Review on Fatigue and Damage Tolerance Evaluation of Aircraft Lug-Joint

Pratik Phadnis[1*], G.Anilkumar[2*], T. Madhusudhan[3*]

[1]*PG Scholar, Machine Design, Mechanical Department, SJBIT, Bangaluru, Karnataka, India.*

[2]*Associate Professor, Mechanical Department, SJBIT, Bangaluru, Karnataka, India.*

[3]*Professor, Mechanical Department, SJBIT, Bangaluru, Karnataka, India.*

**S J B Institute of Technology, Bangaluru-60, Karnataka, India*

Abstract: *Aircraft is one of the complex flying structures. In this the wings are the parts which generate lift to the aircraft. The wings are joined or attached to the fuselage through lug-joints. Spars are the important structural components of wings, the entire load is carried by wings through spars. There will be bending moment and shear effects produced and this effect shifts to the lug-joint. It has to withstand the fatigue loads, as generally damage is always due to fatigue loads. In this project bending loads are considered. First the static stress analysis is carried out then the fatigue life is predicted for lug joints for* ***certain boundary conditions using Miner's Rule.*** *Damage tolerance evaluation is made to avoid catastrophic failure of aircraft component. For different crack lengths Stress intensity Factor is calculated using MVCCI (Modified Virtual Crack Closure Integral) method. Also Crack arrest capability is obtained through evaluation of Residual stresses. Finite Element Method is used for analysis. In this paper for modelling Catia V5 tool is used and for analysis Abacus software is used.*

Keywords: lug joint, Damage tolerance, MVCCI Method, Residual stress.

1. INTRODUCTION:

1.1 Lug joints are important structural components of aircraft, which are widely used to connect different structural components of aircraft for example- wing fuselage attachment, landing gear links etc. Lugs are components with simple geometry and helps in better transmission of loads compared to bolts and nuts. Lugs are easy to assemble with major components Thus for lugs it is necessary to create design criteria's and analysis methods for damage tolerance of lugs.

1.2 Fatigue is localized damage which occurs when the material is subjected to cyclic loads. Fatigue phenomenon occurs when a component is subjected to continuous loading and unloading. Fatigue life prediction models are- (i) S-N approach, (ii) E-N approach, (iii) Damage tolerance approach. In Damage tolerance approach residual stress evaluation is done with fracture mechanics approach i.e. Miner's Rule is used for fatigue life prediction which states that ' damage fraction at any stress level is proportional to the ratio of no, of cycles of operation to the total no, of cycles that produce failure at the stress levels.

1.3 Damage tolerance is properties related to the ability to sustain flaws safely until the repair can be affect the part or component. The assumption made for this approach is that the flaw can exist in any component and such damages propagate with usage. In aerospace engineering part is said to be damage tolerant, if the maintenance procedure detects the flaw and then repair of damages and fatigue cracks before the damage reduces the residual strength below acceptable limit. Methods used to Evaluate stress intensity factor are – (i) Displacement correlation method, (ii) Virtual crack extension method, (iii) MVCCI method. And generally MVCCI method is used for evaluation.

2. LITERATURE SURVEY:

B.K.Sriranga [1]: Civil transport aircraft is used for analysis. At the time of flight at maximum lift, the wings will undergo highest bending. Fuselage and wings are attached through wing-fuselage brackets. Bending load joints are used for analysis. In this thesis he has used two

geometries which consist of I-spar and Lug-joints. For I-spar material used is Aluminum Alloy 2024-T351, and for lug part Alloy steel heat treated AISI-4340 is used as material. They have carried out Stress analysis and identified the maximum tensile stress position at lug holes and validation is carried out by considering plate with circular hole.

A.Cera [2]: He has used Railway bogie frame, that to he has paid attention to welded joints. He has used different Fatigue analyzing techniques that are analyzed using two approaches i.e. endurance limit and Goodman diagrams. In this thesis he has analyzed which material is more suitable for bogie frames, in account with accuracy and application and adopted FEM approach. In conclusion he has found out the critical areas of welded part through the Goodman diagram method and computed comparable results.

Liangmo Wang [3]: For the improvement of Aluminum wheel quality, new method is proposed for evaluating fatigue life. Abacus software is used for post processing operation. By the effects of mean loads, fatigue notches, scatter factor, size and surface finish factors; the stress amplitude is calculated by nominal stress method. S-N curve is used to predict the failure. The rotary fatigue bench test was carried out and showed that baseline wheel failed this particular test and crack initiation which was made, was around hub bolt hole area, which agreed the simulation. And concluded that FEA integrated with nominal stress method is efficient for predicting fatigue life.

M.V Mars [4]: Rubber components fail often due to fluctuating loads, due to crack initiation, growth and fail. In this he has listed currently available Fatigue life predicting approaches. In conclusion he proposed two approaches for analysis i.e. crack initiation approach is used extensively and it is advantageous also. But crack growth approach is having challenges in computing energy release rate which is associated with crack and predicting location and path of crack.

Gerard Carrier [5]: In this thesis he has proposed the methodology of fatigue analysis carried out for lug joint. The advanced computational techniques are mentioned for analysis as well as for design of metallic lug joints. In this thesis he has considered for joints of a helicopters. In this methodology he has first constructed 3d- geometrical design and induced non-linearities by clearances existing within components and fatigue life or analysis is carried by safe-life approach and evaluated the endurance for each stress levels.

S.B.Chikalthankar [6]: Connecting rod is the structural component on which cyclic loads are applied. Here they have predicted the connecting rod's life time. In this the complete methodology of FEA is proposed and fatigue study based on S-N theory is done and considered the modified Goodman diagram.

Abass Adeyinka Azeez [7]: In this thesis they have discussed the principles of Fatigue Analysis or failures. They have designed the verification test set-up for fatigue, to validate the performance of dynamic testing machine. By the research they have designed a set-up called 4-Point fully reversed bending for dynamic testing. He has concluded that dynamic testing machine serves for various laboratory works and helps for structural design tests also.

Robert Stone [8]: In this paper they have proposed the proper methods for spring manufacturers to estimate the fatigue life of a helical compression springs when the design phase is in progress. It includes S-N curves, Weibull distribution and Goodman's modified diagrams. He has predicted the life using modified diagrams. The calculations are compared with the graphical methods of traditional approach. Results are found out by interpreting with Weibull distribution.

Ambrish Tiwari [9]: Considered the example of connecting rod as it under goes high fatigue stress always. During development phase numerical tools will be used, so it is designed based on mechanisms involved and reliability present through numerical methods. He has used FEA approach to reduce cost for production and reduce weight i.e. optimisation. It is observed that there is difference in connecting rod's behaviour between axial fatigue loading and dynamic loading. Found differences in analytical results also. It is found that fatigue strength is most significant factor to optimise the connecting rod.

Jong-Ho Kim [10]: In this thesis he has discussed experimental and Analytical investigation of fatigue crack growth of lugs. He has initiated crack, i.e. through the thickness crack near lug holes and calculated stress intensity factors and compared through weight function method, also boundary element method. They have obtained stress intensity factors for a corner cracks using correction factors. Under load spectrum fatigue life was predicted. It is concluded that due to fretting action the

contact between pin and bushing helps the crack to propagate faster and thus reduces fatigue life. It is observed that clipping level increases if fatigue life decreases for lug joint.

Prasad Kabade [11]: In this thesis analysis is carried out for landing gear lug. It is vital part in the structural unit of aircraft. In this they have taken example of Tri-cycle arrangement which consists of one nose landing gear unit and two main landing units. The landing will have to withstand the weight of aircraft also, so they have designed a lug joint to withstand failure under fatigue and static loads. In this thesis the design is provided for the safety against failure of pin and failure of lug. Axial loading and transverse loading are considered. They have used Miner's Rule to calculate fatigue life. They have concluded that for lug joint design fail safe approach is used.

Yongming Liu [12]: In these thesis traditional methods of fatigue analysis of notched component is done and has used Empirical formulae. They have used asymptotic interpolation method to evaluate the stress intensity factor. They have used the specimens with edge notched and centre crack components and included correction factor also. In conclusion they have suggested that for future life estimation and for crack growth prediction where long growth is existing can use this method. Fatigue notch factor can be estimated by present proposed methodology.

B.Dattaguru [13]: In this thesis he has proposed some effective methods for Non-linear analysis of joints in aircraft as they require contact stress analysis about the pin and hole boundary. They have solved the problems regarding the fits i.e. clearance, interference etc. He has used MVCCI to calculate fracture parameters. It is concluded that by using MVCCI method we can take care of long deformations and strain energy release rate was estimated. Damage tolerance method is crucial in aerospace designs.

A.Fatemi, L.Yang [14]: Cumulative fatigue damage plays an important role in prediction of life under cyclic loading conditions. They have published different damage theories of fatigue for metals as well as their alloys. He has proposed or listed six categories of cumulative damage models for fatigue loading. He has briefly explained all the 6 categories for example- Crack growth based approach, Life estimation based on curve modifications, double stage linearization methods and linear damage evolution.

Celalettin Karaagac [15]: In this thesis he has considered agitator shaft for analysis to investigate fracture. They have used facture mechanics approach. He has prepared 3D model, and for analysis FEM approach and ANSYS5.4 tool for postprocessor. He has analysed by the fracture surface that how crack propagates, how shaft leads to failure through macroscopic observations. In conclusion they have stated that fatigue failure is based on tensile stress phenomenon as the torsional stress will not contribute to failure or yielding. Thus presence notch reduces life of shaft.

Christina.A.Stenman [16]: In this thesis Lug and pin joints are designed using finite element method. Based on Mesh density, plasticity approach safety margin was calculated. They have calculated stress strain through strength of material approach. He has used sample of double shear joint. Finally he has concluded that theoretical approach i.e. SOM approach is well compared with FEA approach and has predicted margin of safety using peak stress. And stress developed at contact area.

Tonye.K.Jack [17]: In this thesis he has showed that the weakest part is the bolted joint part so, proper attention is required at the bolted joints. Some worked examples have been shown for the fail safe design operation. He has preloaded and by varying it the reliability degree of joint significantly yields, Thus for preload analysis is performed.ie preload < 70%of yield stress. He has used dynamic conditions i.e. bolts in gas pipelines i.e. flanged connections , bolt excitations, oil flowing flanged connections. He has detected the failure area i.e. threads between bolt and nut connections.

Slobodanka.Boljanovic [18]: He has proposed a model for calculating the residual fatigue life . He has considered the lug joint with single quarter elliptical crack at the corner and also with through the thickness single crack. Author has predicted the fatigue crack behavior of propagation. He has predicted stress intensity factor through analytical and numerical methods. In conclusion he has produced computational model for crack Analysis. Also he has concluded that satisfied results can be obtained between Experimental and Numerical.

3. CONCLUSION:

Static Stress analysis of lug joint is carried out to find out the maximum stress magnitude and location. FEM approach is followed for the analysis for fatigue loading, the corresponding damage accumulated will be obtained

by referring standard SN curves. For various crack lengths, stress intensity factor was calculated by using MVCCI Method. Also crack arrest capability is obtained by calculating residual stresses. The SIF variation is obtained analytically and validated it with numerical approach. Also Residual stress and crack arrest capability is analytically evaluated and validated with numerical approach.

4. REFERENCES:

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BIOGRAPHY

Pratik.Phadnis is a M.Tech (Machine Design) scholar in department of mechanical engineering from SJB Institute of Technology, Bangalore. His interests are in the fields of Finite Element Method, Aerospace engineering,, Fracture Mechanics, strength of Material, and fluid dynamics.

G.Anilkumar is working as Associate professor of Mechanical Engineering department, SJB Institute of Technology, Bangalore. He has completed BE (Mech Engg) in NITK, Surathkal. M.Tech in UBDTCE, Davangere. Now Pursuing PhD in VTU, Belgaum. Fields of interest are Nano Materials, Finite Element Methods, and Automation.

Prof. Madhusudhan T is a faculty serving as head of department of mechanical department SJB Institute of Technology, Bangalore. He has a vast experience in engineering academics. His special interest areas are automobile systems, polymer composites, renewable energy sources and dynamics of machines.

