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Effect of Infinite Friction during Load Transfer in Lug Joints

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Abstract: **Pin joints are structural elements which are extensively used in mechanical and structural design. Friction plays a significant role in fastener joints in redistributing the stress and there by affecting fatigue life. In the current this thesis lug joint with rigid and interference fit is considered. It is well known that as the load is increased on the interface, localised relative slip is initiated between the pin and the lug. This initiated slip is due to the shear forces on parts of interface overcoming the local frictional forces. Therefore the region of slip spreads non-linearly with the applied load. Slip amplitude for interference fit with infinite friction is determined by inverse technique. This slip region leads to high stress concentration at the edge of the hole influence difficulties in fretting damage, crack initiation crack growth life.**

Keywords: **fastener joints, interference fit, friction co-efficient, proportional interference, slip region.**

I. INTRODUCTION

Fatigue causes structural damage, This occurs when material undergoes cyclic loading and fretting damage .Due to fretting crack can initiate in fretting zone ,Hence crack propagates into the material .Lug joints primarily to transfer load from one structural components to other like wing root fitting , under carriage connections ,Pylon attachment etc. are the locations of fretting damage occurrence. At surface interface of lug-pin, Fretting happens and roughness of the surface considered as major factor. Interference fit with infinite friction coefficient for various increments in load reduces the radial stresses and increases the shear stresses at the critical location and after reaching critical load, shear stress increases but slip initiate at the interface. With assistance of known slip region of infinite friction, the actual slip region for defined friction coefficient of interference fit has to be determined. This actual slip region is more than the known slip region of finite friction lug with interference fit. This amplitude of slip develops fretting damage and reduces the life of joints.

1.1Geometry of lug-pin

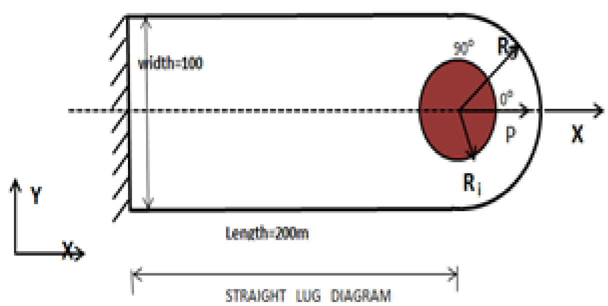


Fig 1.1.1Geometry of lug-pin

Parameter	Geometry (mm)
Length	200 mm
Outer radius	50 mm
Inner radius	20 mm
Thickness	1 mm

Fig 1.1.2 Dimension of the lug

1.2 Component materials of lug-pin joint

Component	Material	Poisson's ratio	Young's modulus	Tensile strength	Yield strength
Lug	Aluminium	0.3	73000 Mpa	483 Mpa	345 Mpa
Pin	Mild steel	0.27	210000 Mpa	410 Mpa	250 Mpa

Fig 1.2 Material Properties Used In Analysis

1.3 Stress analysis

To know the stress fields and stress concentrations for various applied loads of 2d lug joint, finite element method (FEM) is adapted. Fem is used for structural analysis like static, linear, dynamic, buckling, material nonlinear, geometry nonlinear, fracture mechanics, composite structures, contact stress, thermal problems. Method of interpolation is solved by FEM.

1.4 Geometric modelling

To model a lug geometry MSC PATRAN uses input parameters. The design of lug is accomplished through geometric parameters. A systematic lug model considered with the symmetric boundary conditions. ½ or ¼ of the original or full structure consider to decrease the total no of elements and nodes. At the symmetry or ½ refined mesh used and coarse mesh used for full model there by reduction in no of elements than full model and the size of analysis domain reduced by factor of two which consumes less time and higher accuracy in results.

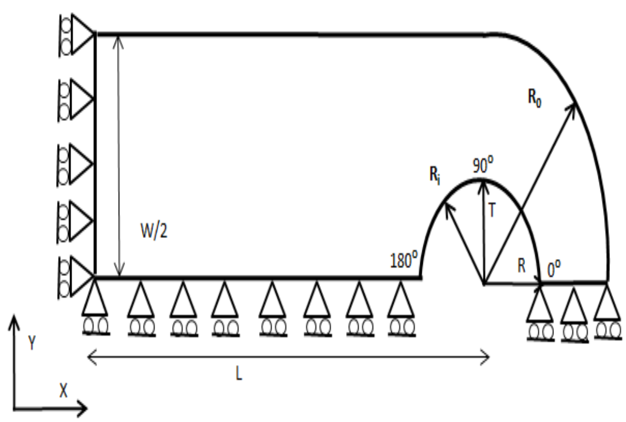


Fig 1.4Symmetric Lug Diagram

Here 2 co-ordinate systems are used in the modeling. i.e Cartesian (X,Y,Z) and polar co-ordinate (r,θ,z) system. Cartesian is a reference co-ordinate and polar is an analysis coordinate system.

1.5 Element Shape

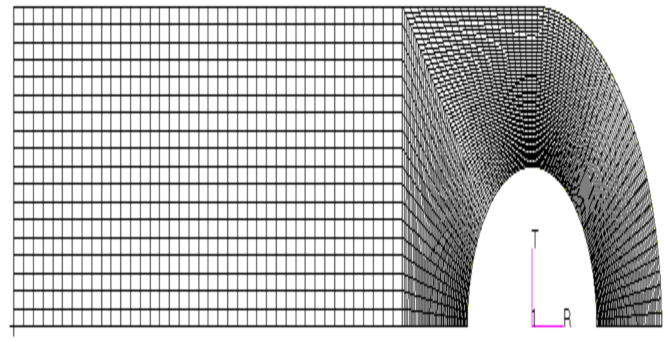
Displcement Function

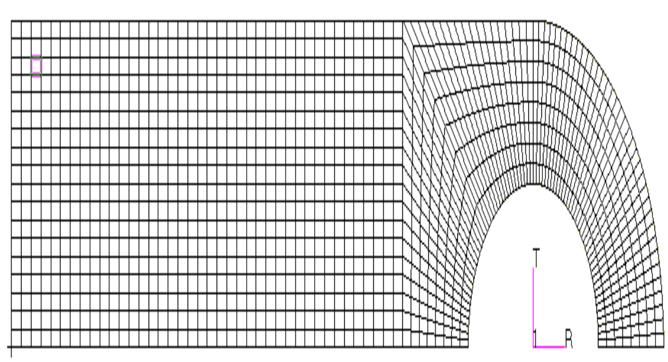
For linear triaingular element is$u_0=a_0+a_1x+a_2y$

For linear quadrilateral element is $u_0=a_0+a_1x+a_2y+a_3xy$, The extra term which present in the linear quardrilateral element ensures the results more accurate. Hence throughout the analysis linear quardrilateral element is used.

1.6 Refined meshin the critical region

Bias factor= maximum element length/ minimum element length= L2/ L1





1.6 comparision of biased and unbiased mesh

1.7 Inverse technique of loading

In pin loading the pin will move with a load which leads to complicated geometry analysis.In inverse technique due to rigid body displacement at the far the pin will be stationary position.hence reduces complication in geometry.

Loading condition	**Interface constraint force**	**Far-end constraint force**
Pin loading	351.97 (N)	264.67 (N)
Inverse loading	351.97 (N)	264.67 (N)

Fig 1.7Comparison of Pin and Inverse Loading

Because of same results in pin loading and inverse loading, we have used inverse loading throughout the analysis for convinience.

II. RELATED WORKS

2.1Friction

Friction force is the force exerted by the surface as an object moves across it or makes an effort to move across it. Two types of friction force sliding and static friction. Though it is not always the case, the friction force often opposes the motion of an object. Friction depends upon the nature of the two surfaces and upon the degree to which they are pressed together. The maximum amount of friction force can be calculated by using the formula below.

FRICTIONAL FORCE ($F_{friction}$) =μN

Where μ=coefficient of friction, which is the quantity that expresses the dependence of frictional forces on the particular surfaces in contact.

2.2 Slip

At the lug-pin interface there is occurrence of slip, this slip is characterized by relative tangential displacement between originally adjoining points. There are three cases for relative tangential displacement explained as follows.

Case (1): If the interfacial shear stress less than μ times radial stress, then there is no relative tangential displacement between the lug-pin, from there no slip.

$|\tau_{r\Theta}| / |\sigma_r| < \mu$

Case (2): If the interfacial shear stress greater than μ times radial stress, then there is a relative tangential displacement between the lug-pin, hence there will be slip.

$$|\tau_{r\Theta}| / |\sigma_r| > \mu$$

Case (3): If the tangential shear stress is equal to the μ time's radial stress, then there will be a start of relative tangential displacement between lug-pin. Hence slip starts at interface.

$|\tau_{r\Theta}| / |\sigma_r| = \mu$

2.3 Boundary conditions

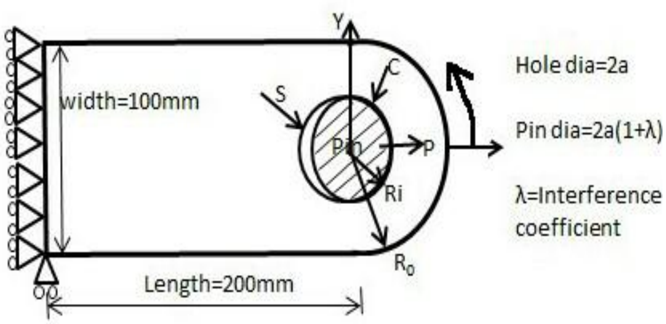


Fig 2.3 Representation of Lug Joint (S, C) S = Separation, C = Contact

Separation region

In this case there is no contact between lug-pin, hence boundary conditions becomes as follows

σ_r of lug = 0 and σ_r of pin = 0, $\tau_{r\Theta}$ of lug =0 and $\tau_{r\Theta}$ of pin = 0

Contact region

This case there is a contact between the lug-pin interface, hence boundary conditions are as follows

$\sigma_{r\Theta}$ of lug = $\sigma_{r\Theta}$ of pin

U of lug = U of pin + aλ

V of lug = V of pin,

σ_r of lug= σ_r of pin

These boundary conditions vary accordingly for different types of fits inserted into lug joint of contact and separation regions.

2.4 Interference fit with infinite friction coefficient

When the diameter of the pin is greater than the diameter of the hole, this kind of fit is called as interference fit.in this the considered proportional interference is positive. There will be uniform radial stress all along the interface due to the pin diameter greater than hole diameter.

The radial stress changes from compressive to tensile then there will be a separation between pin and plate.by increasing load P, on loading side compressive stress will be more where on the opposite side reduces. By increasing the load continuously at some point compressive stress will become zero and separation will start according to the level of the load increased.

2.4.1 Boundary conditions for interference fit

Interference fit with infinite friction: for this the interface of the lug and pin is 0^o to 90^o **at the interface**: Radial displacement U_r=aλ, a= radius of the lug, λ =proportional interference

Tangential displacement U_Θ =0

For Symmetric Geometry, Displacement in (Y, Z) direction, i.e, $U_y = U_Z = 0$

Rotation about(X, Y) is zero, i.e, $\theta_x = \theta_y = 0$

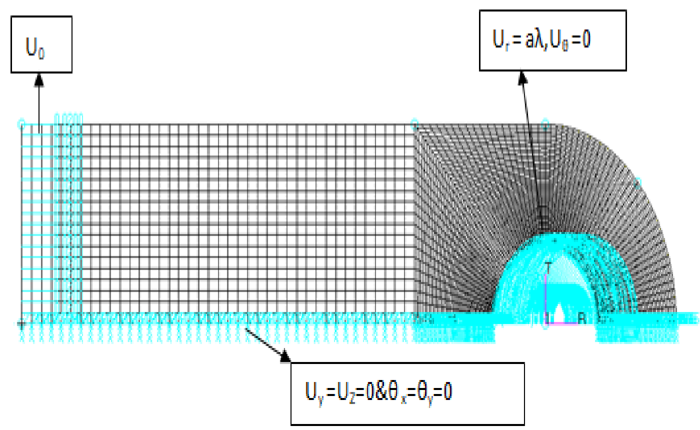


Fig 2.4.1 Interference Fit With Infinite Friction Boundary Condition

2.4.2Analysis for interference fit with infinite friction

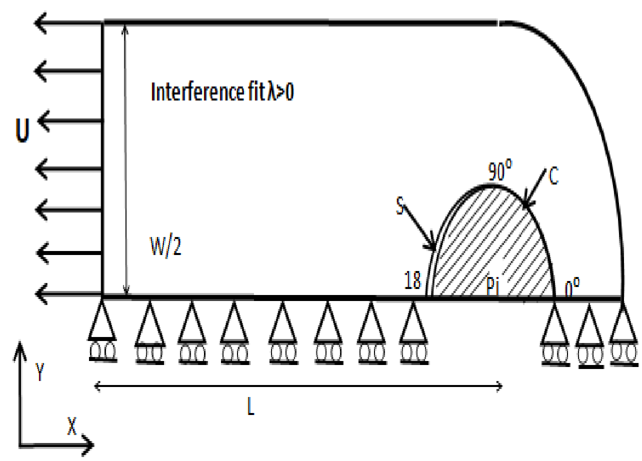


Fig 2.4.2 Symmetric Lug with Interference Fit

III. RESULTS

3.1 Radial stress distribution for λ=0.0035

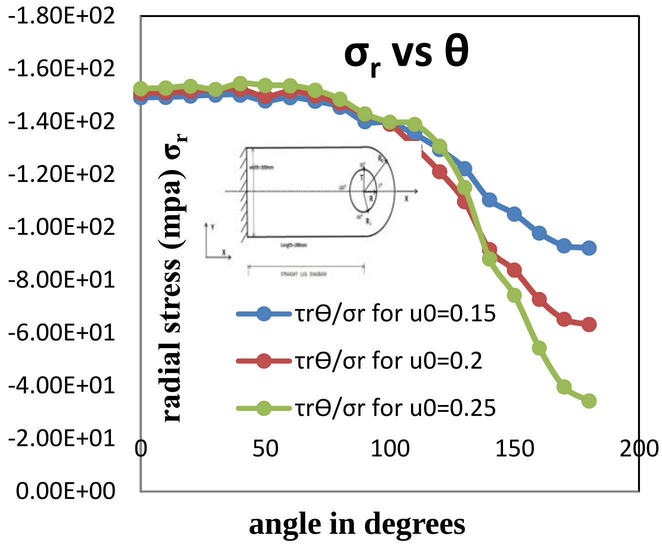


Fig 3.1 σ_r **vs.θ** for λ=0.0035 for interference fit

Above figures shows that for various proportional interface values there is increase in radial stresses up to some level and sudden drop with increase in displacement load. Hence separation starts at the interface of the interference fit.

3.2 Shear stress distribution for λ=0.0035

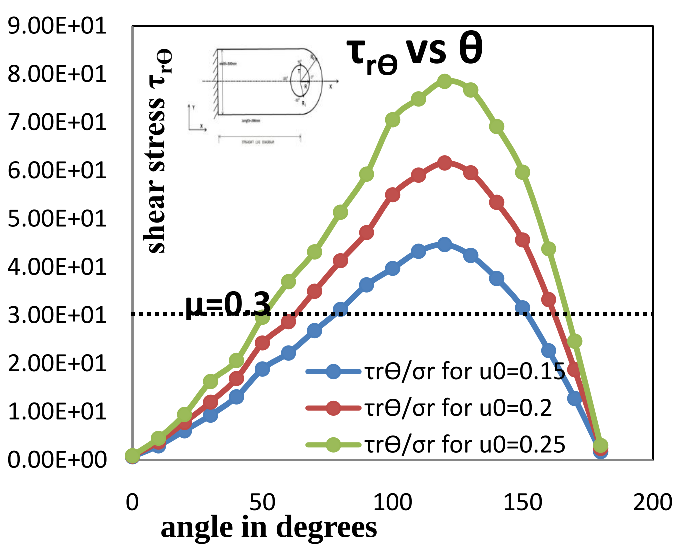


Fig 3.2 for λ=0.0035, $\tau_{r\Theta}$ **vs. θ** shear stress distribution

Above figures shows that Shear stress also increases upto certain level and decreases by increasing in displcaement load.

3.3 Slip region for infinite friction coefficient

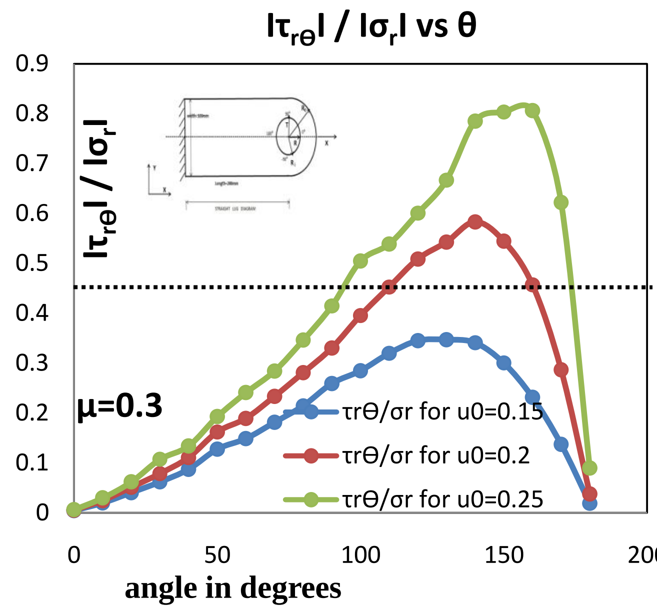


Fig3.3 $|\tau_{r\Theta}|$ / $|\sigma_r|$ vs. **Θ** for **λ=0.0035**

If the $|\tau_{r\Theta}|$ / $|\sigma_r|$ ratio is less than, equal,greater than coefficient of friction μ=0.3,then there is no slip, start of the slip, generated slip regions are known .by increment in load slip spreads accordingly.

3.4 slip region for λ=0.0035

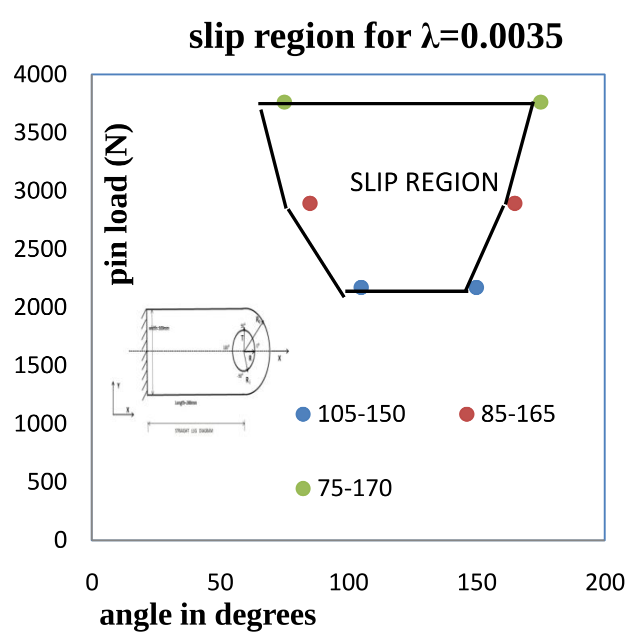


Fig 3.4 slip region of interference fit for λ=0.0035

3.5 slip region for various λ

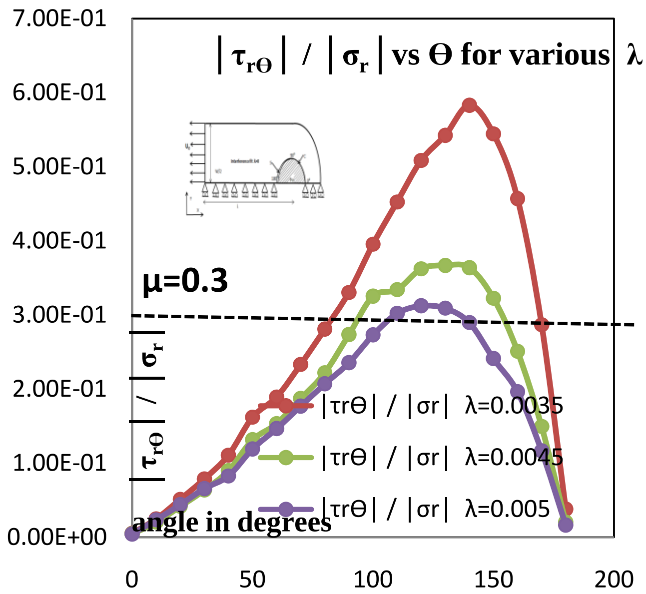


Fig 3.5 $|\tau_{r\Theta}|$ / $|\sigma_r|$ vs.Θfor various λ of interference fit

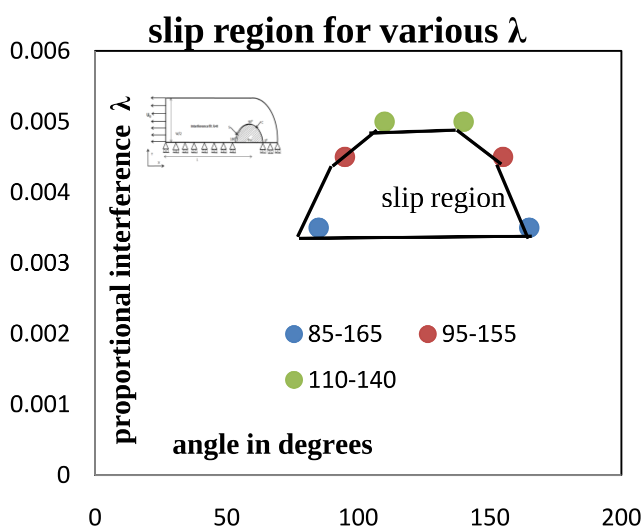


Fig 3.5.1 region of slip for various λ for interference fit

From above fig we can observe that by incresing proportional interface the region of slip decreses i.e for λ=0.0035 slip region is 85º to 165º, for various increment in values of proportional interference slip reduces.

IV. CONCLUSION

2-D stress analysis of lug- rigid pin joint is carried out and the amplitude of slip for interference fit with rough interface with infinite friction has been determined. The push fit amplitude of slip is high,due to more slip in push fit the fretting is more and life of lug lug joint reduces than interference fit. this slip region used to know stress concentration of the model.from the results the slip region which is useful to find where fretting damage and fatigue life of the joint occurs.

V. FUTURE ENHANCEMENT

- slip amplitde of lug joint with interference fit with finite friction coefficient has been analysied for further problems.
- Actual Slip region for finite friction has been determined for straight lug joint.with the help of this actual slip amplitde we can find fatigue life and crack initiation problems .
- Tapered lug with finite friction problems are taken for further analysis
- For validation of theoretical calculations ,a strctural testing of wing fuselage lug is considered.
- Instead of metals , composite materials can be used

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