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DESIGN AND EXPERIMENTAL ANALYSIS OF ADHESIVELY BONDED SINGLE RIVETED LAP JOINT

M.M.Krishna*, K.S.S.Rao, M.V.Ramana

*M.Tech Student(Machine Dynamics), Swami Vivekananda Engineering College, Bobbili
Assistant Professor, Mechanical Engg. Dept.,Swami Vivekananda Engineering College, Bobbili.
Sr.Assistant Professor, Mechanical Engg. Dept., Aditya Institute of Technology and Management, Tekkali.

ABSTRACT

This project deals with the stress analysis of adhesively bonded riveted lap joints. The present work involves the appropriate configuration and characterization of these joints for maximum utilization. The present study includes the effectiveness of bond line thickness, the bonded layer configuration. This is also applicable to dissimilar thickness joints, but in this project we have placed the adhesives at different places for riveted joints and also we had calculated the strength of riveted joint without adhesive by designed it to compare both the joints. By using finite element method, stress carried out under the external tensile loading. Using a two-step simulation, riveting process and subsequent tensile loading of the lap joint are simulated to determine overall stress state.

First the riveted joint was designed by manually and made calculations by applying load under UTM (universal testing machine).As a second task the Modeling is done on CATIA V5 and converted into step file (.stp) for FEA analysis under ANSYS Workbench. The finite element technique was used the analysis of present work. The present work showed that adhesively bonded riveted joints are superior in strengthening compared to the normal riveted joints. The riveted joint seems to strengthen and balance the stress and distributed uniformly. This improves the efficiency and life time of the riveted joints.

KEYWORDS: CATIA, ANSYS, frequency, vibration

INTRODUCTION

The Oil pan is a large metal pan mounted to the underside of the engine. Bonding of metals is becoming increasingly important, both in absolute terms and relative to mechanical fastening. Applications of adhesive bonding are found in the assembly of many products including aircraft, cars, trucks, and office furniture. This is because adhesive bonding offers more uniform distribution of stresses, increased fatigue life, weights savings, reduction of corrosion between dissimilar materials, added to the ability to join small and delicate parts. Bonded structure can be of two types based on either purely adhesive or on adhesive/mechanical connection. The purely adhesive connections include shaft-pinion joints, laminated metal-metal joints the bonded mechanical types include bonded-riveted and bonded-screwed connections. The combined connections (bonded-welded, bonded-riveted and bonded-screwed) ensure high fatigue strength of the structures. The single lap riveted joint is an important part of an aircraft structure and rivets are used extensively for joining plates together.

Fasteners play an important role in the aerospace industry. There is a big range of bolt and riveted joint applications, both in aircraft and jet engine structures. The need of accurate joint strength evaluation constantly grows due to higher performance and low weight expectations, thus a wide knowledge spectrum in this range is definitely required to make products more efficient from the performance and cost point of view. Cold structure department has a need of knowledge growth in the range of fasteners strength and life evaluation, especially riveted joints.

Advanced FE-models demands a lot of computing power when performing simulations/calculations and can thereby not be run in the complexity you would want it to. Therefore parts are replaced in the model with idealized parts which should behave approximately like the none-idealized part. These idealized parts demands a lot less computing power. Riveted joints are extensively used in these big simulation models and finding a working idealized model is considered as a high priority. In order to get

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even more data on how these riveted joints behave in the physical jet engine structure a shear test of different riveted joints will be performed at VAC during the second quarter of 2012. In jet engines there are often a riveted flange design is often a riveted flange design. VAC wants an improved method for modeling the rivets with higher accuracy in the results. This should be studied using a single riveted joint model, with similar dimensions on rivet and plate thickness as in a realistic riveted flange design.

In engineering practice it is often required that two sheets or plates are joined together and carry the load in such ways that the joint is loaded. Many times such joints are required to be leak proof so that gas contained inside is not allowed to escape. A riveted joint is easily conceived between two plates overlapping at edges, making holes through thickness of both, passing the stem of rivet through holes and creating the head at the end of the stem on the other side. A number of rivets may pass through the row of holes, which are uniformly distributed along the edges of the plate. With such a joint having been created between two plates, they cannot be pulled apart. If force at each of the free edges is applied for pulling the plate apart the tensile stress in the plate along the row of rivet hole and shearing stress in rivets will create resisting force. Such joints have been used in structures, boilers and ships.

Rivets are used to make permanent fastening between the plates such as in bridges, tanks and boiler shells. The riveted joints are widely used for joining light metals. The boiler and pressure vessels are cylindrical in shape and withstand high internal pressure. The cylindrical pressure vessel is identified by two dimensions, the length and diameter. The cylinders are made from plates and whole length of shell may not be obtained from single sheet. Therefore, cylindrical sections are obtained by bending sheets and joining edges by riveted joint. The sections are then joined together by another riveted joint along circumference. Thus there are two types of joints longitudinal and circumferential. The longitudinal joint bears hoop stress (σh) and circumferential joint bears longitudinal stress (σl). As $\sigma h = 2\ \sigma l$, the longitudinal joint will have to be two times as strong as circumferential joint. Therefore, longitudinal joints are made butt joints whereas the circumferential joints are mode as lap joints. Farah et al. developed software for designing and analyzing rivets of boiler shells as an example to use rivets in industry [1].

Until recently the primary analysis method had been hand calculations and empirical curves. David Heckman studied finite element analysis of pressure vessel using ANSYS [2]. William Barnet concluded that the difference between the diameter of rivet hole and of the rivet should vary with the size of rivet [3]. Nidhi et al. showed burst pressure prediction of pressure vessel using FEA. They proposed various types of finite element methods used for the calculation of burst strength of pressure vessel [4].

Kale et al. studied analysis of adhesively bonded riveted joints [5]. Hossein et al. studied parameters including squeeze force, rivet length, rivet diameter and hole diameter tolerance associated with a riveting process that directly affects the quality of rivets [6-7]. Elzbieta et al. showed influence of technological imperfections on residual stress fields in riveted joints [8]. Gutman et al. purposed a method for determining the critical time of stability loss in thin-walled high-pressure vessels subjected to uniform corrosion from the inside [9]. Masayuki et al. studied the failure pressure of pipe with wall thinning using three-dimensional elastic–plastic finite element analyses [10].

A number of analyses have been performed on thin pressure vessels and riveted joints. But static structural analysis of boiler shell with riveted joints (which is designed on the basis of thin pressure vessel theory) using ANSYS has not been studied yet. By using finite element method, a stress analysis has been carried out under the application of pressure at the inner surface of boiler shell. Using the two materials, structural steel and aluminum alloy, stress values have been compared for same working conditions.

Rivets are highly used in aircraft fuselage manufacturing and repairing processes. Great number of rivets is used for the assembly of aircraft body. For instance, approximately 100,000 solid rivets are utilized for one subassembly of Boeing 747 aircraft [11]. Therefore the integrity of fuselage structures is directly related to the integrity of riveted joints. The reasons why the rivets are preferred over the threaded fasteners are the lower unit cost, short installation time and permanence of rivets after installation. In order to investigate the riveting process, controlled laboratory experiments can be carried out. By experimental method, realistic models can be obtained to give more accurate results. However experiments are usually difficult to apply.Fitzgerald and Cohen [12] developed a new procedure to measure the residual stresses in and around rivets in clad aluminium plates. For this purpose, X-Ray diffraction method was employed. Residual stress values (radial and tangential components) were

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obtained on and near the rivet head and tail before and after riveting state. Also in studies [13] and [14], residual stress field created by cold expansion was experimentally obtained by using the X-Ray technique. Cold working of rivet holes is a technique which improves the fatigue life of riveted joints.

Langrand et al. [15] carried out experimental studies to investigate the riveting process and to improve the design of riveted joints. They stated that complex riveted joints are considered as the sum of single riveted joints (simply 2 plates one rivet joints). Residual stress and strain in rivets and plates were measured by applying a strain gage method. Besides the experimental methods, finite element methods (FEM) (also known as finite element analysis) are frequently used to investigate the riveting process. By the help of the finite element methods, approximate solutions are obtained by using certain simplifications and idealizations. In order to obtain the residual stress field in a single lap joint structure, Szolwinski and Farris [16] made a simulation of rivet installation process which is quasi-static and squeeze force controlled. Relationship between riveting process parameters and fatigue behavior of the joints was investigated. The results of the analysis revealed both a strong through-thickness gradient in residual stresses and change in the distribution of residual hoop stress near the rivet/hole interface with squeeze force. Residual hoop stress has a major effect on the propagation of fatigue damage that nucleates at either rivet/hole interface or faying surface. Ryan and Monaghan [17] had carried out numerical simulation of riveting process for both a fiber metal laminate (FML) and typical aluminum alloy fuselage material (2024-T3), and made comparisons. To obtain a better comprehension of the deformation process due to riveting and the stress state after elastic recovery a number of axisymmetric models were considered. Results of simulations revealed that forming load and rivet material had a significant effect on the initial stress distribution (residual stress state) within the panels. Also it was shown that localized compressive hoop stresses occurred in the panels, which is beneficial to the fatigue life of the joint. Karasan [18] studied the residual stress state from riveting process. He developed various finite element models in 2-D and 3-D to simulate the installation of the rivet. The effect of clearance between the rivet shank and the hole on the residual stress field was investigated for a universal head rivet.

OBJECTIVE OF THE WORK

Experimentally the design of riveted joints with detailed specifications has been done and subjected to tensile tests, apart from this CATIA V5 has been used for part design and assembly of riveted joints and ANSYS workbench 14.0 has been used for Finite Element Analysis to find the stresses and natural frequencies. The experimental and numerical values of the stresses are compared.

DESIGN AND EXPERIMENTATION

The specifications of the present job has taken from the design considerations from the plate

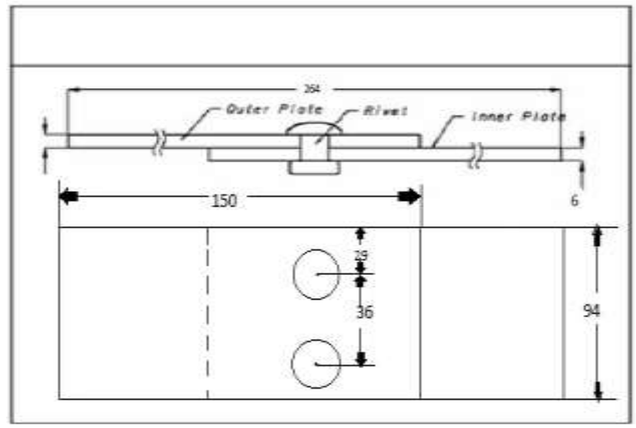

Fig 1

thickness as 6 mm and that are specified in the following diagram. Figure 1 shows the configuration, dimensions, constraints and loading conditions. The following assumptions and boundary conditions were considered throughout the idealization process.

MANUAL DESIGN OF RIVETED JOINT:

Fig. 2. Riveted joint With adhesive

Fig.3.Riveted joint with adhesive under applying load

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Fig .4. Shear failure of rivet under tensile loading

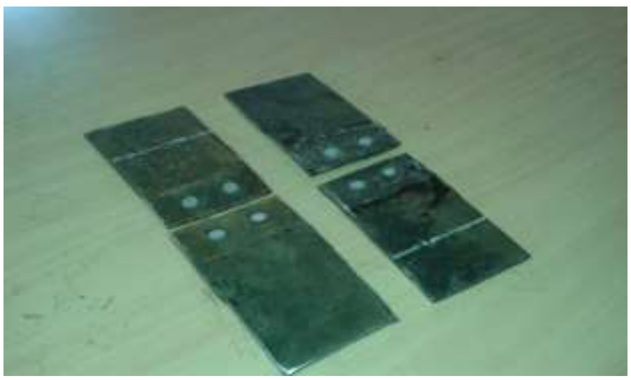

Fig .5. After failure of riveted joints (Both with and without adhesive)

Building the Model

In this project model is designed with the help of CATIA V 5 and also given the material property in this software by providing the proper constraining. This model developed with three stages first upon developing all the object as a part file single pieces with separate file and then assemble with constrained in assembly, i.e., product environment. Then converted this model into "step" format to importing the ANSYS (workbench).

PART DESIGN IN CATIA V5

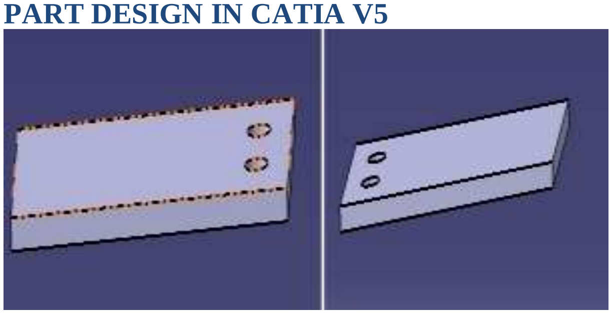

Fig 6 plates

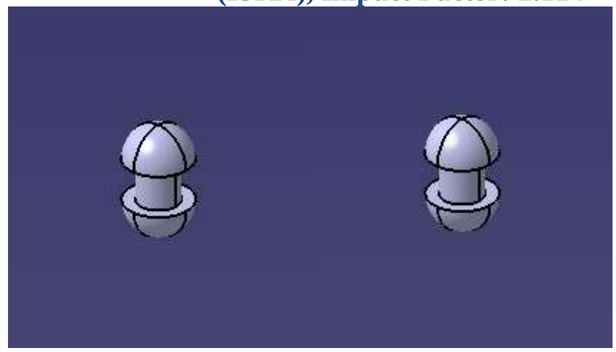

Fig.7. rivets

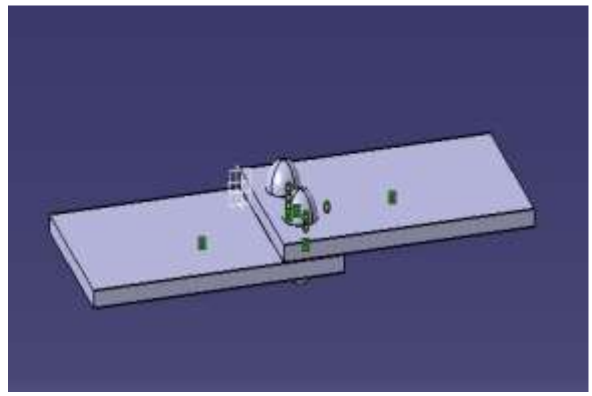

Fig.8 assembly in catia

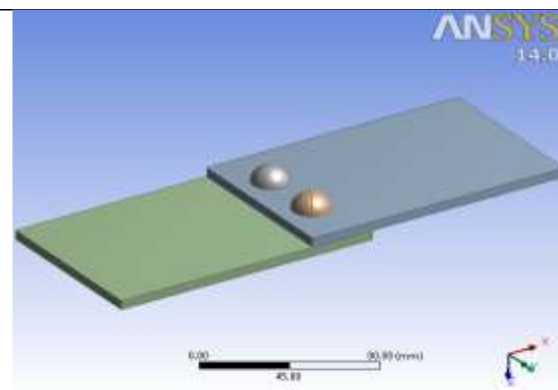

Fig.9.Imported model

The above CATIA model is saved as a .stp file(step file) to get access from ANSYS workbench 14.0. After dragging the static structure on to the dialog box and right click on the geometry and import the step file to get geometry as shown below.

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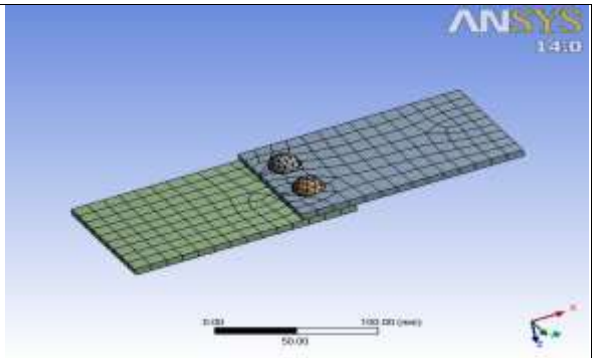

Fig.10. Meshing

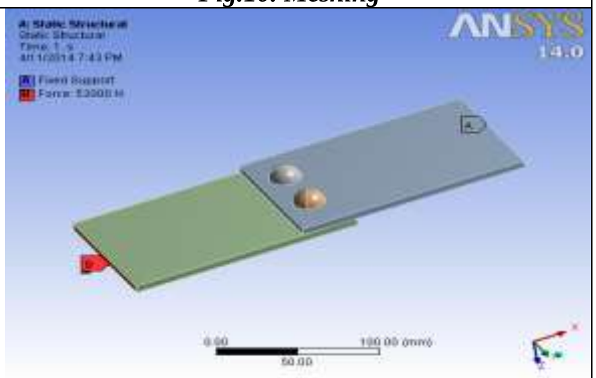

Fig.11. Boundary conditions

Apply Loads and Obtain the Solution

Applying Loads

Boundary conditions and Different loads acting on the model are applied either in the preprocessor as well as contact surface between the object also given. The loads in the ANSYS program are: DOF constraints, Forces, Surface loads, Body loads

Defining the Type of Analysis and Analysis Options

Static Analysis:

Used to determinedisplacements, stresses, etc., under static loading conditions. Both linear and nonlinear static analysis. Nonlinearities can include plasticity, stress stiffening, large deflection, large strain, hyper elasticity, contact surfaces, and creep. Our present analysis is “static Analysis”.

Specifying Load Step Options:

The following path is used to specify load step options.

Main Menu => Solution => Insert option

Initiating the Solution

The solution to the given problem is initiated by using the following path.

Main Menu => Solution => Solve

Initiating the Results

After the solution any type of result can be seen by following path.

Main Menu => Solution => Insert Results.

Finite Element Model with Meshing, Boundary Conditions and Material Properties:

Figures 9 and 10 shows the CAD model prepared in CATIA and imported to ANSYS 14 software. This model is meshed in ANSYS for analysis with element size 2 mm brick and triangular meshing with fine type. The end surfaces on two plates on either side of the rivet are assumed to be fixed for analysis as shown in Figure 11, and the material considered is to be steel, and hence its Young's modulus is considered to be 200 GPa, Poissons ratio is taken as 0.3 and the density is taken as 7850 kg/m3.

RESULTS AND DISCUSSIONS

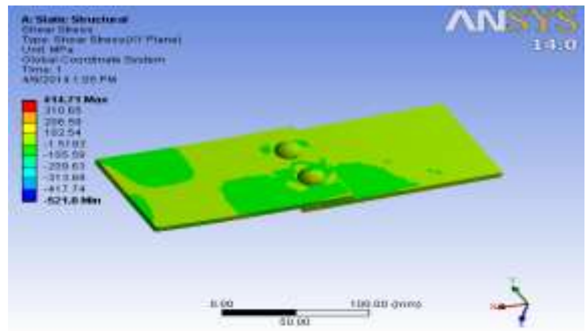

Fig.12 Maximum shear stress on riveted joint with adhesive

Boundary conditions:

Internal pressure in an engine block recorded from lab test engine is 4Kpa around the crankcase and rest of the block. During the combustion and valve mechanism the pressure rises exponentially.

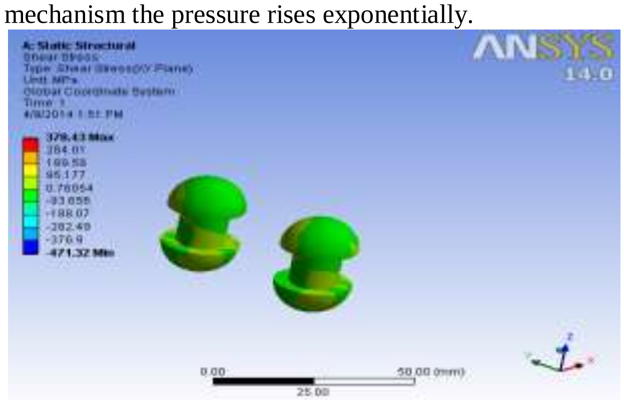

Fig.13. Stress on rivets when the joint is without adhesive

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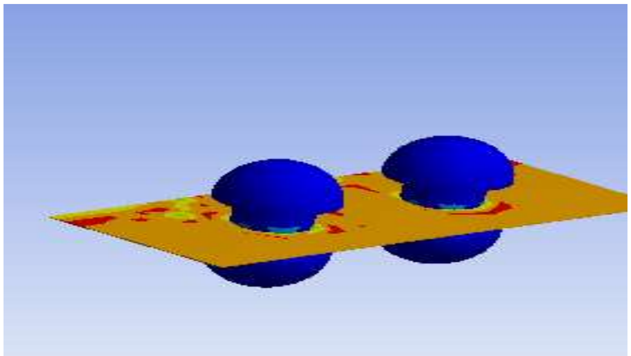

Fig.14. Stress on rivets when the joint is with adhesive

STRESS RESULTS

Occupation	Experimental Shear Stress	F.E.A Shear Stress
Without adhesive	334Mpa	376Mpa
With adhesive	358Mpa	414Mpa

FREE VIBRATION ANALYSIS

Eigen value modal analysis is carried out in ANSYS using Block Lanczos method. The discretized model of riveted lap joint is shown in Fig.15 and the mode shapes obtained are shown from Fig.16 to Fig.17. In all the modes it can be observed that the rivet is not deformed which shows that the strength of rivet head is high.

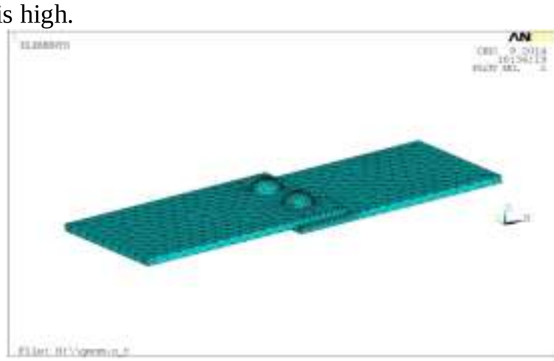

Fig.15. Discretized Model of the riveted lap joint

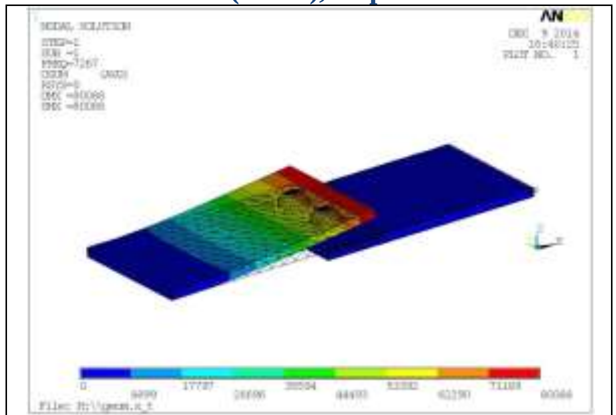

Fig.16. Mode 1 of Riveted joint

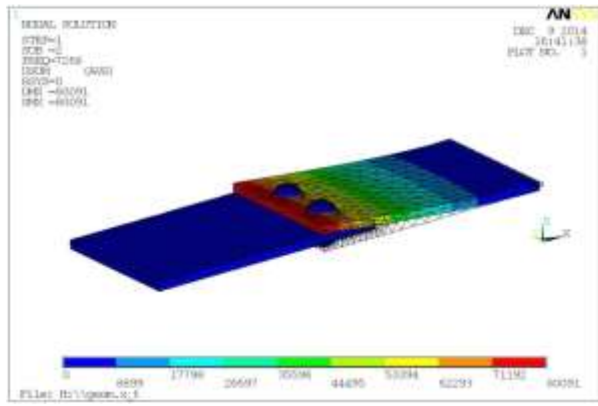

Fig.17. Mode 2 of Riveted joint

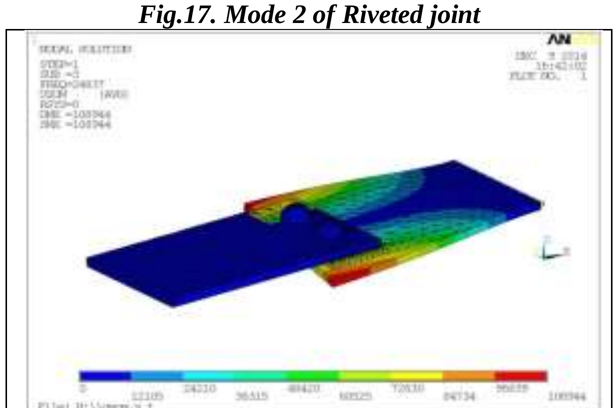

Fig.18. Mode 3 of Riveted joint

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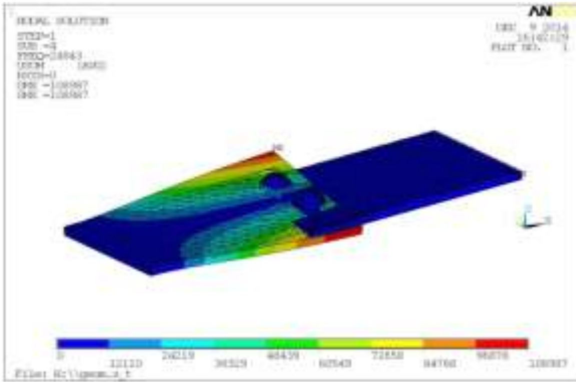

Fig.19. Mode 4 of Riveted joint

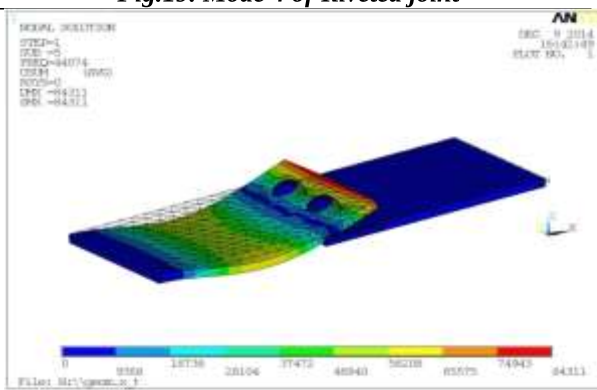

Fig.20.Mode 5 of Riveted joint

This investigation confirmed that shearing stress in the rivet determined by experimentation and F.E. analyses are in close agreement. Analytical and F.E. static stress analysis of riveted butt joint is performed by varying parameters like thickness of main plate, linear pitch of rivet, transverse pitch of rivet and method of riveting, from which it is revealed that the result obtained are in good agreement to each other. The results obtained from ANSYS software for the Adhesively Bonded Single lap riveted joints are compared with each other at different conditions of using adhesives at described locations leads to decreasing the stresses, uniform distribution of load gives more efficient and life to the joints. From modal analysis, it can be observed that rivet is not displaced compared to the plates under free vibration which shows the strength of the rivet head.

References

[1] Farah KamilAbid Muslim Dr. Essam L. Esmail, Computer aided design of rivets for Steam Boiler Shell Al-Qadisiya Journal for Engineering Sciences, Vol. 5, No. 4, 377-393, Year 2012.

[2] Harris C E, Piascik R S and Newman C (1999), "A Practical Engineering Approach to Predicting Fatigue CrackGrowth in Riveted Lap Joints", International Conference on Aeronautical Fatigue (ICAF), WA, Seattle.

[3] Silva L F M, Gonçalves J P M, Oliveira F M F and de Castro P M S T (2000), "Multiple Site Damage in Riveted Lap- Joints: Experimental Simulation and Finite Element Prediction", Int. J. Fatigue, Vol. 22, pp. 319-338.

[4] David Heckman, Finite Element Analysis of Pressure Vessels, University of California, Davis Mentor: Gene Massion, Mark Greise Summer 1998

[5] William Barnet Le Van, Riveted joints in Boiler shell, Read at the state meeting of institute, held Nov 19,1890.

[6] Fitzgerald T.J., Cohen J.B.,1994, "Residual stresses in and around rivets in clad aluminium alloy plates," Materials Science and Engineering,A188, pp. 51-58

[7] Matos P.F.P., Moreira P.M.G.P., Nedbal I, Castro P.M.S.T., 2005,"Reconstitution of fatigue crack growth in Al-alloy 2024-T3 open-hole specimens using microfractographic techniques", Engineering Fracture Mechanics,72, pp. 2232–2246

[8] NidhiDwivedi, Veerendra Kumar, Burst Pressure Prediction of Pressure Vessel using FEA, International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 1 Issue 7, September – 2012

[9] Kale Suresh, K.L.N.Murty&T.Jaynanda Kumar, Analysis of adhesively bonded single lap riveted joint using ANSYS International Journal of Mechanical and Industrial Engineering (IJMIE) ISSN No. 2231 –6477, Vol-2, Iss-4, 2012

[10] Faisal Aman& S. HosseinCheraghi& Krishna K. Krishnan & Hamid Lankarani, Study of the impact of riveting sequence, rivet pitch, and gap between sheets on the quality of riveted lap joints using finite element method Springer-Verlag London Limited 2012.

[11] Karasan M.M., 2007, "Residual Stress Analysis of Riveting ProcessUsing Finite Element Method", M.S. Thesis, Middle East TechnicalUniversity, Ankara

[12] Iyer K., Rubin C.A., Hahn, G.T., 2001, "Influence of interference andclamping on fretting fatigue in single rivet-row lap joints," Journal ofTribology, Vol. 123, pp. 686-698.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114

[13] Fung C.P., and Smart, J., 1997, "Riveted Single-Lap-Joints. Part 1: ANumerical Parametric Study," Proc. Instn.Mech. Engrs. –G- J. ofAerospace Engineering, 211 (1), pp. 13–27
[14] Bedair O.K, Eastaugh G.F, 2007, "A numerical model for analysis ofriveted splice joints accounting for secondary bending and plates/rivetinteraction", Thin-Walled Structures 45, pp. 251–258
[15] Xiong Y., Bedair O.K., 1999, "Analytical and finite element modeling ofriveted lap joints in aircraft structure," AIAA Journal, Vol. 37, No.1, pp.93-99.
[16] Harish G. and Farris T.N., 1999, "An Integrated Approach for Predictionof Fretting Crack Nucleation in Riveted Lap Joints," American Instituteof Aeronautics and Astronautics, pp. 1219-1226
[17] Moreira P.M.G.P., Matos P.F.P., Camanho P.P., Pastrama S.D., CastroP.M.S.T., 2007, "Stress intensity factor and load transfer analysis of acracked riveted lap joint," Materials and Design 28, pp. 1263-1270.
[18] Szolwinski M.P., Harish G., Farris T.N., 1995, "ExperimentalObservation of the Effect of Contact Parameters on Fretting FatigueCrack Nucleation", Proceedings of the 1995 USAF Structural IntegrityProgram Conference, San Antonio.
[19] Szolwinski M.P., Farris T.N., 1998, "Observation, Analysis andPrediction of Fretting Fatigue in 2024-T352 Aluminum Alloy", Wear,221:24-36.183
[20] Pitt S., Jones R., 1997, "Multiple-site and widespread fatigue damage in aging aircraft", Engineering Failure Analysis, Vol. 4 No. 4, pp. 237-257.