attachment.

Material used for the lug joint is steel alloy of AISI434

1	Young's Modulus	E=2.1E5N/mm^2
2	density	7800kg/mm^3
3	Poison's Ratio	µ=0.3
4	Yield Strength	1014.3N/mm^2
5	Ultimate Strength	1035N/mm^2

Material considered for I section of wing spar and rivets joint is aluminum alloy-2024T351

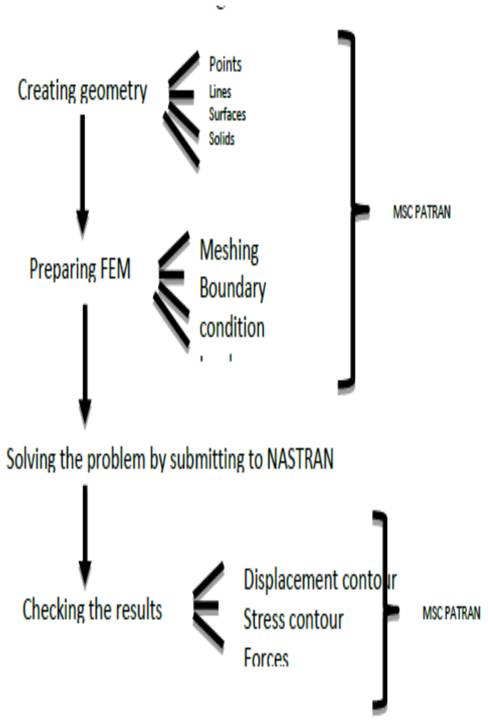
1	Young's Modulus	E=70000N/mm^2
2	density	2800kg/mm^3
3	Poison's Ratio	µ=0.3
4	Yield Strength	378N/mm^2
5	Ultimate Strength	485N/mm^2

IV.LODS ON THE WING FUSELAGE ATTACHMENT

1) Type of Aircraft =medium size of fighter aircraft
2) Aircraft total weight=6500kg=63765 N
3) Load factor considered in design=3g.
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 different finite element solvers. In Finite Elements 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 spar. 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 480mm 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



The finite element method (FEM) is a numerical technique for solving engineering problem this method can solve complex geometry, shape, material properties, load and boundary condition. In this method given problem is divided in to small elements these elements are connected each other by nodes. Nodes are the points where the properties of elements determined. For static linear problem a system of the linear algebraic equation should be solved. The software used for the analysis of the wing fuselage attachment bracket of a fighter aircraft airframe structure is MSC.Patran & MSC.Nastran.

VI. FE MODEL OF THE LUG ATTACHMENT

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 modeled and creates appropriate input files for the 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.

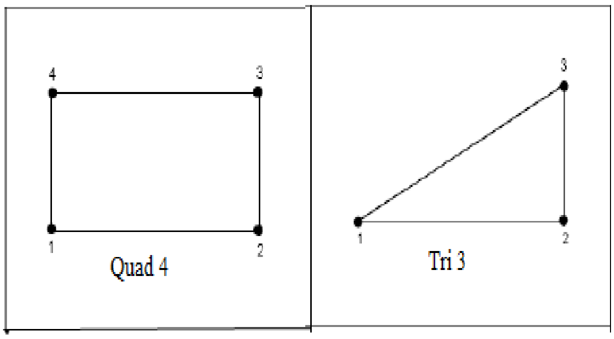


Fig 6.1: 3 Noded TRIA and 4 Noded Quadrilateral shell elements.

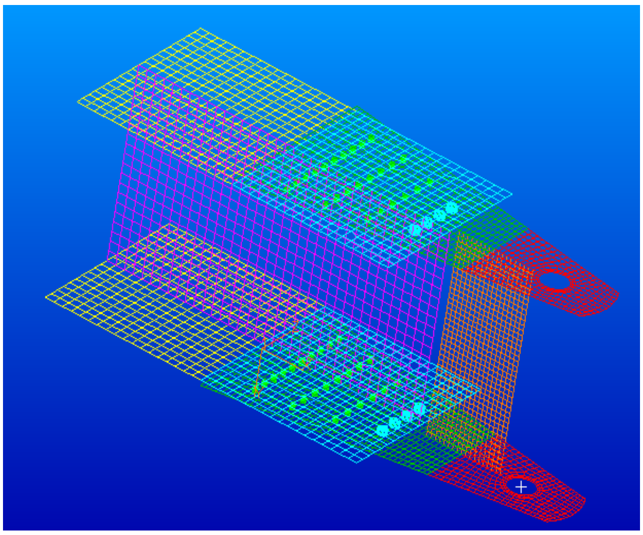


Figure 6.1: FE Model of wing fuselage lug attachment

A: Different members of wing fuselage lug attachment bracket are

1. Lug
2. I-spar
3. Top and bottom of the lug attachment bracket
4. Rivets

Meshing for these above mentioned members is shown in below figures

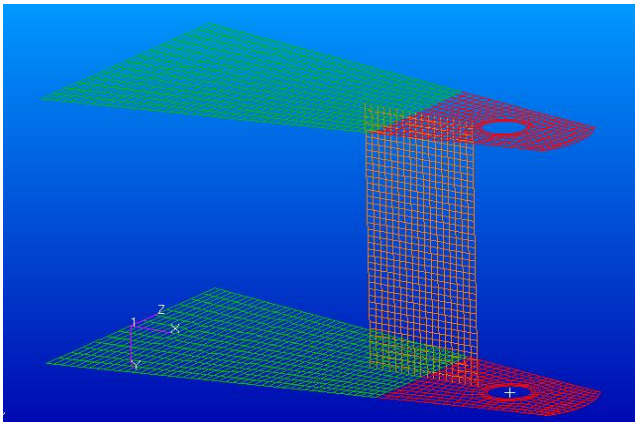


Figure 6.2: FE Model of lug attachment

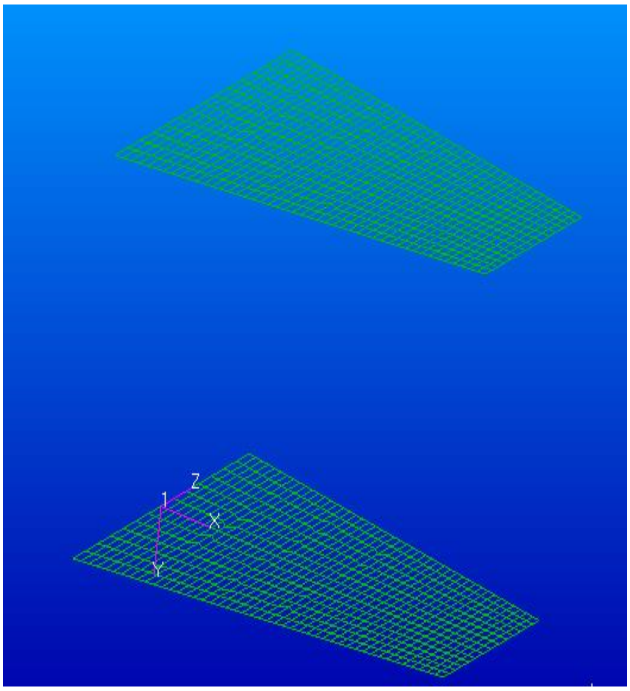


Figure 6.3: FE model of variable thickness plate

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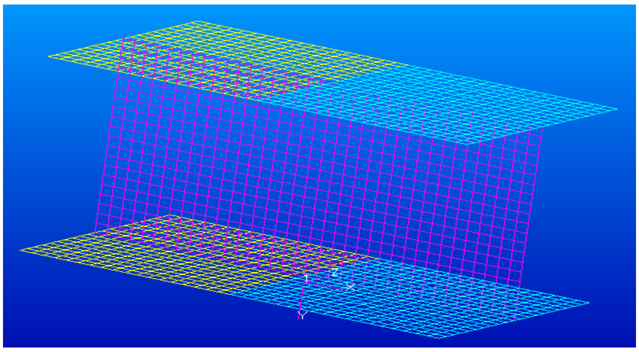

Figure6.4: FE Model of I-spar

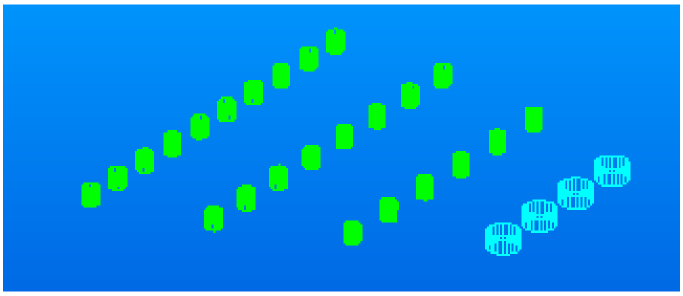

Figure 6.5: FEA Model of Rivets

VII. LOAD AND BOUNDRY CONDITION

Load acting on lug joint is 26.9E3 at free end of I spar beam. This load applied on FE model and it will produce required bending moment in the root of spar. Lug hole of wing fuselage lug attachment constrain to lock translations and rotational degrees of freedom. Show in figure 7.1

VIII. FE MODEL AND LOCAL STRESS

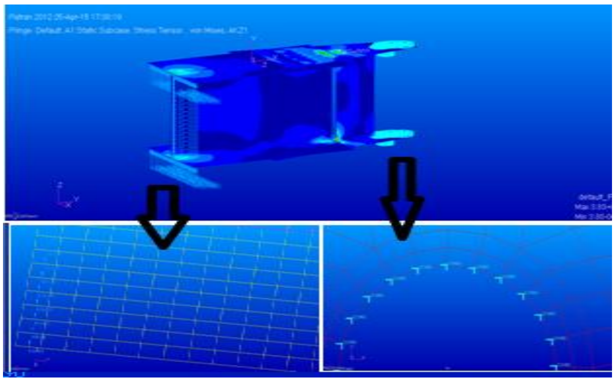

Figure 7.1: Load and Boundary condition applied to Lug joint

ANALYSIS FOR LUG JOINT

The maximum stress of 901N/mm^2 occurred at root section of the lug hole this is shown in bellow figure. By using maximum stress it is possible to find out fatigue life of lug joint.

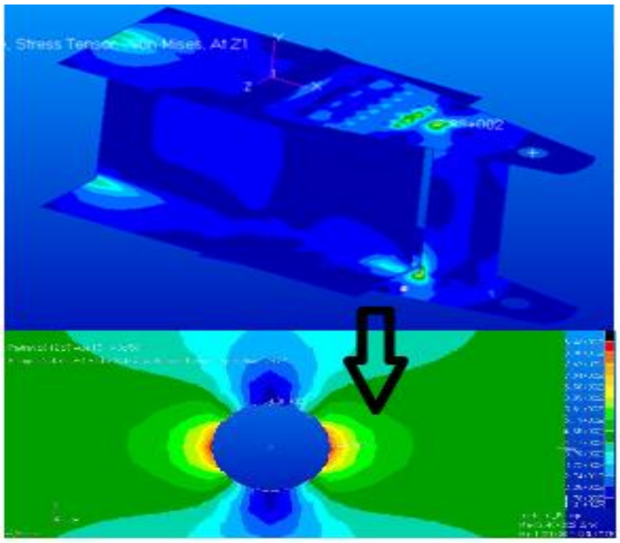

Figure 8.1: Maximum stresses near lug hole

IX. RESULTS AND DISCUSSION

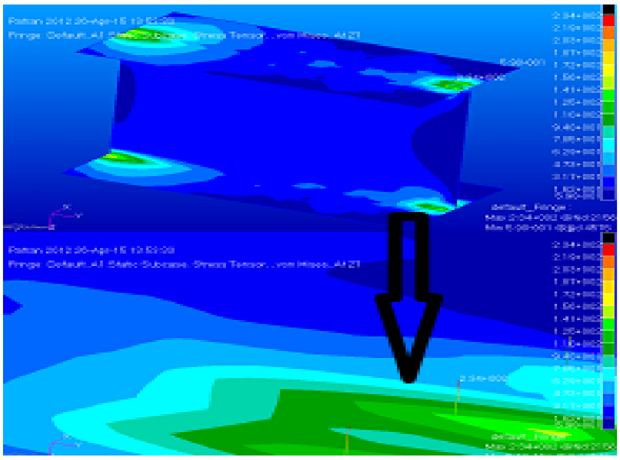

Figure.9.1: Maximum stress in I section spar in Z1 234N/mm^2 direction

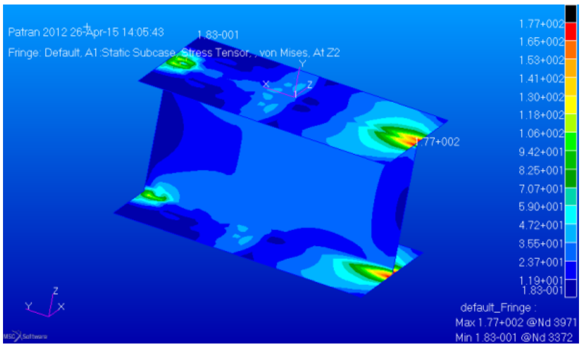

Figure 9.2: Maximum stress in I section spar in Z2 177N/mm^2

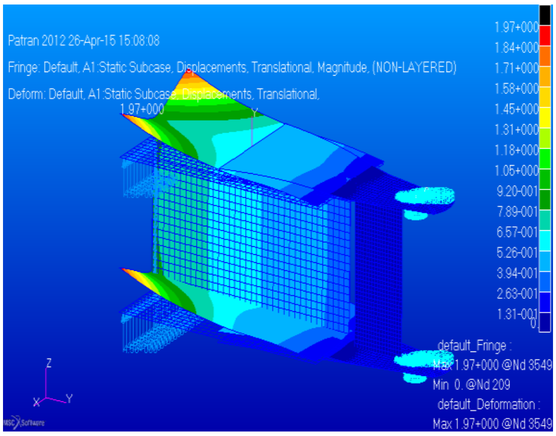

Figure 9.3 :Displacement counter of lug attachment is 1.97mm

X.CONCLUSION

In this study stress analysis of wing-fuselage lug attachment of medium size fighter aircraft is carried out. The maximum stress 901N/mm^2 in critical lug area i.e. around lug hole. The excessive stresses around lug hole were main reason for premature fatigue failure.

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