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Modal Analysis of Load Compartment Rear Panel of Piaggio Ape

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Abstract— The vibration is an undesirable phenomenon which occurred in most of the systems. Due to vibration, the structures or machine components are subjected to fatigue failures resulted from the cyclic variation of the induced stresses. Furthermore vibration creates excessive noise. In machines, vibration can loosen fasteners such as nuts, rivets. Resonance leads to excessive deflections and failure. To avoid this vibration should be reduced. Adding a stiffener is one of the methods to reduce vibration and to add stiffness to the structure. In this work study is carried out on load compartment rear panel of piaggio ape. Different shapes of stiffeners are studied. Stiffeners are attached to specimen by spot welding and compared with stiffeners attached by arc welding. Software analysis is done by ANSYS.
Keywords— modal analysis, vibration, spot welding, stiffeners,

I. INTRODUCTION

Any motion that repeats itself after an interval of time is called vibration or oscillation. If a system, after an initial disturbance, is left to vibrate on its own, the ensuing vibration is known as free vibration. No external force acts on the system. The oscillation of a simple pendulum is an example of free vibration. If a system is subjected to an external force (often, a repeating type of force), the resulting vibration is known as forced vibration. The oscillation that arises in machines such as diesel engines is an example of forced vibration. If the frequency of the external force coincides with one of the natural frequencies of the system, a condition known as resonance occurs, and the system undergoes dangerously large oscillations. Failures of such structures as buildings, bridges, turbines, and airplane wings have been associated with the occurrence of resonance.

Vibration is put to work in vibratory conveyors, hoppers, sieves, compactors, washing machines, electric toothbrushes, dentist's drills, clocks, and electric massaging units. Vibration is also used in pile driving, vibratory testing of materials, vibratory finishing processes, and electronic circuits to filter out the unwanted frequencies. Vibration has been found to improve the efficiency of certain machining, casting, forging, and welding processes. It is employed to simulate earthquakes for geological research and also to conduct studies in the design of nuclear reactors.

Along with the above applications the vibration has some undesirable effects. The structure or machine component subjected to vibration can fail because of material fatigue resulting from the cyclic variation of the induced stress. Furthermore, the vibration causes more rapid wear of machine parts such as bearings and gears and also creates excessive noise. In machines, vibration can loosen fasteners such as nuts. In metal cutting processes, vibration can cause chatter, which leads to a poor surface finish. Resonance leads to excessive deflections and failure. In many engineering systems, a human being acts as an integral part of the system. The transmission of vibration to human beings results in discomfort and loss of efficiency. The vibration and noise generated by engines causes annoyance to people and, sometimes, damage to property. Vibration of instrument panels can cause their malfunction or difficulty in reading the meters. Thus it is important to study the vibration and to reduce it.

In this work, study is carried out on load compartment rear panel of piaggio ape. When the vehicle is running on the road, due to an engine and road roughness the vibrations are generated and are transferred to load compartment. The three panels of load compartment are rigidly fixed to the body but the rear panel is not so rigidly fixed and provision is made to material loading and unloading. Hence maximum vibrations are generated in rear panel. When the natural frequency of rear panel matches with excitation frequency, resonance occurs. Due to this rear panel failures occur.

A. Problem Statement

We have to avoid resonance by changing the natural frequency of load compartment rear panel, since we are unable to change the excitation frequency.

B. Objectives

Based on the above problem statement following objectives were set to the project work.

To find out the effect of stiffener profile on natural frequency of specimen

To find out the effect of spot welding on natural frequency of specimen.

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To find out the effect of electric arc welding on natural frequency of specimen.

II. LITERATURE REVIEW

The spot weld strength and natural frequency are most important part in the any of the structure which is spot welded. Hence it is very much important to study the parameters which affecting the strength and natural frequency of spot weld. In this section the summaries of previous researches on characteristics of spot weld strength; effect factors are discussed. The previous research work describes structural investigation; finite element analysis work and experimental investigation. The overview of some of literature is given below.

Ahmet H.Ertas, Fazil 0. Sonmez [1] studied the optimum locations of spot welds and the optimum overlapping length of the joined plates. Minimum weld-to-weld and weld-to-edge distances recommended by the industry are considered as side constraints for optimum design of spot weld. The total strain life equation is used to predict the fatigue life. They suggest that number of spot welds significantly affects the strength of structure. The distance between two spot welds, arrangement of the spot weld and diameter of spot, these are the parameters considered for optimum design of spot weld. Spot weld is studied by using FEA and under different loading conditions. They introduced penalty functions to prevent the close spot welding and the boundaries of the plate, which cause effect on optimal characteristics of spot weld. The parameters of optimum design of spot weld are briefly studied; also finite element analysis of spot welded structures is mentioned in this study. E. Rusinski, A. Kopczynski, J. Czmochowski [2] investigates briefly the effect of diameter of spot weld on structural characteristics. The strength of spot welded structure is studied under compression considering effect of diameter and pitch of the spot weld. FEA study is also carried on the same structure taking into account physical and geometrical nonlinearities. The strength of the spot welded structure is precisely determined under the test of compression. The information regarding structural details including all the parameters of the spot weld are referred for the study of vibration analysis of plates with spot welded stiffeners.

S.M.Nancy, M. Q. Abdullah, M. M. Ali [3] investigates the study of vibration analysis of stiffened conical shell. Experimental and FEA study is performed for this investigation. The effect of conical shape stiffeners considering its stiffness, mass, damping factors are studied in details. They describe structural and modal analysis of conical shape stiffeners considering effect of spot weld. Matteo Palmonella, Machael I. Frisswell, Arthur W. Lees. [4] Studied two types of the spot weld structures are CWELD and ACM-2. It is shown in this paper that, natural frequencies of proposed structures are very sensitive. These structures are mainly useful for many sheet metal applications to optimize the design. In this paper the techniques of model updating in structure are used to analysis and to improve CWELD and ACM-2 model. Guidelines are given for the model updating and Implementation mainly in application of an automotive body in white has thousands of spot welds and major influence on the structural dynamics of the whole body. They also studied the effect of spot weld diameter on the dynamics of the spot welded sheet metal structures using FEA and experimental analysis. N.A. Hussain, H. H. Khodaparast, A. Snaylam, S.James, G Dearden, H Quyang [5] includes the model updating procedure by two stages. One is the updating an FE model of the welded structure and another is the updating FE model of the individual components. The model is also analyzed by using FFT analyzer. In this study the development of the initial finite element model for its components are described. Modal testing by FFT analyzer and the modeling and updating works of the welded structure including CWELD element are discussed. The set of spot welded hat plate structure is studied for model updating including information regarding parameter selection of the structure for analysis. The aim of the model updating study is to investigate the feasibility of utilizing one of the mostly used elements for spot weld modeling of the structure for behavior. Matteo Palmonella, Michael I. Frisswell, Cristinel mares, John E. Mottershead [6] This paper gives overview of the finite element modeling of spot welds for the analysis of dynamic response of structures. The model updating on the basis of several parameters such as types of weld, structural dimensions and analysis are studied. The effects of patch shape, spot weld position and eccentricity between the patch and spot element have been investigated. They investigate that weld and patch properties greatly affect the dynamics of the structures and the effect is almost equivalent. The effect of the diameter of spot weld is very less. HessamoddinMoshayedi, IradjSattari-Far [7]: Two dimensional finite element simulation of resistance spot welding process is performed using fully coupled electrical thermal and incrementally coupled thermal and mechanical analysis on steel sheets to predict weld nugget formation through temperature distributions at different welding cycles and current intensities. Finite element modeling is used for investigation of effect of welding current and temperature.

Q.I.Bhatti, M. Quisse, S. Cogan [8] The effect of number of spot weld and its location on the performance of the welded structures are studied. For the study of optimization of spot welded structures, the problem has been formulated in two ways; Performance optimization and quality optimization. Finite element analysis of the spot welded automobile structure has been studied. BiswajitTripathy, Srinivasan Suryanarayan [9]: In this paper study of weld-bonded rectangular plates having simple supports on two opposite edges and weld bonded support conditions with periodic welds along the other two edges is presented for vibration and buckling. These types or structures are widely used in automotive and other engineering structures. A

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parametric study is presented to bring out the effect of plate aspect ratio, adhesive joint parameters and the number of spot welds on the buckling loads and the natural frequencies. An adaptive optimization procedure is presented which iteratively adds and removes spot welds to find the optimum distribution as well as number of spot welds needed to improve the performance characteristics of the structures. Also, to analyze performance characteristics of the structures missing or defective spot weld due to manufacturing defects are considered. StijnDonders, Marc Brugh mans, Luc Hermans [10] studied the effect of spot weld failure on dynamic vehicle performance. The impact of spot weld quality and design for vehicle functional performance also an industrial robustness study is presented that assess the effect of spot weld failure on dynamic vehicle characteristics. The FEA of body in white (BIW) structure of vehicle is introduced in the study.

Xin Zhang, Bing Liu [11] investigated the strength of multiple spot weld joint. They also studied its automobile application i.e. vehicle chassis having many spot welds. Analyses of these structures are based on finite element study and experimental study. They have studied the finite element models for multiple spot weld joints under tensile shear load by experimental method, The effect of multiple spot weld joint strength is analyzed considering spot weld spacing edge distance, weld size and thickness using FEA. The conclusion of this study is weld parameters like weld size and thickness are primary factors affecting the strength of the joints of materials. Dipam S. Patel, S.S. Pathan, I. H. Bhoraniya[12] studied vibration behavior of rectangular plate with angular shaped stiffener. The natural frequencies of the structures are studied using FEA software. Modal analysis is carried out for the study of structures varying thickness and angle of stiffeners. Salvini P., Vivio F. Vullo V. [13] developed an FE model of spot welds considering the structural behavior of the regions surrounding the spot welds. The model composed of number of 3D beam elements oriented in the radial direction and formulated such that easily employed in complex structures with many spot welds. They studied the characteristics of the spot weld and their contribution towards the behavior of the stiffened structures.

The FEA modeling is described by considering spot weld nugget and 'surrounding area i.e. faying surface. A fine mesh is to be employed for the weld nugget, which gives most accurate results in FEA. Stress concentration appeared near the nugget boundary while the centre of the nugget was mostly stress free, which indicates the centre of the nugget does not contribute much more the load bearing capability of the spot weld. Soo-Won Chae, Ki-Youn Kwon. Tae-Soo Lee [14] investigates an optimal design system for spot welding locations in shell structures. They arrange the location of each spot weld to endure maximum loads & calculate the transmitted forces by the joints and the safety factors for the failure of spot weld. The size of elements near weld joints should be small compared to other area of the panel in order to include stress concentration or singularity effect at the joints. Also application of spot weld for car body roof stiffeners is studied. The function of roof stiffener is absorption of vibration and guiding force of side impact.

They investigate the characteristics of spot welded roof structure of automobile using ANSYS software and studied the effect of spot welded stiffeners for this application during crashworthiness testing. Soranhassanifard, mohammadZehsaz and FiroozEsmaeili [15] Studied the effects of spot weld arrangement of multi-spot welded joints on the fatigue behavior of the joints. One row four spot parallel to the loading direction. One row four spot perpendicular to loading direction and two-row four-spot weld specimen. The fracture mechanism of multi-spot welded steel joints strongly dependant on the arrangement of spots and applied load levels in the multi-spot welded joints. Brian J. schhwarz, Mark H. Richardson [16] presents modern methodology to perform the experimental modal analysis. Brief information of frequency response function (FRF) measurement, modes shapes, shaker and impact excitation technique and modal parameter estimation i.e. curve fitting curve methodology is covered. FumiyasuKuratani, Kazuhei Matsubara, Takashi Yamauchi [17] Focus is on ACM 2 (Area contact model) for the vibration analysis and reveals its dynamic characteristics. The study show that the configuration and patch size affects on mode properties of model. As the patch size increases natural frequencies also increases. When the centre of the patch and the shell element size is large, the natural frequencies vary widely. When size of patch is smaller than solid element size determines by the spot weld diameter, the variation in the natural frequency is small. They studied spot weld parameter and its effect by using mathematical model and finite element analysis.

Mr. Pravin Nana Jadhav1, Dr. Kaushal Prasad [18] In this research work author have studied the structures of plate with spot welded stiffeners using Hyper Mesh and Ls Dyna software under the loading conditions for dynamic analysis. These structures were mainly consisting two parts i.e. Upper and lower part which are joint together using spot weld. The finite element (FE) modeling of plates with spot welded stiffened structures and its dynamic analysis was done in this study. Ch.Goutham, D.Vijay Praveen, Dr.M.Venkateswara Rao [19] In this research paper author have studied the structures of plate with spot welded stiffeners using Ansys (14.5) software under the loading conditions for Harmonic analysis. These structures mainly consists two parts i.e. Upper and lower part which are joint together using spot weld. The finite element (FE) modeling of plates with spot welded stiffened structures and its Harmonic analysis was research area of this paper. In FEA study, modal analysis method is used to find the natural frequencies of all test structural models.

Ninshu Ma & Jiangchao Wang & Yasuhisa Okumoto [20] A holistic investigation on out-of-plane welding distortion in

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fabrication of several stiffened welded structures with considering prediction and mitigation is presented. Experiments of typical fillet welded joints and its assembled stiffened welded structures are conducted first, and out-of plane welding distortion is systematically measured. Different welding distortion patterns, so-called bending distortion and welding buckling, are obviously obtained from the measurements of the examined parallel and cross stiffened welded structures, respectively. A combined computational approach, which involves thermal elastic plastic (TEP) finite element (FE) analysis, Eigen value analysis, and elastic FE analysis, is then employed to predict the out-of-plane welding distortion and clarify the generation mechanism for different welding distortion patterns. In particular, Eigen value analysis can support the critical condition for welding buckling occurrence. Since the bending and welding buckling are caused by different reasons, the mitigation processes with flame heating are carried out individually. In detail, line heating is implemented in the opposite side of welded joint to produce inverse bending, and spot heating is employed to heat the region far away from welding line to eliminate effect of inherent deformation on welding buckling generation.

A review of literatures indicated that finite element and experimental modal analysis method is able to predict the characteristics of plates with spot welded structures during vibration. Also finite element analysis can give accurate result of strength of stiffened structure during dynamic analysis. There have been very few studies to find combine effect on stiffened structure of spot weld parameters and stiffeners parameters. There is lack of study of various shapes of the stiffener plates as per the industrial application. Also no study is carried out on actual application. Also no study is carried out on effect of spot welding and different shapes of stiffeners on vibration.

III. MODELLING OF SPECIMEN

All the dimensions were decided from piaggio ape workshop manual and from actual measurement. The material selected is mild steel (CRS). The modelling of all five specimens were done by using Auto CAD software. Also for some specimen solid-works software was used. The details of all the specimens are given bellow.

TABLE I
NOMENCLATURES OF SPECIMEN

Sr. no	Specimen	Description	Nomenclature
01	Stiffener type 1	Rectangular stiffener	S1
02	Stiffener type 2	Triangular stiffener	S2
03	Welding type 1	Arc welding	W1
04	Welding type 2	Spot welding	W2
05	Specimen 01	Base plate without stiffener & without welding	PS0W0
06	Specimen 02	Base plate with rectangular stiffener arc welded	PS1W1
07	Specimen 03	Base plate with rectangular stiffener spot welded	PS1W2
08	Specimen 04	Base plate with triangular stiffener arc welded	PS2W1
09	Specimen 05	Base plate with triangular stiffener spot welded	PS2W2

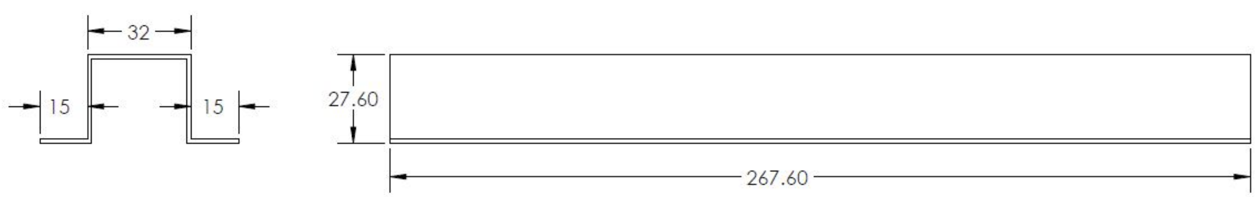

Fig. 1 Dimensional details of rectangular stiffener

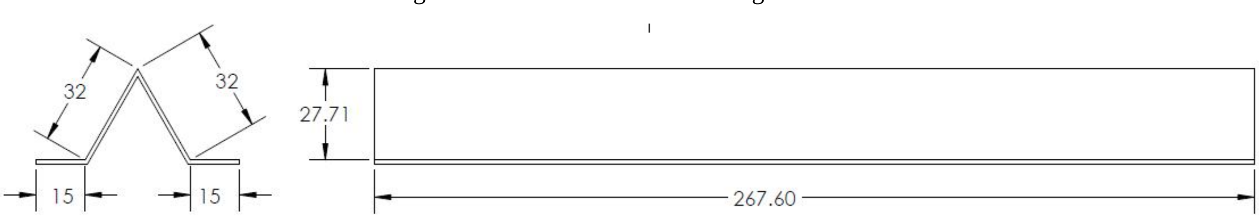

Fig. 2 Dimensional details of triangular stiffener

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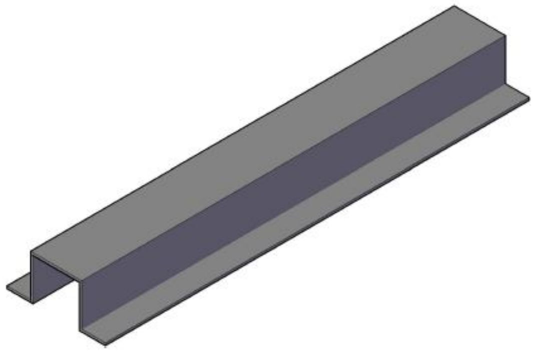

Fig. 3 3D model of stiffener S1

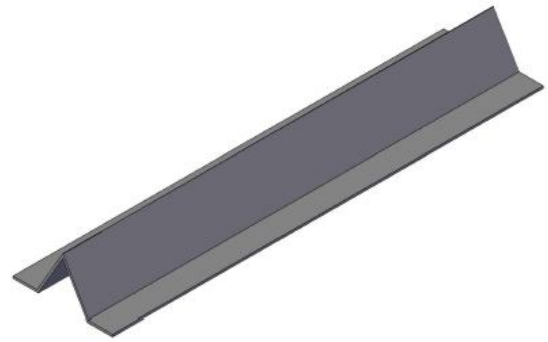

Fig. 4 3D model of stiffener S2

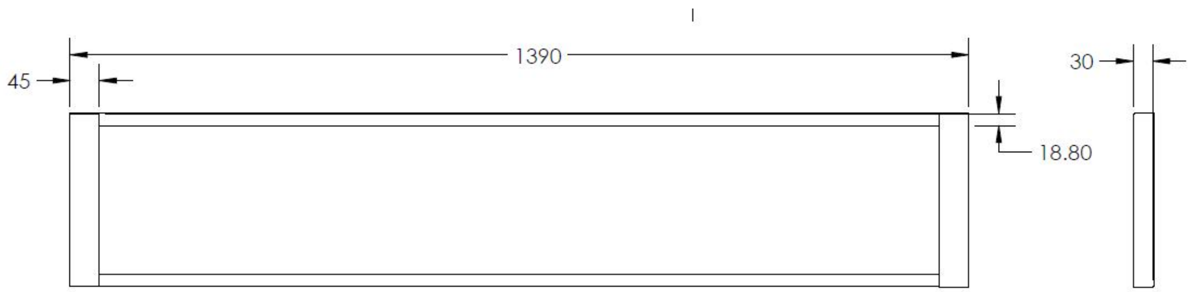

Fig. 5 Dimensional details of base plate / specimen PS0W0

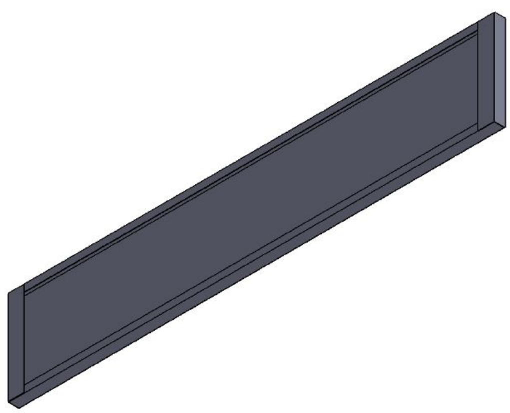

Fig. 6 3D model of base plate/ specimen PS0W_0

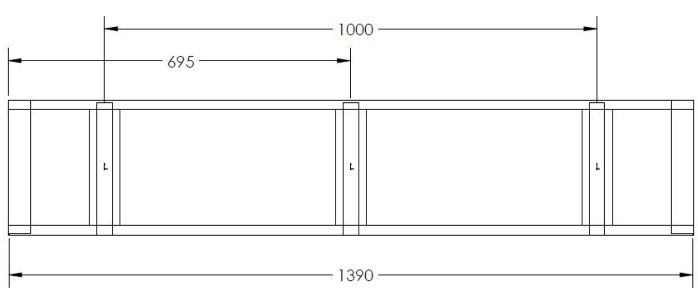

Fig. 7 Dimensional details of specimen PS1W1 & PS1W2

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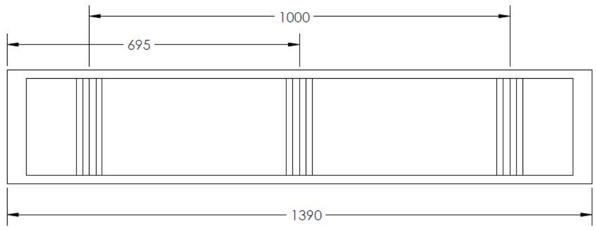

Fig. 8 Dimensional details of specimen PS2W1 & PS2W2

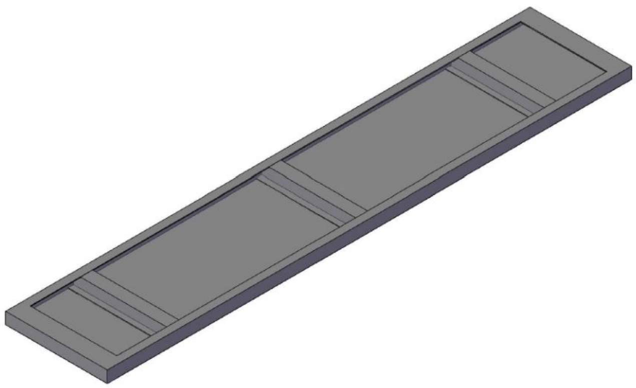

Fig. 9 3D model of specimen PS1W1 & PS1W2

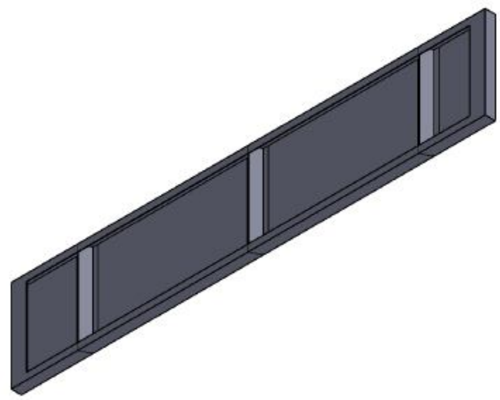

fig. 10 3D model of base specimen PS2W1/PS2W2

IV. MODAL ANALYSIS USING ANSYS

This is most representative technique to prepare the model of structural object. FE models are generated to obtained detailed response of structures and to determine structural characteristics. F.E Models are more practical because they predict realistic structural response. This section describes the geometrical and finite element modeling process in detail. Also brief information regarding analysis of structural models are included. The following mentioned design of experiment matrix used for this study.

Modes are inherent properties of structure and are determined by material properties (mass, damping and stiffness), and boundary conditions of the structure. Each mode is defined by natural frequency, mode shape (modal parameters).If either the material properties or the boundary conditions of a structure change its modes will change. Also natural frequencies are different due to different vibrations. This study includes the different structures. So, material properties and boundary conditions are different. Thus analysis of structures is carried out by observing natural frequencies of the same structures.

A. Flow Of Work And Methodology For Modal Analysis Of Project Structural Models

Start
Create the geometry of the structural models using Auto-Cad software/Solid Works
Export geometry file in ACIS (.sat) form
Open the ANSYS software
Import the same geometry file
Meshing and weld of the structural model as per required standards
Set the contact points for welding.
Do the pre- analysis setting.
obtain the results
Stop

B. Frequencies of All Structural Models and Mode Shapes

The result includes frequencies of all structural models in Hz. First six modes are the rigid modes. Therefore remaining modes are considered for analysis.

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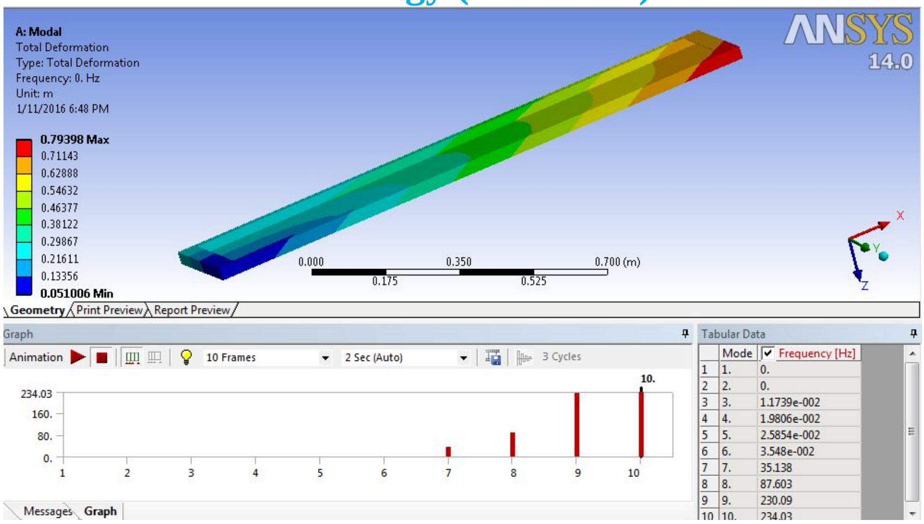

Fig.11 Frequency results of specimen PS0W0

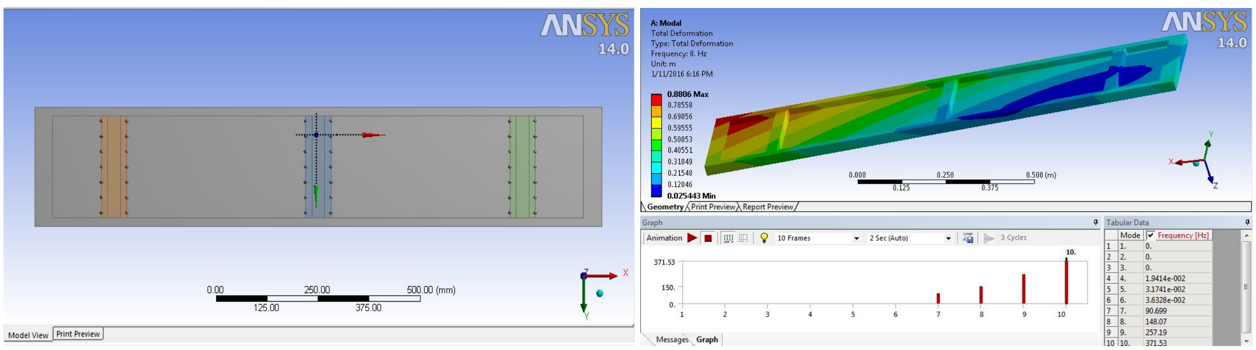

Fig.12 Frequency results of specimen PS1W1

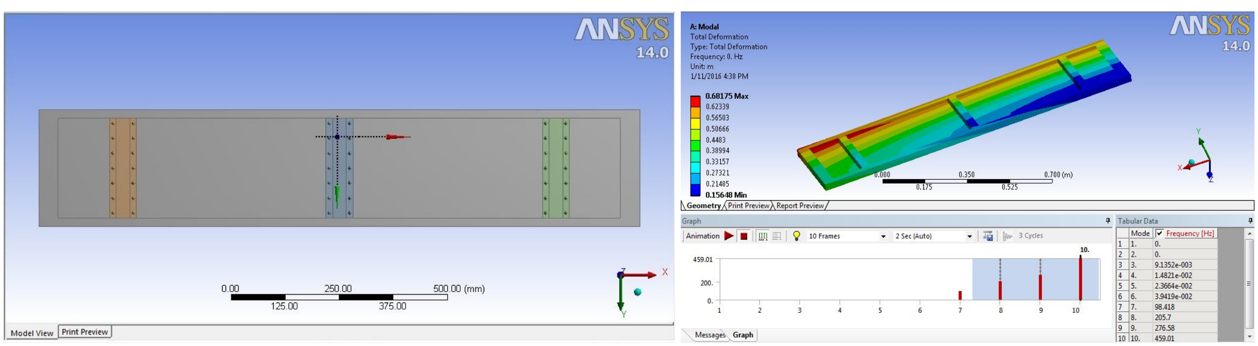

Fig.13 Frequency results of specimen PS1W2

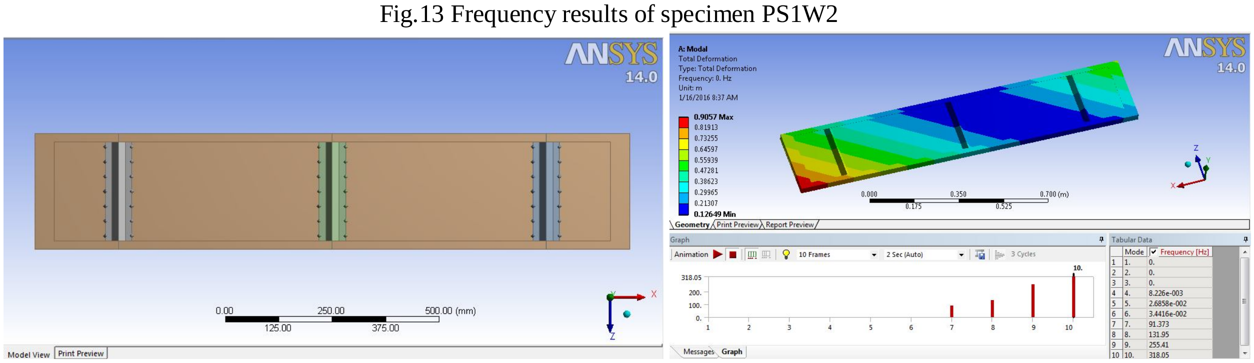

Fig.14 Frequency results of specimen PS2W1

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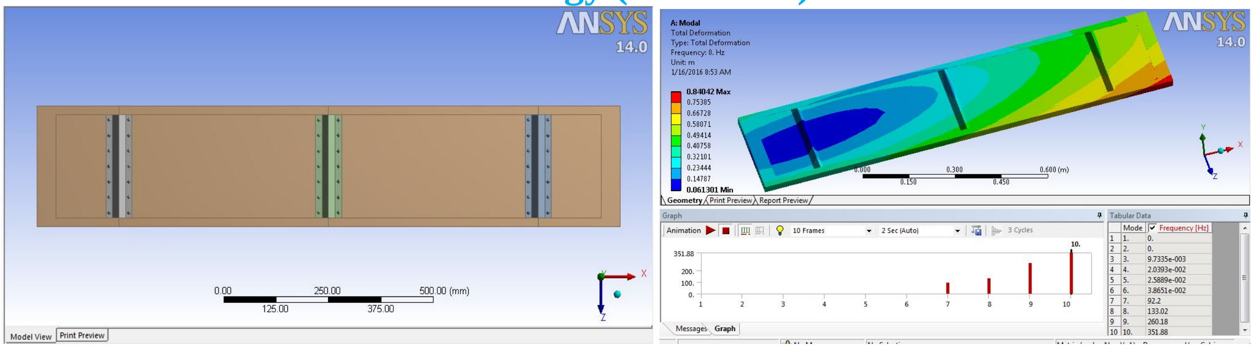

Fig.15 Frequency results of specimen PS2W2

TABLE II
ANSYS RESULT SUMMARY

Sr. no.	Specimen	Frequency (Hz) (ANSYS)	Sr. No.	Specimen	Frequency (Hz) (ANSYS)
1	PS0W0	35.13	4	PS2W1	91.37
2	PS1W1	90.69	5	PS2W2	92.2
3	PS1W2	98.41			

V. CONCLUSIONS

From the above FEA results, we conclude-
By changing the stiffener type and welding type we can change the natural frequency of specimen.
The specimen PS0W0 has the lowest frequency and which is equal to 35.13 Hz.
The specimen PS1W2 has the highest frequency and which is equal to 98.41 Hz.
The selection of profile of stiffeners and weld pattern depends upon the excitation frequency of the system in order to avoid resonance condition of the system.
The specimen having high natural frequency (PS1W2) is useful for the given application since excitation frequency is less and will not match with specimen frequency.

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