



# DESIGN AND ANALYSIS OF LANDING GEAR LUG ATTACHMENT BRACKET FOR SMALL TRANSPORT AIRCRAFT

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## ABSTRACT

*Landing gear is one of the primary structural components of the airframe. Landing gear enables the airplane to take off and land on ground. The most common type being tri-cycle arrangement with a nose landing gear and a main landing gear. Impact loads during landing are the main design loads for the landing gear design. Landing gears should also be checked for various other ground handling loads as specified in the regulatory requirements. Lugs are the primary structural elements in airframe structure that are widely used in connecting different components of the airframe. Failure of lug may lead to the catastrophic failure of the whole structure.*

*Stress analysis of the landing gear 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 landing gear lug attachment bracket. A validation for FEM approach is carried out by considering a plate with a circular hole. The lug joints made up of steel and aluminum material is analyzed using MSC Patran and Nastran, the stress contour is plotted and maximum stress is found below the stress limit thus the design is safe and also the deformation contour is plotted, deformation is found below the safe limit thus the design is safe.*

*Then the results of analytical calculations are compared with results of finite element analysis. Hence the validation is done.*

**Keywords:** Finite Element Model; Ultimate Tensile Stress; Degrees of Freedom; MSC Patran and Nastran; airframe structure.

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## 1. INTRODUCTION

Air ship is machine that can fly starting with one place then onto the next. Various investigations were made to fly the machine.

An air ship is equipment that tries to fly by picking up backing from the air or the air of a planet. It counters the force of gravity by using either static lift or by using the dynamic lift of an airfoil, or in a few cases the diving push from plane engines. Air ship might be arranged by various criteria, for example, lift sort, impetus, use etc. The landing gear is a part in an aircraft that helps the aircraft to fly as well as land smoothly on the ground. Ordinarily wheels are utilized, however slips, glides or a mix of these and different components can be sent, contingent upon the surface. The landing gear helps the aircraft to land on the ground.

Connection carriers can be probably the most break basic parts in air ship structure and the outcomes of basic carry disappointment can be exceptionally serious (lamentable) (it is so extreme that many times the fuselage and wings of a flying machine gets isolated). In this manner, it is essential to build up configuration criteria and examination strategies to guarantee the harm resilience of air ship connection lugs.

Landing rigging is one of the essential auxiliary parts of the airframe. Its outline contemplations are fundamentally distinctive. The arrival gear withstands the ground sway stack and retains the effect vitality and diffuses the heap to the surroundings connection.

Carrier is the essential basic components in airframe structure that are broadly utilized as a part of associating diverse segments of the airframe. Connection drags can be probably the most break basic parts in air ship structure and the outcomes of basic haul disappointment can be exceptionally serious. In this manner, it is vital to set up outline criteria and examination strategies to guarantee the harm resilience of flying machine connection drags.

To accomplish a configuration most versatile to the predefined motivation behind the plane, sound judgment must be practiced in considering the estimation of the essential alterations and/or bargains.

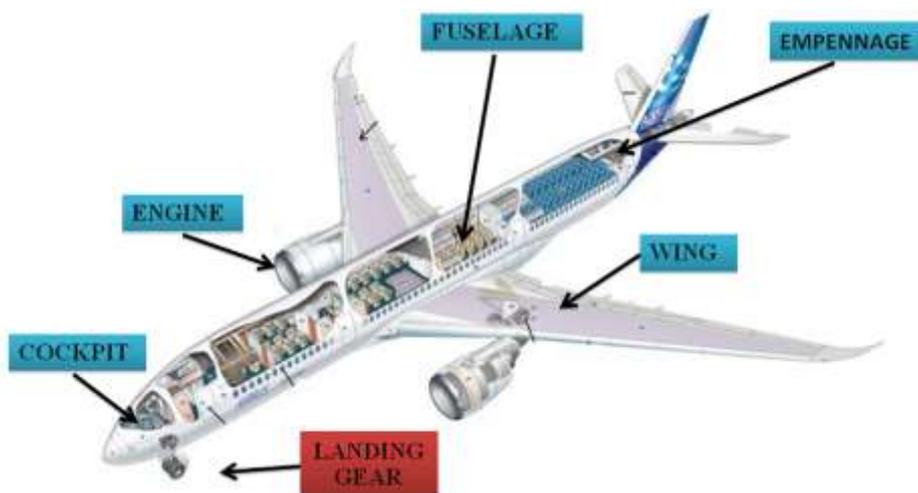


Figure 1 Aircraft Details

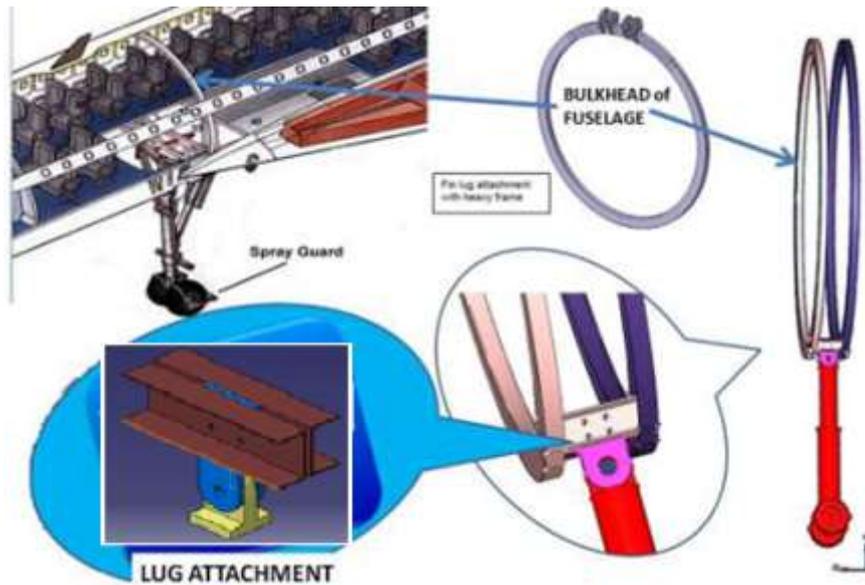


Figure 2 Location of lug joint

### Components of Lug joint

The following is a list of major components found in a Lug joint.

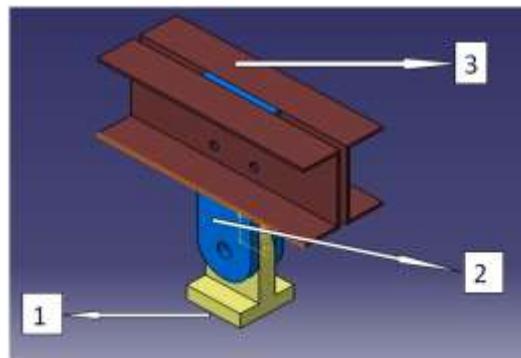


Figure 3 shows Cross-section of lug attachment bracket showing lug components (1) Tongue (2) Fork (3) Attachment bracket

- **Tongue**– It is a part of lug joint which is connected between fork and landing gear wheel alignment.
- **Fork** is used to connect between attachment bracket and tongue
- **Bracket** is used to connects fuselage and fork through riveted joint

## 2. MATERIAL SELECTION, MODELING AND MESHING OF LUG JOINT

The material used for lug joint must be least affected at high load. Also lug joint material must have long life and must be mechanically strong. During earlier days, aluminum alloy 2025 was used as. Nowadays aluminium7075 T6 materials were used due to low density high thermal conductivity, good cast ability and sound high temperature strength.

Lug joint material must have the following properties:

- Retain its properties at high temperatures
- High tensile strength at higher temperature
- High yield strength
- Lower thermal expansion
- High thermal conductivity

**Aluminum - 7075 T6 alloy** used a slug joint material consisting of 1-5.6% of zinc, 2.1-2.5% of magnesium and.

### 3. GEOMETRIC DIMENSIONS OF JOINT LUG

Here the commercial transport aircraft of 150-200 seating capacity is considered.

#### CALCULATION OF LOAD ON LUG JOINT

The specifications used in calculation are mentioned below

$W = \text{Max weight} = 36000\text{Kg} = 353.16\text{kN}$

$B = \text{Wheel base length} = 6.47\text{m}$

$L = \text{Length of the Fuselage}$

$K = \tau\text{swald's efficiency factor}$

$\mu = \text{Friction co efficient} = 0.5$

$T = \text{Thrust of engine}$

$\text{Ground and aircraft centre of gravity clearance} = 6\text{m}$

$S = \text{Platform area of lifting}$

$S_{wf} = \text{Platform area of wing fuselage}$

$S_H = \text{Platform area of horizontal tail}$

$V_L = \text{Velocity of landing} = 132 \text{ knots} = 67.90\text{m/s}$

$V_C = \text{Velocity of cruise} = 438 \text{ knots} = 225\text{m/s}$

$\text{Aspect Ratio} = 2.5$

$\text{Eccentricity} = 0.92$

$\text{Wing fuselage fluid flow co efficient} = 0.205$

$L_H = \text{Lift of horizontal tail}$

$\text{Horizontal wing fluid flow co efficient} = 1.1$

$C_{D0} = \text{Co efficient of drag flow} = 0.0305$

$\Delta C_L = \text{Coefficient of lift} = 0.6$

Where

$F_n = \text{Vertical load (kg)}$

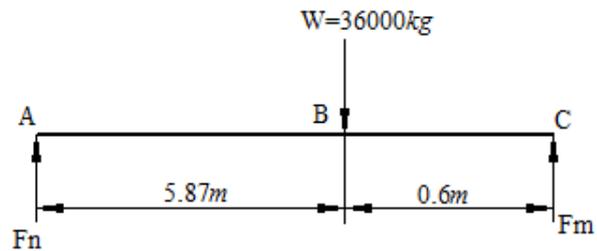
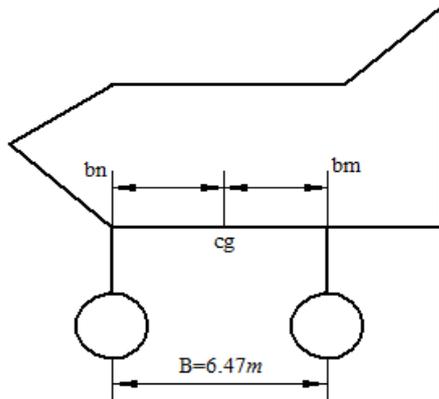
$F_h = \text{Horizontal load (kg)}$

$P = \text{Resultant load (kg)}$

$\sigma = \text{yield stress}$

$\text{Total weight of air craft under 1G condition} = 12000\text{Kg}$

$\text{Total weight of air craft under 3G condition} = 36000\text{Kg}$



$$\sum M_c = 0$$

$$(F_n * 6.47) - (36000 * 0.6) = 0$$

$$F_n = 3338.48 \text{ kg}$$

$$F_h = 0.5 * F_n$$

$$F_h = 1669.24 \text{ kg}$$

$$P = \sqrt{(F_n^2 + F_h^2)}$$

$$P = \sqrt{(3338.48^2 + 1669.24^2)}$$

$$P = 3.732 * 10^2 \text{ kg}$$

### DESIGN OF PIN

$$\sigma = P/2A$$

$$0.7 * 51.47 = 1866.26/A$$

$$A = 51.797 \text{ mm}^2$$

$$(\pi/4)d^2 = 51.797$$

$$d = 10 \text{ mm}$$

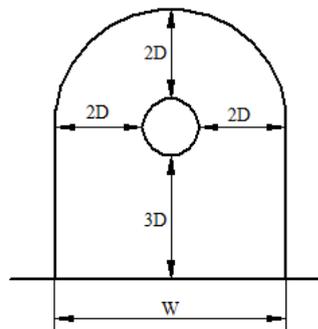
Where, A=cross sectional area of pin (mm<sup>2</sup>)  
d=diameter of pin (mm)

### TONGUE DESIGN

$$d = 10 \text{ mm}$$

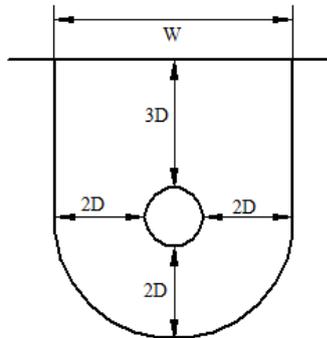
$$2d = 20 \text{ mm}$$

$$3d = 30 \text{ mm}$$



### DESIGN OF FORK

- d = 10mm
- 2d = 20mm
- 3d = 30mm

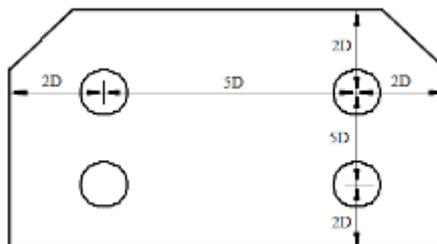


### RIVET DESIGN

- $\sigma = P/4A$
- $0.7 * 51.47 = 3732.53 / (4 * A)$
- $A = 25.89 \text{mm}^2$
- $(\pi/4) d^2 = 25.89$
- $d = 6 \text{mm}$
- Where  $\sigma$  = Shear stress ( $\text{kg/mm}^2$ )
- $A$  = area of cross section of rivet
- $d$  = diameter of rivet (mm)

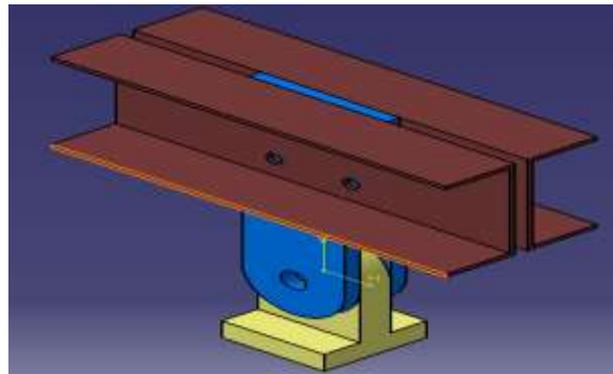
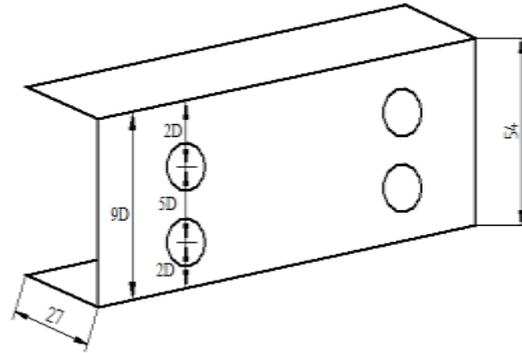
### DESIGN OF FORK (PART 2)

- 5d = 30mm
- 2d = 12mm

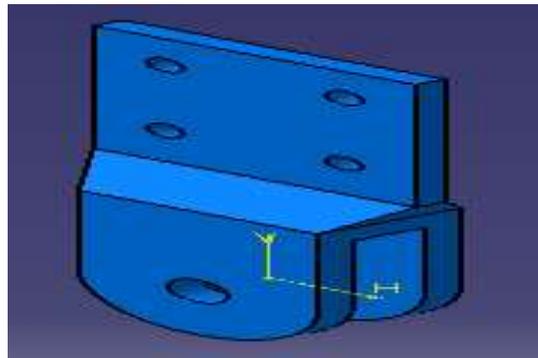


### DESIGN OF FLOOR BEAM (BRACKET)

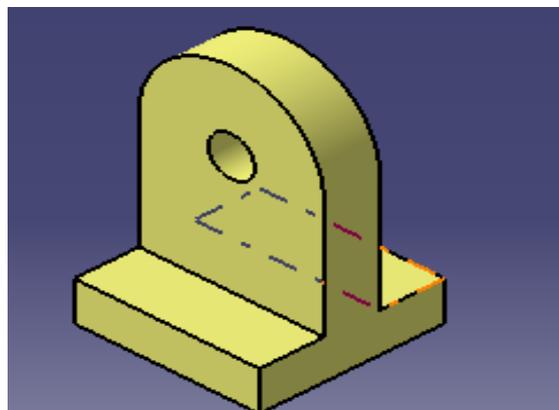
- Since the rivet has to be inserted in hole, dia of hole = dia of rivet
- $9d = 9 * 6 = 54 \text{mm}$
- $2d = 2 * 6 = 12 \text{mm}$
- $5d = 5 * 6 = 30 \text{mm}$
- $t = 2 \text{mm}$
- where,  $d$  = rivet diameter
- $t$  = bracket thickness



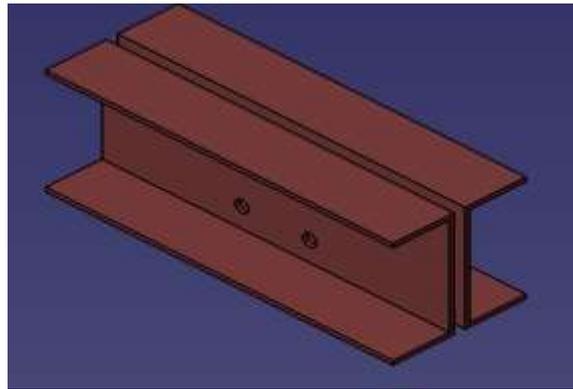
**Figure 4** 3D model of lug joint



**Figure 5** CAD model of fork



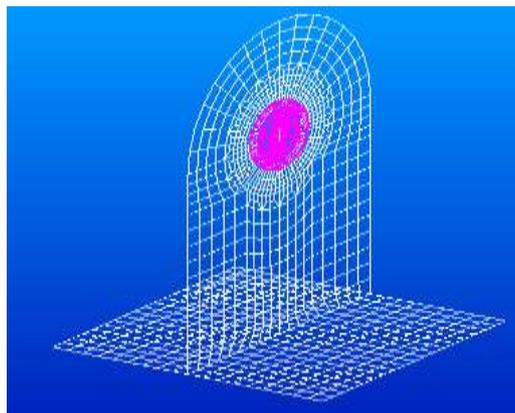
**Figure 6** CAD model of tongue



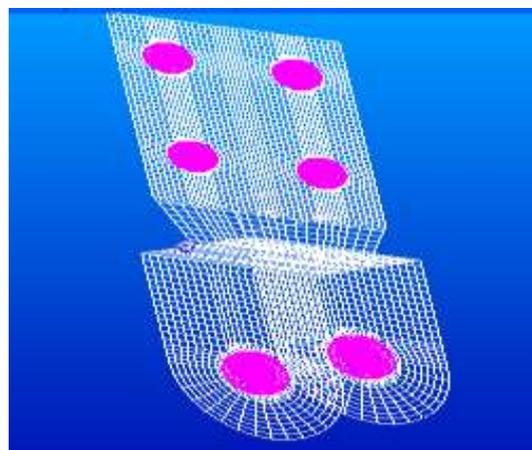
**Figure 7** CAD Model of bracket

### Meshing of Lug joint

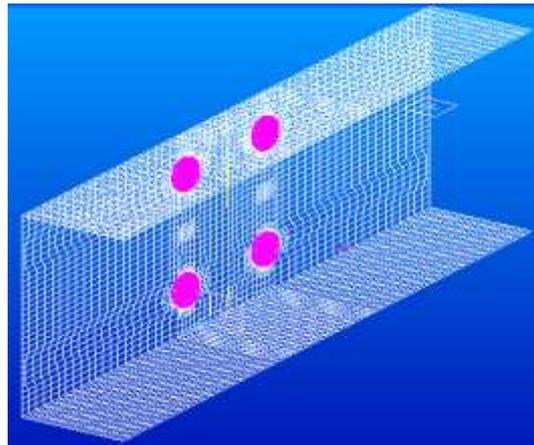
Finite element meshing was carried out for lug joint using PATRAN tool. The Lug joint was meshed with the QUAD and TRIA elements depending on the complexity of the structure. QUAD4 mesh was employed for Lug joint considering element size 10. Figure shows the meshed model of the lug joint. Total number of nodes were 21810 and total number of elements was 20282, in which 37352 linear hexahedral elements were of type C3D8T and 160 linear pentahedral elements were of type C3D6T. Three dimensional nonlinear coupled thermo-mechanical solid elements with eight nodes C3D8T were used for thermal and structure analysis.



**Figure 8** Meshed model of tongue



**Figure 9** Meshed model of fork.



**Figure 10** Meshed model of bracket

**Table 1** Shows Type of element and component details

Component	Idealization	Type of Element
Tongue	Solid	Quad
Fork	Solid	Quad and Tria
Floor beam	Solid	Quad

### Quality verification summary of lug joint

Aspect=max 2.5

Warpage=max5

Jacobian ratio=max 0.9

Scew=max 50

**Table 2** below shows total number of Nodes & Elements used in analysis

PARTS	TYPES AND NO OF ELEMENTS		NO OF NODES
	QUAD	TRIA	
TONGUE	1072	0	1173
FORK	5602	4	6025
FLOOR BEAM	13608	0	14612
TOTAL	20282	4	21810

## 4. LOADS AND BOUNDARY CONDITIONS FOR LUG JOINT

### 4.1. Loading and Boundary conditions

The figure shows the loads and boundary conditions applied in the FEM model. The load will create the bending moment. All six degrees of freedom are constrained in the top and bottom holes of landing gear lug attachment.

The Patran software is used to mesh and prepare the model as shown in the figure 4.3. The model assembled is extracted into Patran software and is meshed with QUAD and TRIA elements. The pins are connected using multi point constraint (MPC).

Also here the parameters such as aspect ratio, jacobian, warpage, skew etc. are checked. And also the discontinuities at the boundaries are checked and corrected in the meshed model.

The loading condition and boundary conditions applied on the model are shown in the figure 4.3. The displacement of the attachment bracket is fixed in all degrees of freedom. That is Translation (123) and Rotation (456) is fixed as shown in figure . The load obtained is distributed uniformly over the lug.

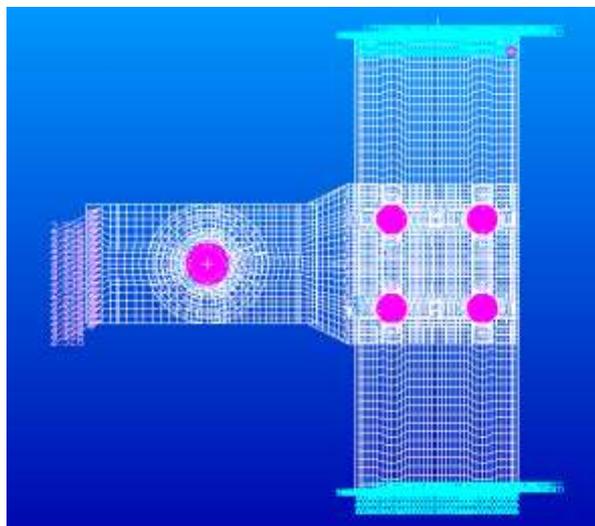
- Finite Element Model of lug attachment used for landing gear is shown in figure . Quad4 and TRIA3 elements are used for meshing. TRIA 3 elements are used to obtain finer mesh.

Different parts of the landing gear Lug Attachment Bracket are

- Tongue, Fork, Bracket

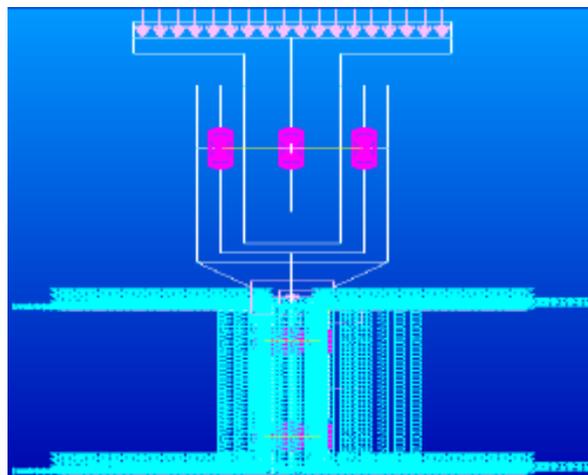
Load case	Stress(kg)
1.36000kg	748.88kg
2.45000kg	55.72kg

The mesh generated for each and every component is shown in the figure



**Figure 11** lug joint constrained in all three directions (X Y Z) i.e. <0 0 0>

Loads and boundary condition of lug

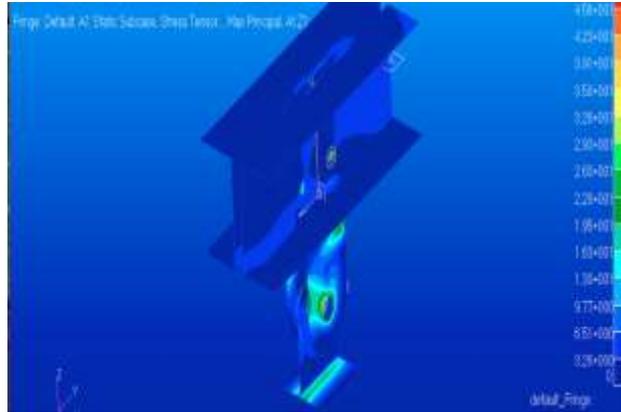


**Figure 12** Magnified view of mechanical loading

## 5. RESULTS AND DISCUSSIONS

The vertical load stress contour is plotted and shown in the figure below. The maximum stress found in the model is 45.66kg. The yield stress of material is 51.47kg.  $45.66 < 51.47$

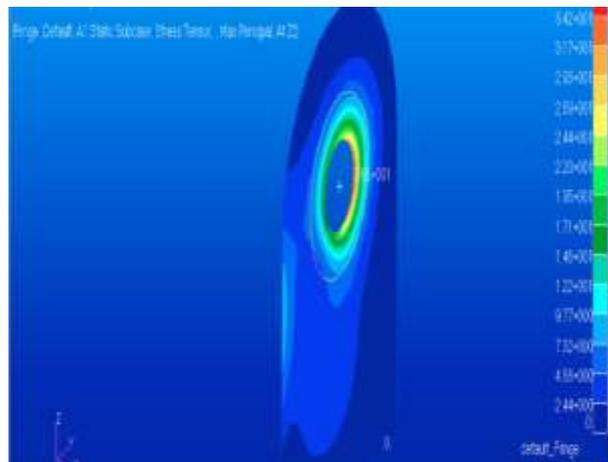
Hence the design is safe.



**Figure 13** Stress and deformation contour of Aluminium 7075 T6 material subjected to vertical load

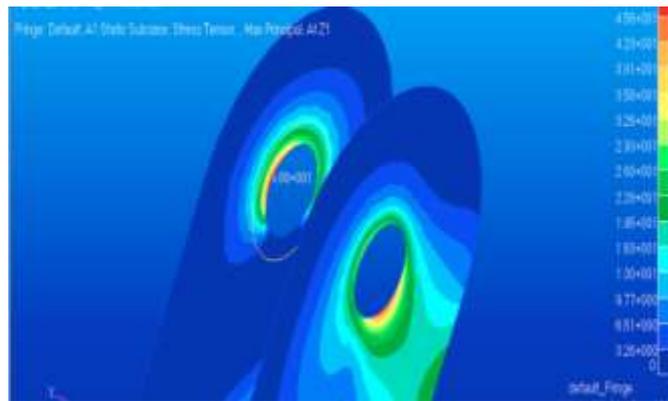
Maximum stress (kg/mm <sup>2</sup> )			
	Tongue	Fork	Floor Beam
Strength of material approach	51.47	51.47	51.47
FEA Approach	34.2	45.6	45.6

Stress values at the lug hole and the displacement contours are shown in the figures. A maximum stress of  $34.2 \text{ kg/mm}^2$  is observed at the midpoint of the hole section.

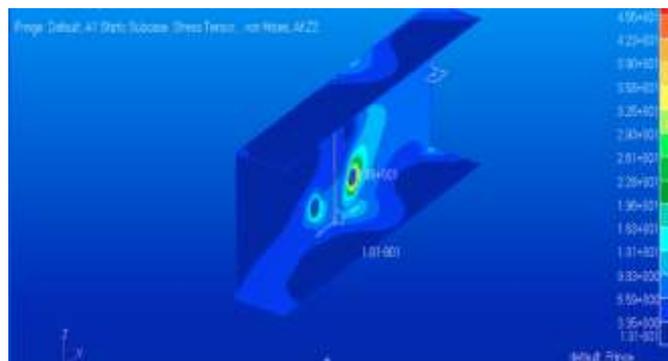


**Figure 14** Maximum stress in the Tongue

The stress distribution without considering the fork is shown in Figure. This Figure shows that the maximum stress induced in the lug joint was  $45.6 \text{ kg/mm}^2$  for Al 7075 T6. Maximum stress obtained was much below the yield stress of the material used for lug joint.



**Figure 15** Maximum stress in the Fork.



**Figure 16** Maximum stress in the bracket.

## 6. CONCLUSION

- The maximum tensile stress is obtained at one of the lug holes by carrying the structural analysis of landing gear lug attachment bracket.
- Validation of FEM approach is done with plate with a circular hole as the FEM approach is used to analyze the lug joint.
- Maximum tensile stress of  $45.6\text{kg/mm}^2$  is observed in the lug.
- Mesh independent value of maximum stress is obtained after much iteration.
- Initially the load is calculated by strength of material approach & factor of safety is taken as 1.5. Based on this lug dimensions are obtained. The drag load 0.25 times of total vertical load.
- The lug joints are meshed in Patran and analyzed in Nastran, the stress contour is plotted and maximum stress is found below the stress limit thus the design is safe. And also the deformation contour is plotted, deformation is found below the safe limit thus the design is safe.
- The analytical and numerical results are compared. Hence the validation is done.

## SCOPE FOR FUTURE WORK

- Different configurations of lug joints can be considered.
- The work can be carried for different materials such as composites.
- Crack initiation studies can be done.
- Test set up of fatigue testing is needed to do the analysis of lug joint

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