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Analysis of Riveted Joints under Vibration

[1]Khaja Abulfaiz A.H., [2]R.D. Shelke

[1] Student, Department of Mechanical engineering, EESCOET, Aurangabad.

[2] HOD, Assistant Professor, Department of Mechanical engineering, EESCOET, Aurangabad.

Abstract

This research deals with the vibration analysis of riveted lap joints, which involves appropriate pattern and characterization of these joints for maximum utilization. The present study includes the effectiveness of riveting patterns or configuration. We have placed the rivets at different places at the time of joining the plates by riveted joint and also calculated the damping strength of joint with comparison of different pattern of riveted joints. By using CATIA we modeled the different patterns of riveting then we simulated using ANSYS for analysis of vibration frequencies. It is found that the results obtained computationally are compared with the experiments. The vibration analysis is carried out using FFT analyzer.

Keywords: ANSYS Workbench**,** Riveted Lap joint, FFT analyzer, Vibrational Analysis.

1. Introduction

Manufacturing large and complex structures is usually possible only when they are made by assemblies of smaller parts joined together by using various joining techniques since most products are impossible to be produced as a single piece. Manufacturing small components and then joining them into a single product is easier and less expensive then manufacturing the whole product as a single piece. In order to ensure the manufacturing ability, and reduce the overall manufacturing cost, economic fastening and joining method should be utilized.

Riveted joints are widely used in various industries such as automotive, Boiler, chemical industry, electrical industry, aircraft and even in cryogenics.

In engineering applications it is often required that two sheets or plates are joined together and subjected to 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 out. A riveted joint is easily applied 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 holes, which are uniformly distributed along the edges of the plate. With such a joint created between two plates, they cannot be pulled apart. If excitation is applied to free end then continues damping force is developed on plate surfaces. Such joints have been used in structures, boilers, ships and automobiles.

In this research the specimen includes two plates and four rivets dimensions of all plates and rivet are same, all the two plates and four rivets are made of same material that is the Aluminum alloy.

Types of Geometrical Pattern in rivets are:

I. Square   II. Rectangle

III. Rhombus   IV. Diamond

2. Literature review

B.C.Huskamuri et.al. [1] This project deals with the shear strength analysis of riveted joints. This investigation provides the study of various design parameters are considered and effect of this parameter on shear strength of riveted lap joint is discussed. Like, in single chain riveting for same diameter of rivets if thickness of plates to be joined is increased beyond the recommended value then shear strength of joint decreased. Experimental results shows that as pitch is increases at different thickness of joint which increases shear strength of joint. And in case of double chain riveting, variation in pitch and thickness of plate shows good shear strength for its recommended values as compare to single chain riveting.

As comparing with Ansys result that also verify that increasing of joint strength by varying the pitch, transverse pitch and thickness of plate.

V. K. Khemnar et.al. [2] Has investigated that hybrid joints have a mixture of adhesive bonding and mechanical fasteners. The advantages of using a combined bonded-riveted design apply mainly in joining process. It is generally accepted that a bonded joint is stronger than a mechanically fastened joint and a well-designed bonded joint is stronger than a hybrid joints. A 'Hybrid Joint' combines multiple joining methodologies. A basic example is the bonded and bolted joint. It has been observed that it is possible to improve strength and fatigue characteristics of bonded joints through the inclusion of a single, or multiple, reinforcing bolts. Advanced hybrid joints typically use more accurate mechanically interlocking. In experiment three types of riveting pattern has been used (Transverse, longitudinal and triangular rivet arrangements). At the end of study maximum shear stress and displacement of rivet and adhesive layer has been observed and it is observed that the performance of longitudinal rivet arrangement is good as compare to other arrangements.

Suyogkumar W. Balbudhe et.al. [3] This project deals with the stress analysis of riveted lap joints with various arrangements of riveted lap joints (Chain riveting, zigzag riveting and diamond riveting). The study also correlate the maximum shear stress and maximum principal stress with pitch of rivet. And performance of riveting pattern under maximum shear stress and maximum principal stress has been focused. This work involves the suggestion of appropriate configuration and pattern of these joints for maximum utilization.

Kale Suresh et.al. [4] Discussed about the analysis of adhesively bonded single lap riveted joints. The study of this project involves the suggestion of appropriate configuration and characterization for maximum utilization of adhesively bonded riveted lap joints. And this project also involves the study of efficiency and life span of riveted joints with varying thickness and dissimilar material of joint. The present study includes the effectiveness of bond line thickness and bonded layer configuration with its position to reduce the stress.

M.M.Krishna et.al. [5] Authors discussed about the stress analysis of adhesively bonded riveted lap joints. The presented study for maximum utilization involves the appropriate configuration and characterization of these joints. At present the study of this research includes the effectiveness of bond line thickness and the bonded layer configuration of joints. This is also applicable to dissimilar thickness joints, but in this project adhesives has been placed at different places for riveted joints and also 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.

Prof. Mahavir I. Darda et.al. [6] Basically this research was based on thermal stress analysis of riveted joints. In this investigation two load steps were applied to the model. First, the simulation of riveting was carried out and then an external tensile load was applied to the deformed and residual stress loaded rivet joint. Riveting process is simulated by a simplified method, namely the interference and clamping misfit method. For validating the model, the convergence check study was carried out by altering the overall mesh density of the numerical model. Results of the models with different mesh densities were compared and check for accuracy and convergence of certain values. The analysis in this research has been is executed by running ANSYS/Standard procedure. To understand the dynamic behavior of the joints and the failure modes, the study can be extended by running ANSYS/Explicit procedure to include the time-domain in the analysis because this process will help investigating influences of different parameters on riveted and rivet-bonded joint such as the sensitivity of the strain rate of fracture limits. And at the end it is recommended to carry out some experimental works to verify the results.

Objectives

1. To study effect of geometrical layout of rivet on vibrational analysis of rivet Joint.
2. Modeling and analysis of riveted joints, with specific focus on vibrations.
3. Recommend best design practices for this type of joint for helping effort over similar applications in the industry.

Problem Definition

The main focus to carry out research is to find out the optimum damping of riveted joints for its application in industries, where joints are subjected to heavy vibrations. For structures that may contain excessive number of rivets, there is a real need to model the rivets in the structure in an effective way, especially to determine the natural frequencies and mode shapes with acceptable accuracy and also to see the effects of design modifications.

However, this is in focus with the real need in industry due to the serious difficulty of incorporating excessive number of nonlinear joint models in structures such as aircrafts and helicopters. Therefore, there is a real need for developing approaches that will be applicable to model structures of joint with excessive number of rivets and that will also yield acceptable accuracy using quite simple, approximate rivet models.

Methodology

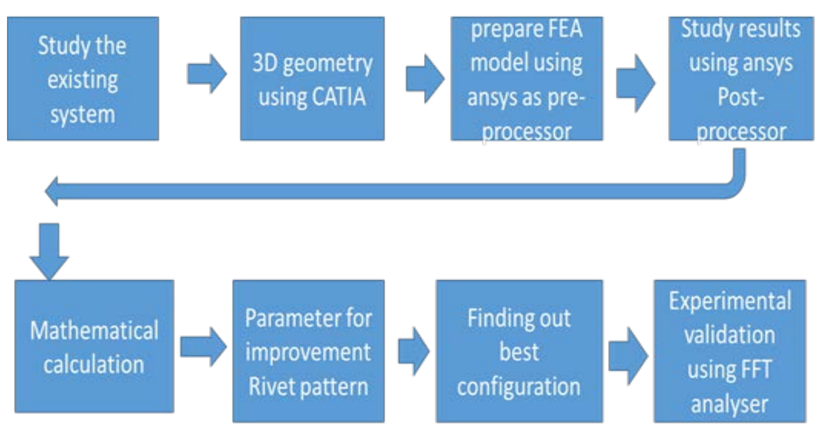


Fig. No. 1. Block diagram of methodology

Actual Working

Modeling and static analysis of 3-D Models of the rivet joints were carried out using CATIA and ANSYS FEA Workbench software. The results were interpreted in terms of Displacement and frequency distribution. The present study deals with the analysis of riveted lap joint subjected to the given vibration excitation in the members under various design conditions are found.

3. Finite Element Analysis of Rivet Joints

CATIA V5 is a feature-based, parametric solid modeling system with many extended design and manufacturing applications. CATIA was used in the model the commercial FEA software ANSYS Work bench (14.5) has been used to analyze the models. Aluminum rivet was used for mechanical fastening. The aluminum material is used for analysis and stress values are found. One end of the each specimen was constrained from x, y, z translations. While the other end of the specimen displaced by 10mm positive X-direction. The CATIA models of riveted joints are prepared and Meshed models of riveted joints are shown in the figures under modal analysis.

ASTM (D3528) specimens of size with geometry are shown below in the table 1.

Table No 1. Dimensions of specimen

Width of plate	40 mm
Length of plate	140 mm
Thickness of plates	3 mm
Plate overlaps	40 mm
Diameter of the holes in plates	4.8 mm
Diameter of the rivet head	8 mm

FEA Model

Two sets of Aluminium plate of width 40mm, thickness 3mm, length 140 mm are modeled using catia and analyzed using Ansys. Initially, two plates of above dimensions are constructed and join using rivet Diameter of the hole in the plate 4.8mm and the Diameter of rivet head 8mm. Model is analyzed for 10 mm of excitation.

Boundry conditions

In finite element analysis of riveted joint boundary conditions are given. One end is fixed and harmonic excitation of 10 mm is given at other end.

Modal Analysis

Modal analysis is carried on 4 geometrical patterns to obtain natural frequencies of riveted joints. 6 modal frequencies are calculated with the help of Ansys. The pattern of riveted joint, its frequency graph and values of its frequency are mentioned below. This will helpful to observe the frequency range of all type of riveted geometries and for further study the matlab graphs are generated.

Figures and tables

a) Rectangle

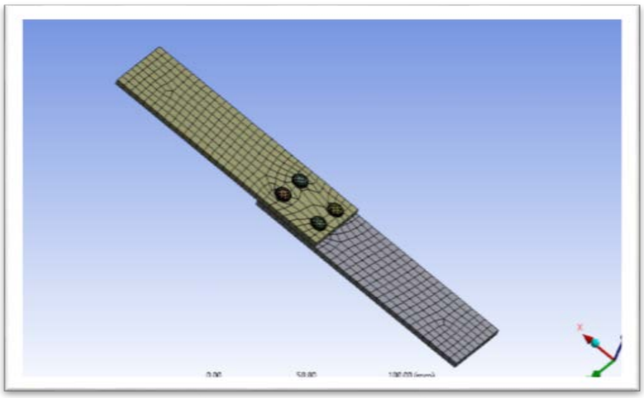


Fig No. 2. Rectangle Layout

Table No. 3. Number of nodes

Mode	Frequency [Hz]
1.	42.689
2.	282.24
3.	478.66
4.	564.61
5.	751.18
6.	1522.9

b) Square

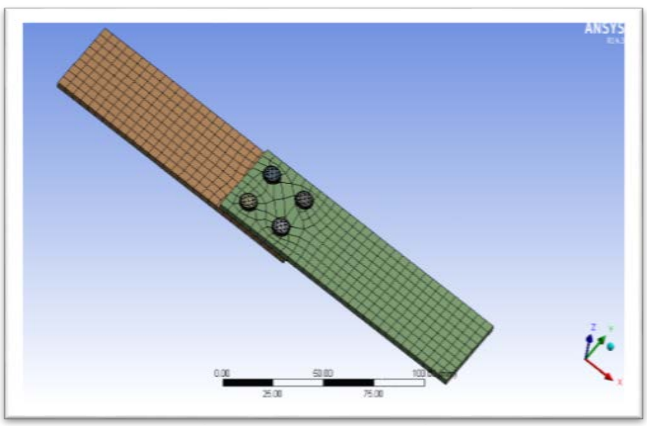


Fig No. 3. Square Layout

Table No. 4. Number of nodes

Mode	Frequency [Hz]
1.	42.567
2.	279.96
3.	475.3
4.	561.24
5.	751.01
6.	1515.5

c)Rhombus

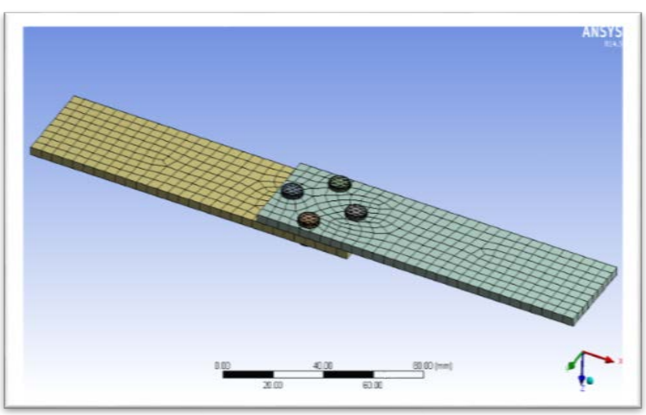


Fig No. 4. Rhombus Layout

Table No. 5. Number of nodes

Mode	Frequency [Hz]
1.	42.58
2.	280.56
3.	475.42
4.	561.36
5.	751.54
6.	1516.5

d) Diamond

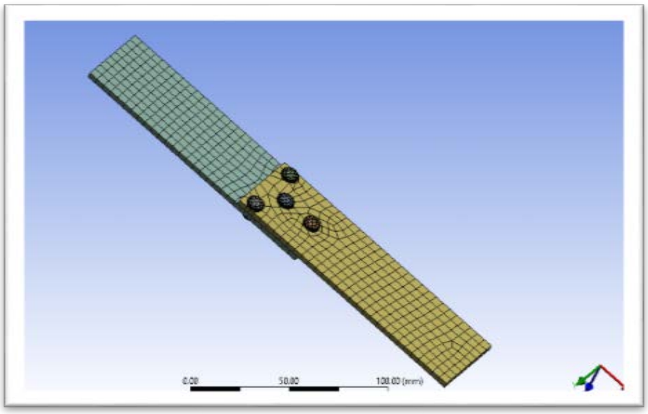


Fig No. 5. Diamond Layout

Table No. 6. Number of nodes

Mode	Frequency [Hz]
1.	42.614
2.	279.66
3.	475.26
4.	561.02
5.	749.97
6.	1507.

Matlab Graphs of Modal Analysis for Each Pattern

a) Rectangle

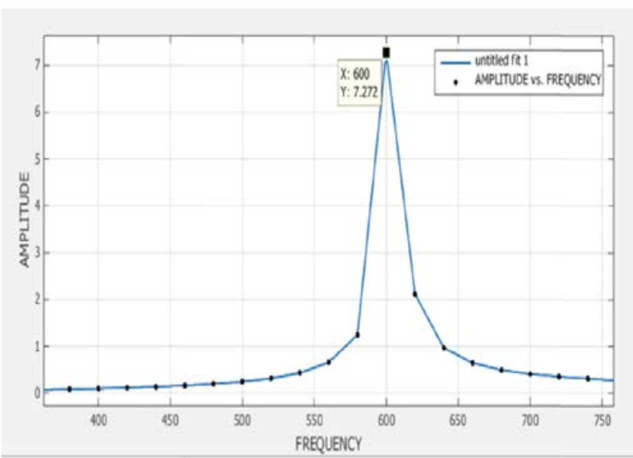


Fig No. 6. Displacement Vs Frequency graph

b) Square

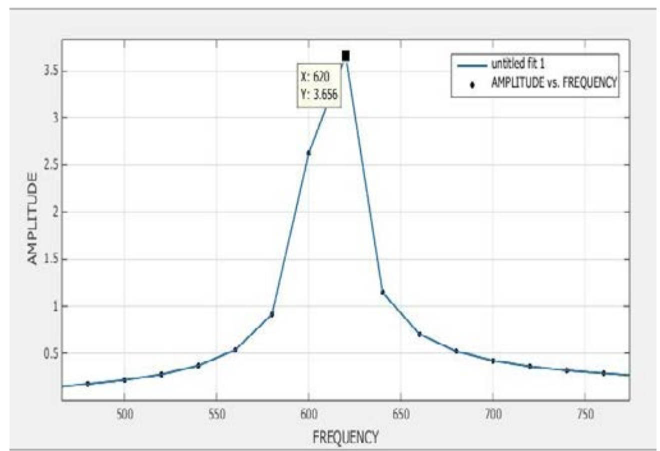


Fig No. 7. Displacement Vs Frequency graph

c) Rhombus

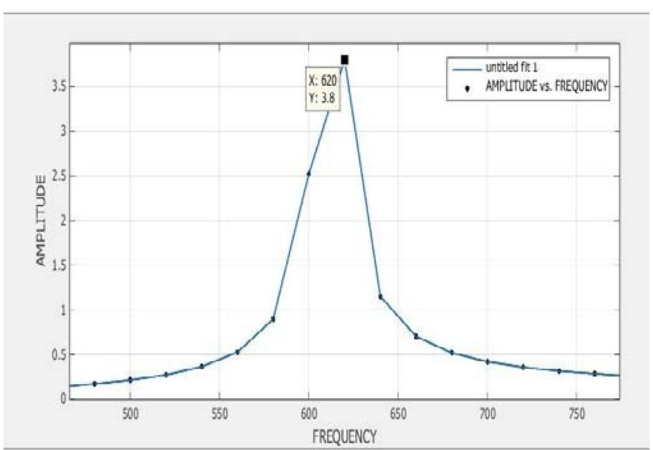


Fig No. 8. Displacement Vs Frequency graph

d) Diamond

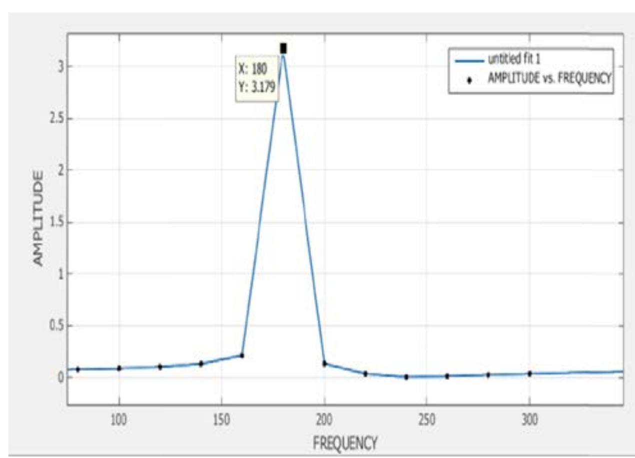


Fig No. 9. Displacement Vs Frequency graph

Introduction to Half Power Bandwidth Method

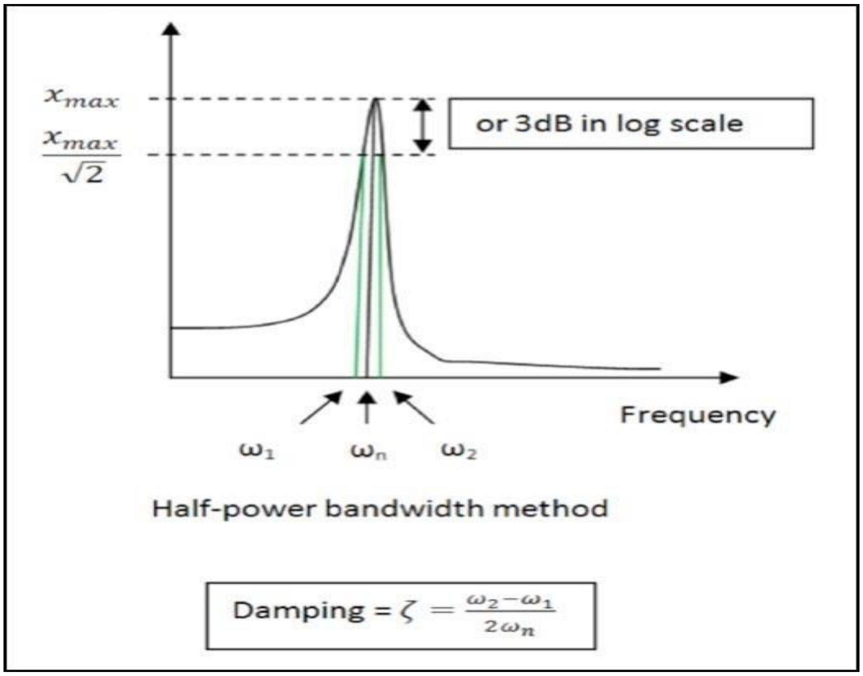


Fig No.10 half power bandwidth method

The data is then analyzed to determine the natural frequency and damping characteristics of the plate structure. To estimate damping ratio from frequency domain, half-power bandwidth method has been used.

Table No. 7. Results of FEA analysis

Pattern	Xn	Xm	W1	W2	Wn	Damping ratio
Diamond	3.179	2.24789246	173.7	186.2	180	0.0347222
Square	3.656	2.5851	599.5	628.5	620	0.023387
Rhombus	3.8	2.68700577	602.5	628.2	620	0.020725
Rectangle	7.272	5.14208051	593	608	600	0.0125

4. Experimental Analysis of Rivet Joint

The main problem to be analyzed in this report is estimation of an influence of rivet geometrical patterns on the riveted joints response to vibrational excitation. The state of damping and natural frequency of the riveted lap joints reinforced by four rivets is presented. In order to underline the advantage of the riveted joints with comparison to the different geometrical pattern with the FEA analyses were performed. In this study the problem of the influence of four rivets geometrical layout on the strength of the riveted joints was investigated. Experimental analysis of rivet joint with different rivet arrangement involved following steps.

Specimen preparation

The samples were prepared from two different kinds of aluminium sheets with a Young's modulus equal to E_s= 71GPa, and Poisson's ratio = 0.33.The rivets, made of Aluminium having the Young's modulus equal to E_r= 71GPa, whereas Poisson's ratio is equal to = 0.33.

Experimental set-up

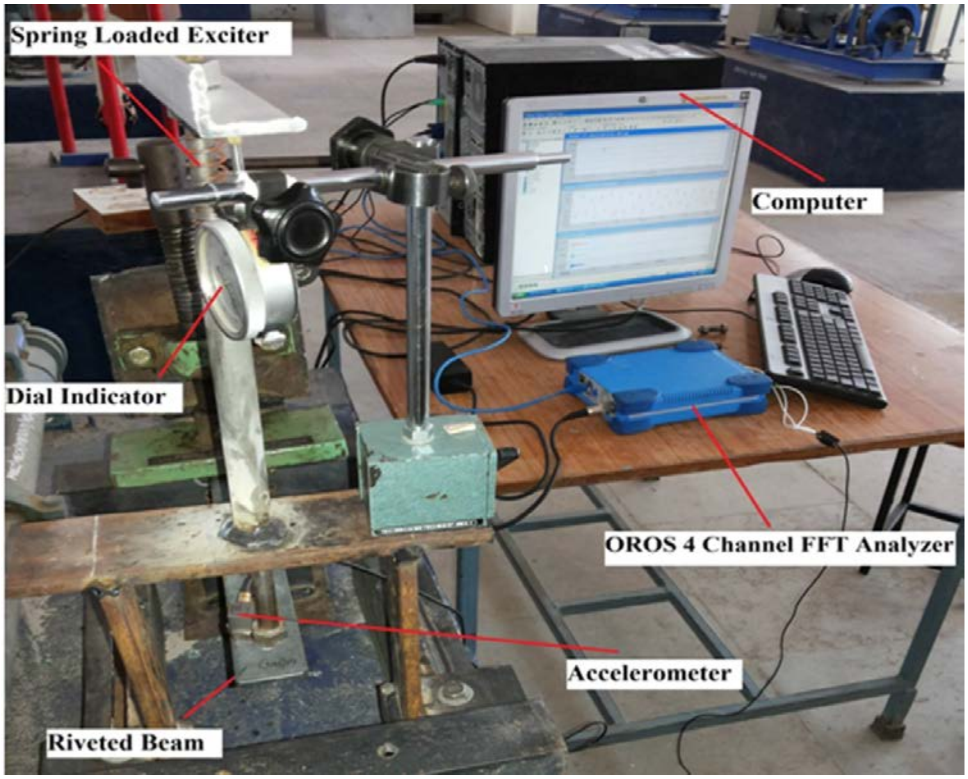


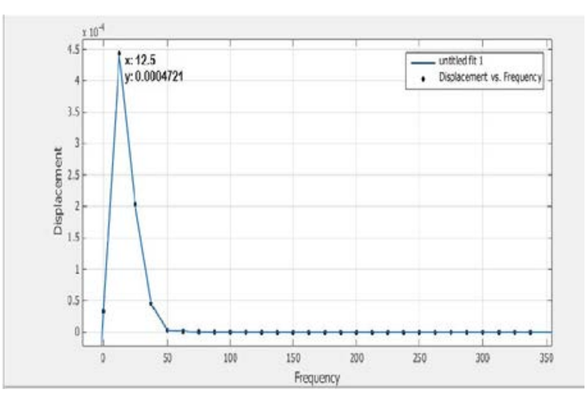
Fig. No. 11. Actual Experimental set-up

Experimental Procedure

The setup consists of OROS 4 Channel FFT Analyzer, Dial gauge, spring loaded exciter etc. The riveted plate is clamped mounted by applying cantilever type arrangement keeping one end fixed and another end free for excitation. The spring loaded exciter is used for providing excitation 1mm, 2mm and 3mm respectively. The accelerometer is an instrument that measures the acceleration of vibrating body. The acceleration data is recorded using FFT analyzer. The acceleration graph is converted into displacement by integrating twice. The displacement vs. frequency data obtained from NVGate 5.0 software is imported in MATLAB for calculating damping ratio (ξ) for different specimen using half power bandwidth method.

Matlab Graphs

a) Rectangle



b)Square

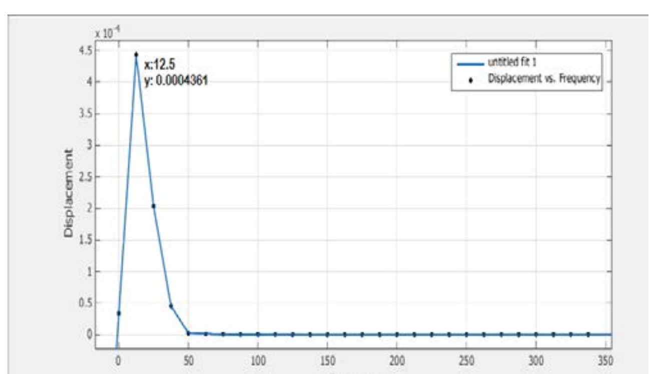


Fig No. 12.Displacement Vs Frequency graph

Fig No. 13.Displacement Vs Frequency graph

c) Rhombus

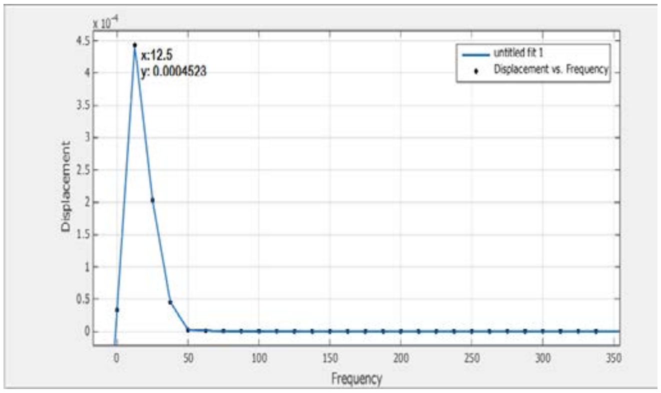


Fig No. 14.Displacement Vs Frequency graphs

d)Diamond

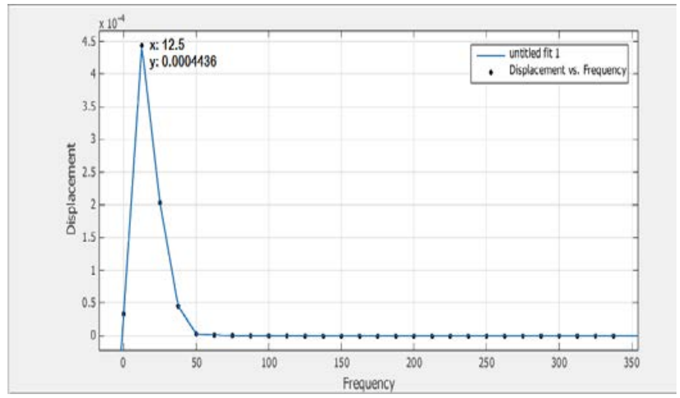


Fig No. 15.Displacement Vs Frequency graphs

5. Result and Discussion

Result obtained from FEA Analysis and experimentation are given in table 3and 4 respectively.

FEA Result:

Sample calculation

$$\xi = \frac{w_2 - w_1}{2w_n}$$

$$= \frac{186.2-173.7}{2\times180}$$

$$\xi = \mathbf{0.0347}$$

This kind of calculation has been done for all riveted patterns.

Table no. 8 Results of experimental analysis

Pattern	Xn	Xm	W1	W2	Wn	Damping ratio
Diamond	0.0004436	0.0003136	8.58	19.85	12.5	0.4508
Square	0.0004361	0.0003083	6.48	17.6	12.5	0.4448
Rhombus	0.0004523	0.0003198	6.95	17.8	12.5	0.434
Rectangle	0.0004721	0.0003338	7.306	17.99	12.5	0.42736

6. Conclusions

- In this analysis, FEA for the prediction of natural frequencies in different pattern of riveted joints have been carried out; 3-D models were created by using CATIA and analyzed using ANSYS workbench FEA software.
- In this study the problem of the influence of four rivets geometrical pattern on the damping of the riveted joints was investigated. And it has been found that damping is more in diamond pattern than other 3 patterns.
- From analysis data it is observed that diamond pattern shows less peak value of amplitude.
- Also diamond pattern shows peak amplitude at lesser frequency.

- From modal analysis it is found that diamond pattern shows lesser modal frequencies at all 6 modes.

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