Effect of Friction during Load Transfer in Lug Joints

P. Neelima & B. Dattaguru

Department of Aerospace Engineering, Jain University, Jakkasandra Post, Kanakapura Road, Bangalore, India 562112

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 paper lug joint with rigid push fit is considered. It is well known that as the load is increased on the interface, localized 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 push fit with smooth and rough interface is determined by inverse technique. 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 push fit, 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

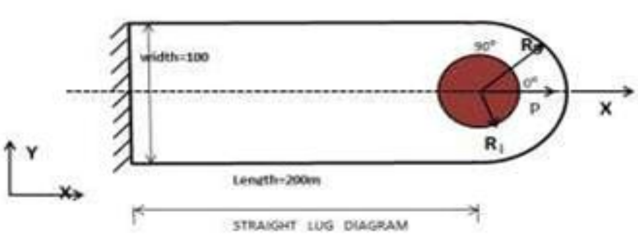


Fig 1.1.1Geometry of lug-pin

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	Aluminum	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

Composite structures, contact stress, thermal problems. Method of interpolation is solved by FEM.

1.4 Geometric modeling

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 decreasing 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.

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,

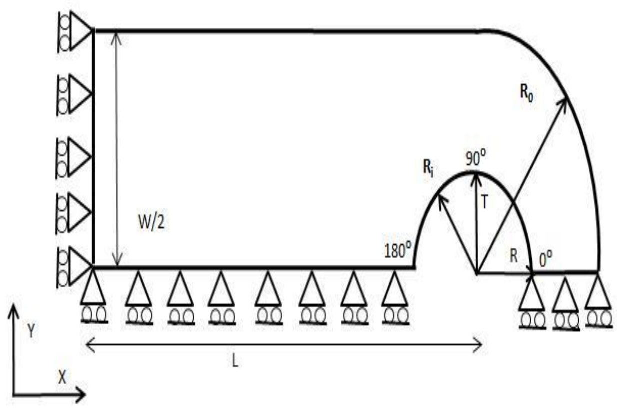


Fig 1.4Symmetric Lug Diagram

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.

1.5Element Shape

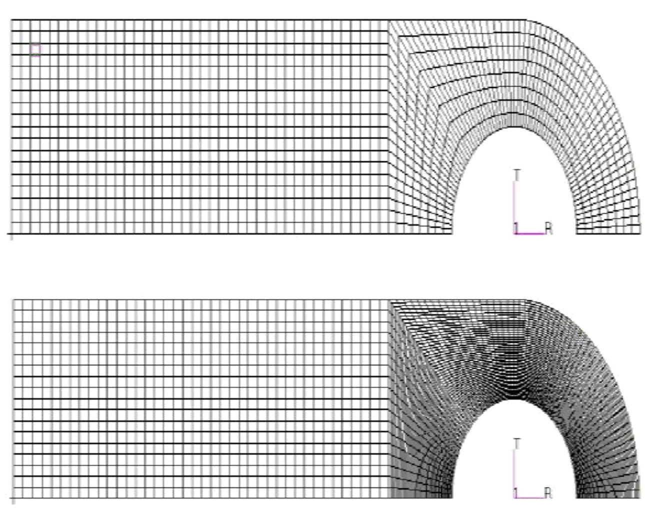
Displacement Function

For linear triangular 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 quadrilateral element ensures the results more accurate. Hence throughout the analysis linear quadrilateral element is used.

1.6 Refined mesh in the critical region

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



1.6 comparison 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 convenience.

II. RELATED WORKS

2.1Friction

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

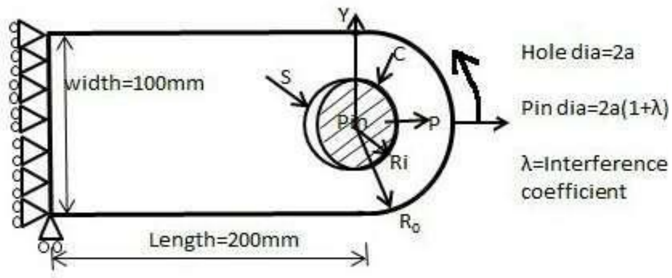


Fig 2.3 Representation of Lug Joint (S, C)
S = Separation, C = Contact

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 interfaces; 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 Push fit

When the diameter of the pin is same as diameter of the hole, this type is called as push fit. In this case proportional interface will be equal to zero. In case of push fit even for a small load it will separate from the 90°, also load and displacement will be linear. in this case contact of separation is constant.

2.4.1 Push fit with smooth interface:

At the interface of lug and pin 0° to 90°, Radial displacement $U_r = 0$

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

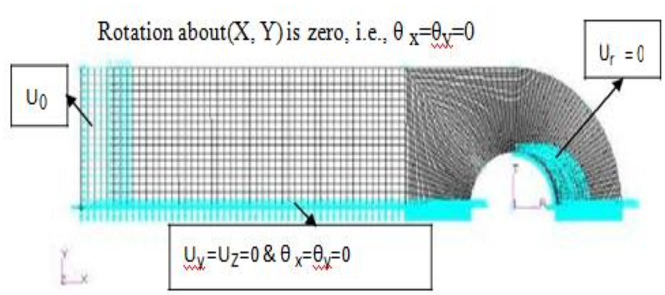


Fig 2.4.1 Push Fit With Smooth Interface Boundary Conditions

2.4.2 Push fit with rough interface:

At the interface of lug and pin 0° to 90°: $U_r = 0, U_\theta = 0$

For Symmetric Geometry, $U_y = U_Z = 0$, $\theta_x = \theta_y = 0$

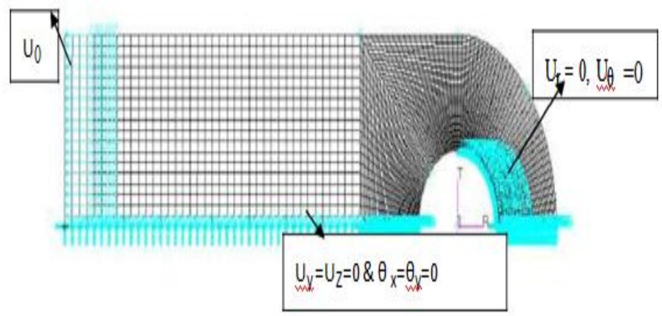


Fig 2.4.2 Push Fit With Rough Interface Boundary Conditions

III. RESULTS

3.1 Analysis of push fit with smooth interface

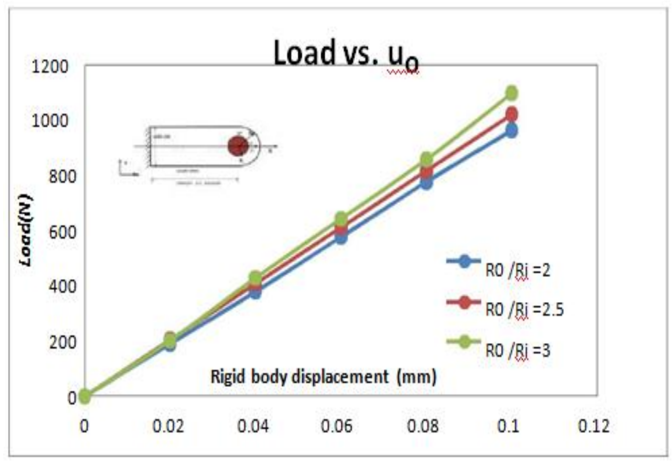


Fig 3.1.1 Load vs. U_0 for push fit with smooth interface

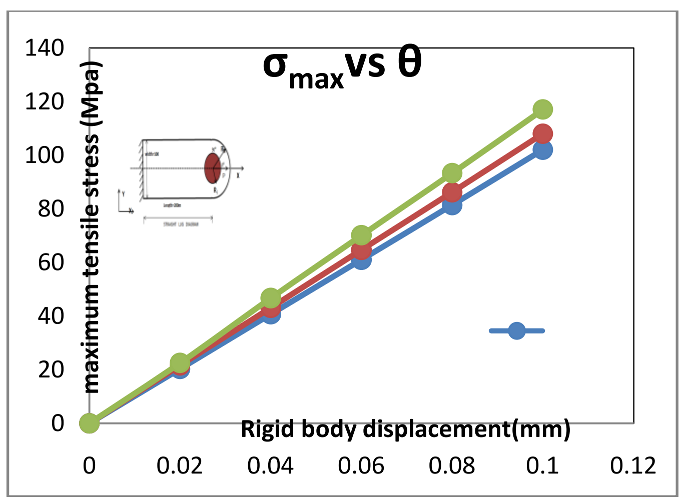


Fig 3.1.2 σ_{max} vs. θ for push fit with smooth interface

3.2 Analysis of push fit with rough interface

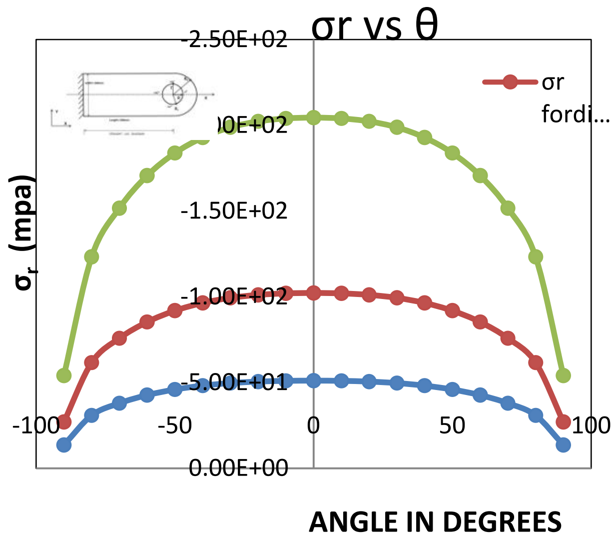


Fig 3.2.1 radial stress variation for push fit with rough interface

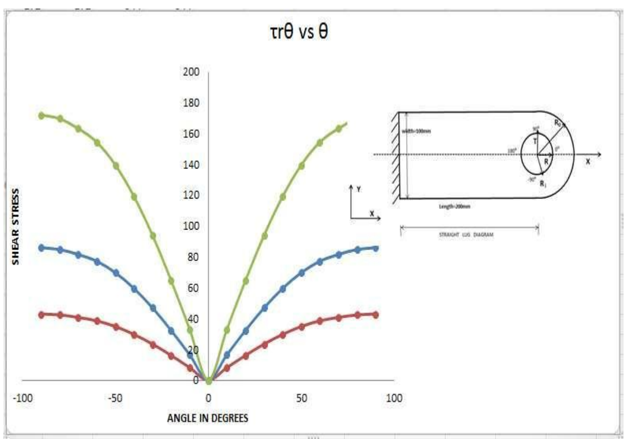
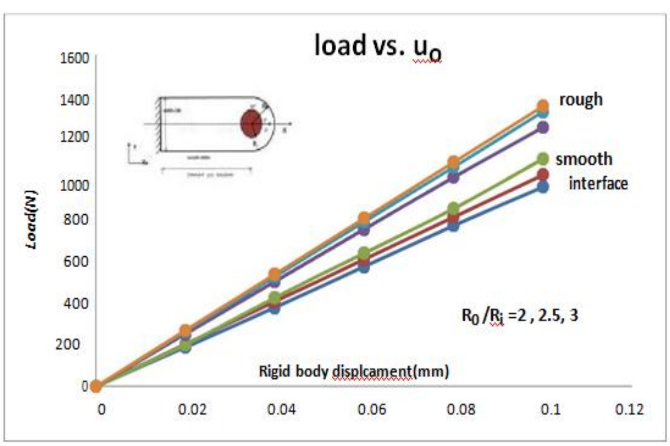


Fig 3.2.2 shear stress variation for push fit with rough interface

Because of separation region boundary condition the shear stress at separation is zero and increases from 0º to 90º as shown in fig



3.3 Slip region for push fit

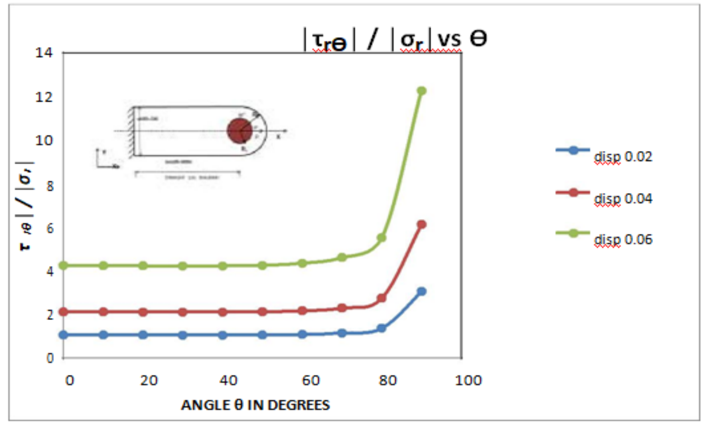
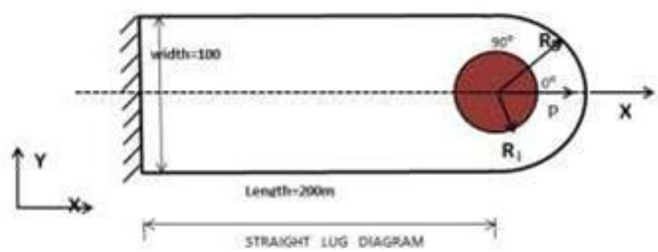


Fig 3.3.1 │$\tau_{r\theta}$│ / │σ_r│ **vs. Θ** for push fit with rough interface



From the above diagram we can observe that for the considered coefficient of friction μ=0.3, the ratio of │$\tau_{r\theta}$│ / │σ_r│ is greater than μ. Hence there is a slip at entire region from 0º to 90º.i.e full region it slips.

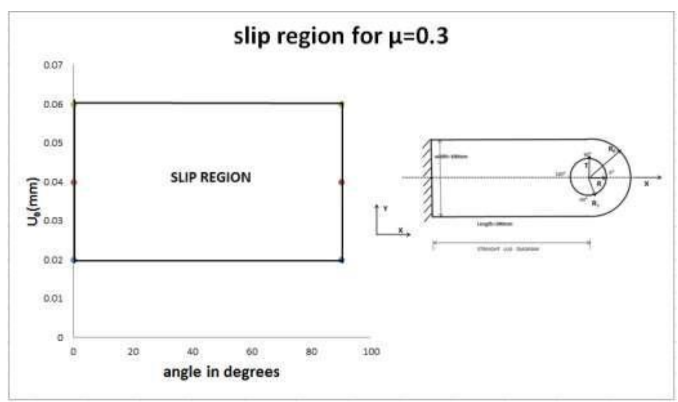


Fig3.3.2 Slip Region for Push Fit with Rough Interface

For various displacement loads slip region is shown in above fig. which slips entire region for lug with push fit.

IV. CONCLUSION

2-D stress analysis of lug- rigid pin joint is carried out and the amplitude of slip for push fit with smooth and rough interface 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

- Actual Slip region for finite friction has been determined for straight lug joint. With the help of this actual slip amplitude 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 structural testing of wing fuselage lug is considered.
- Instead of metals ,composite materials can be used

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