Vibration Analysis Plates with Spot Welded Stiffeners

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Abstract- Spot welding is most preferred and widely used method for joining the metal sheets in automotive and many other industrial assembly operations. So, spot weld is used to join the plates and stiffeners in this work. This study focuses effect of spot weld pattern and profiles of stiffeners under the vibration analysis of structures.
Both FEA and experimental study are carried out for vibration analysis of plates with spot welded stiffeners. In FEA study, modal analysis method is used to find the natural frequencies of all test structural models. Ls-Dyna and HYPERMESH software are used for FEA study. To back up the results obtained by FEA study, experimental analysis is done to find frequencies of the same models using FFT analyzer.

Keywords – Stiffener, Structures.

I. Introduction

The objective of this investigation to study the effect of spot weld patterns and profiles of stiffeners on the vibration characteristics of plates with spot welded stiffeners. The stiffened structural elements are widely useful in engineering mainly for the application of steel plates for hulls of ships, steel bridges and aircraft structures. These types of structures have wide application in modern industries.

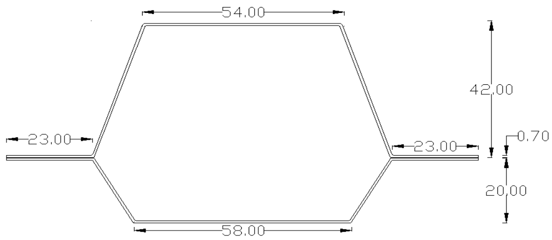
Automotive bodies and many other structures are composed of metal sheets joined by spot welds. A spot weld is materialized by clamping the sheets with two pincers while applying a force and transmitting current. The electrical resistance of contacting sheets generates sufficient heat at the metal surfaces to melt the metal. Thus nugget develops and sheet metals are joined. Spot weld joints provides localized connection thus lead to high stress concentration in the joined plates. Excessive stresses and premature failure occurs due to improper design.
A designer significantly concentrates the strength of component by introducing the changes in its geometry and weld patterns that will reduce the vibration of the structural models. Also increases the strength of the structures. The optimum design of geometry and weld patterns can be obtained optimal performance i.e good strength to the composed structures.

In the literature, there are some studies about optimization of spot welded structures. Ahmet H Er`tas, Fazil O. Sonmez [1] optimized the spot welded plates for maximum fatigue life. They suggest that number of spot welds significantly affects the fatigue strength. Sheet thickness and material are studied to the strength requirements of the structures. The effect of the size of the welds diameter and pitch of the weld on the account of absorbed energy is studied [2].
Some researchers have been published regarding vibration analysis of stiffened laminated plates and shells. It was found that stiffeners profile and its arrangement have great effect on the natural frequencies and mode shapes of the plates [3]. Experimental analysis of composed structures, including setup is studied [4-5] to find the natural frequencies using FFT analyzer.

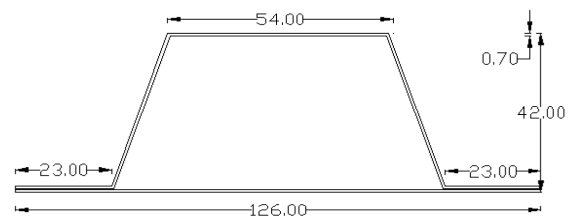
This study of vibration analysis of plates with spot welded stiffeners includes study of spot weld arrangement and stiffener parameters such as profile, dimensions and arrangement. Good agreement of optimum design of structure due to FEA study and experimental study.

II. DETAIL DESCRIPTION OF ALL STRUCTURAL MODELS

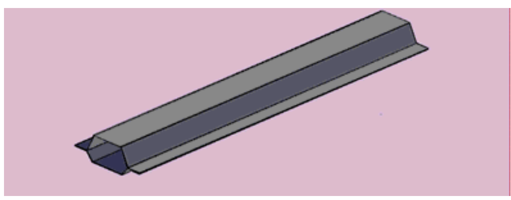
The different structural models investigated for this study, its brief information given below. Models are made of mild steel material.



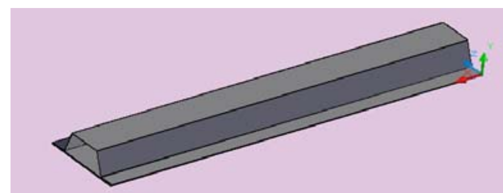
(a) Section View of Structure 1 (S1)



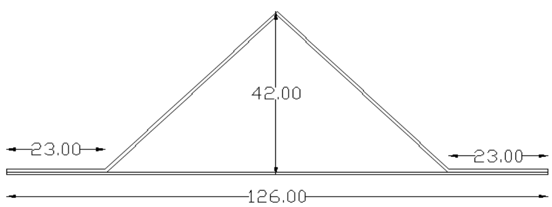
(b) Section View of Structure 2 (S2)



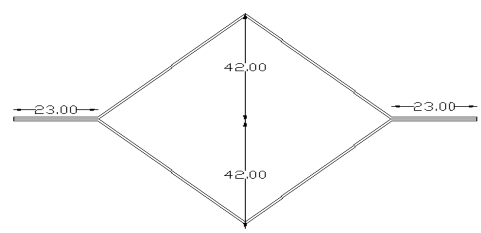
3D Cad Model of Structure S1



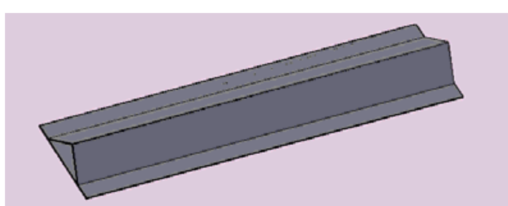
3D Cad Model of Structure S2



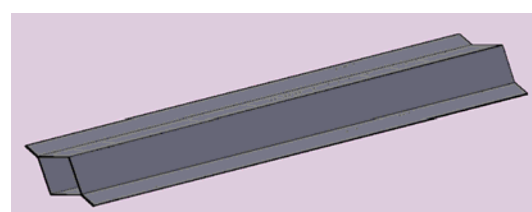
(c) Section View of Structure 3 (S3)



(d) Section View of Structure 4 (S4)



3D Cad Model of Structure S3



3D Cad Model of Structure S4

Figure1. Shapes of different structural models with dimensions

A. Structural models:

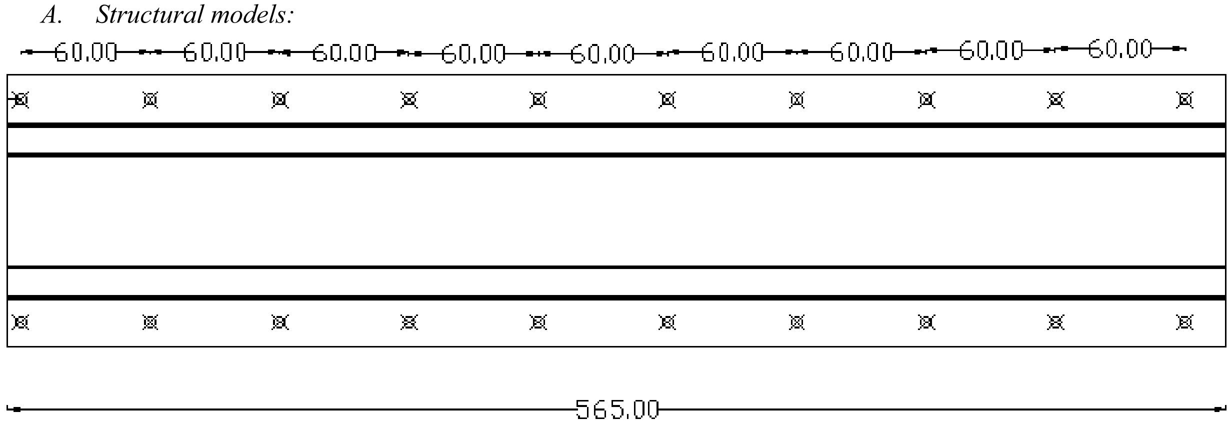


Fig.2 Top view of structural model

Fig.2 describes the dimensional details of weld patterns. Diameter of each spot weld is 5mm.This 28study includes the variation in weld patterns.

B. VARIOUS SECTIONS AND THEIR NOMENCLATURES

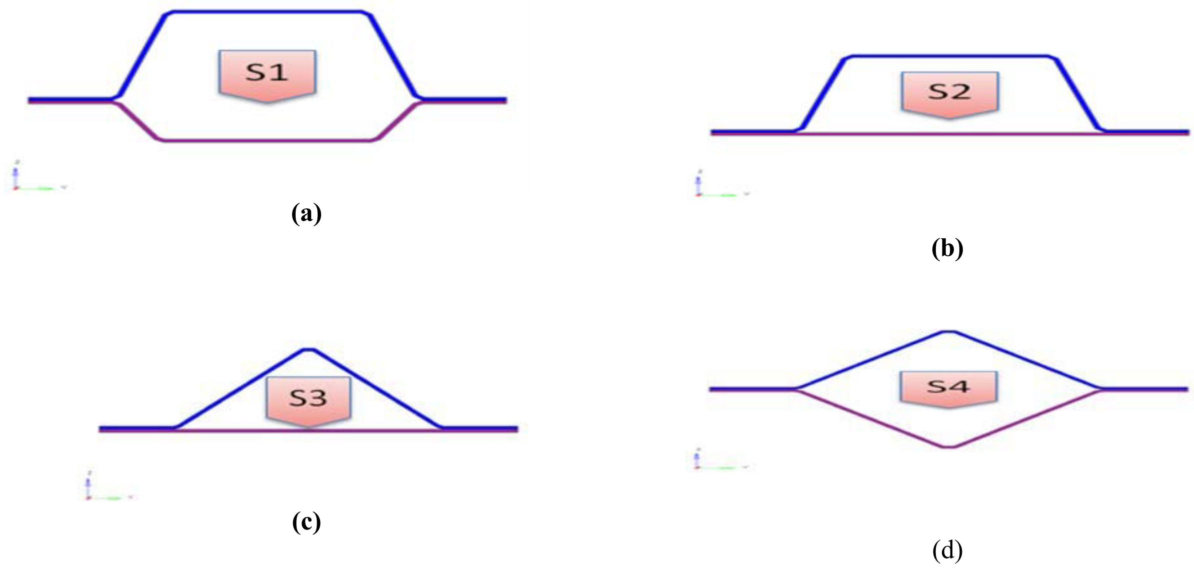
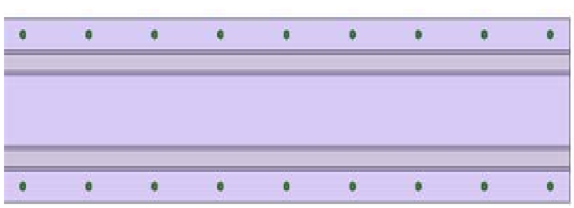


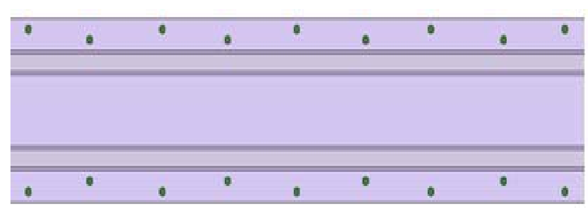
Figure3. Sections of different structures and their nomenclature

C. VARIOUS SPOT WELD PATTERN AND TEIR NOMENCLATURES :

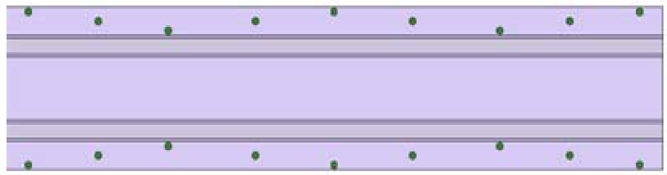
The various spot weld patterns to be tested are as given below



(a) Weld pattern P1



(b) Weld pattern P2



(c) Weld pattern P2

Figure 4. Top view of various spot weld patterns and their nomenclature

III. FINITE ELEMENT ANALYSIS

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.

Table -01 Design of Experiment Matrix

Design of experiment	Section 1	Section 2	Section 3	Section 4
Pattern1	S1P1	S2P1	S3P1	S4P1
Pattern2	S1P2	S2P2	S3P2	S4P2
Pattern3	S1P3	S2P3	S3P3	S4P3

A. MODAL ANALYSIS OF STRUCTURAL MODELS:

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.

B. FLOW OF WORK AND METHODOLOGY FOR MODAL ANALYSIS OF PROJECT STRUCTURAL MODELS:

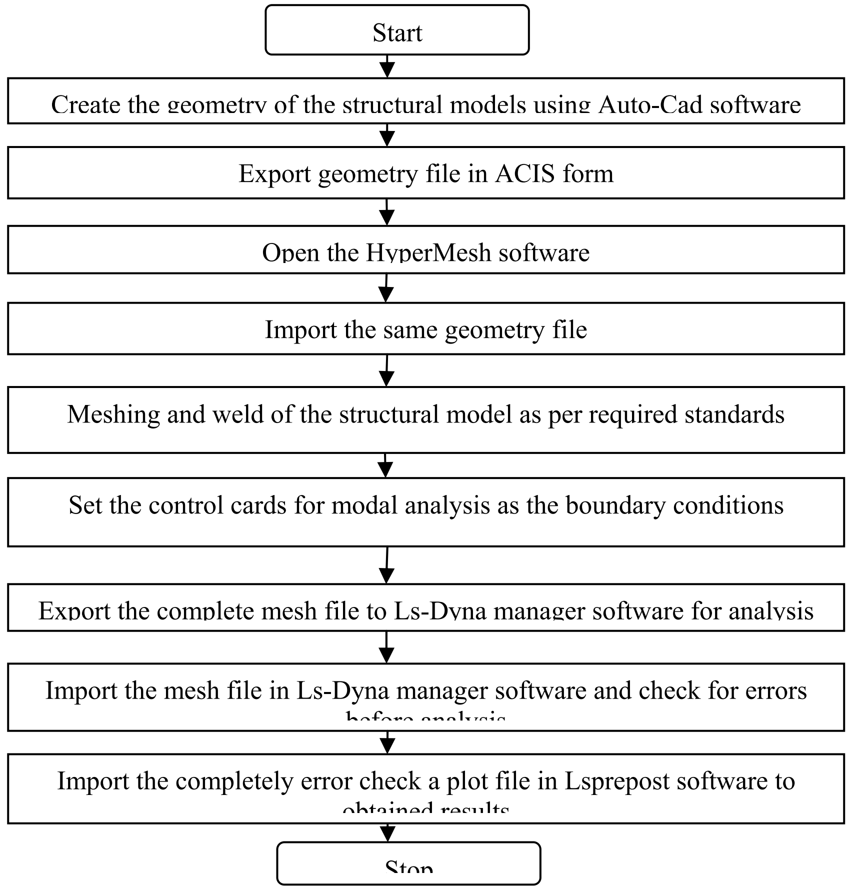
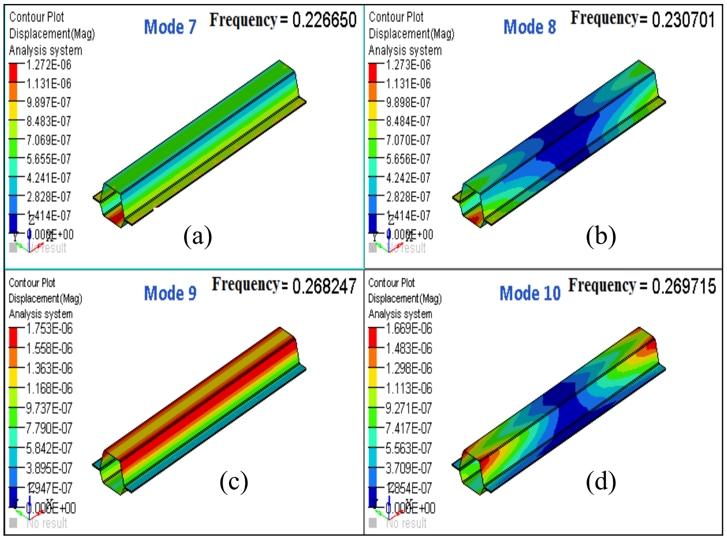


Figure 5. Flow chart of methodology of modal analysis

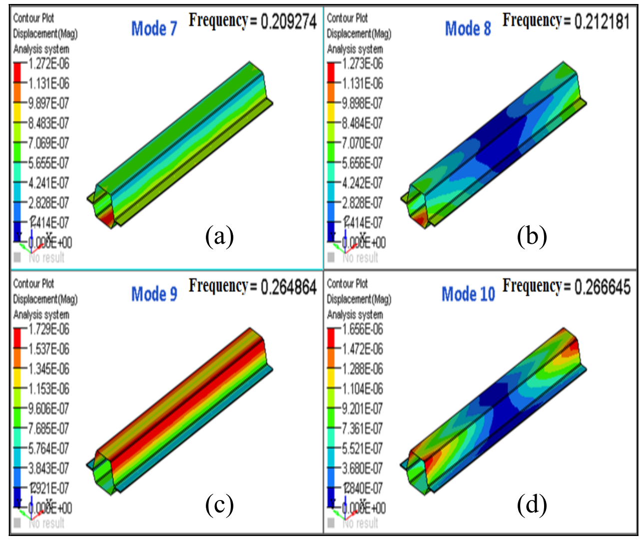
C. FREQUENCIES OF ALL STRUCTURAL MODELS AND MODE SHAPES:

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



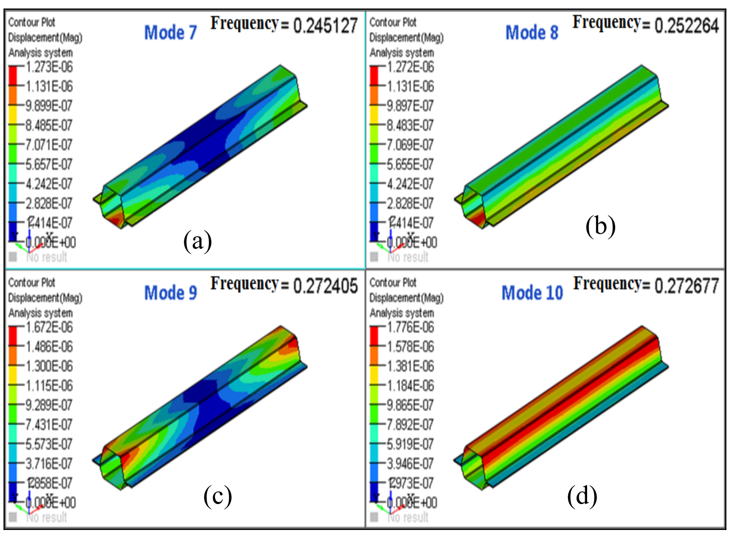
Frequencies: a) 226.650Hz b)230.701Hz
c) 226.650Hz d)230.701Hz

Figure 6. Frequency results of structure S1P1



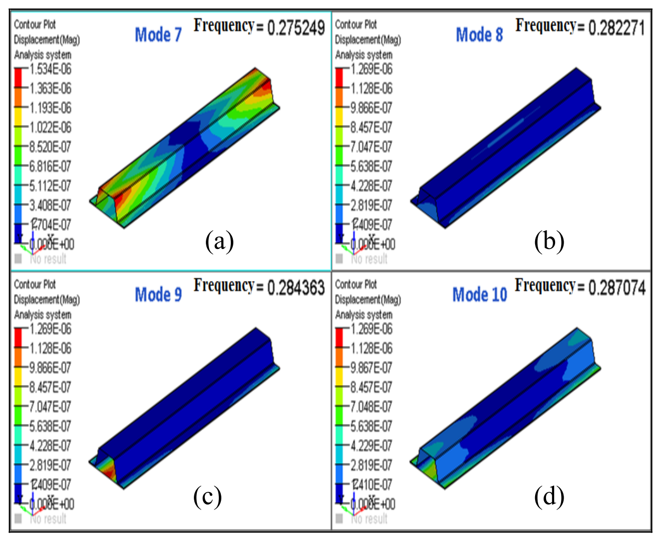
Frequencies: a) 209.274Hz b)212.181Hz
c) 264.864Hz d)266.645Hz

Figure 7. Frequency results of structure S1P2



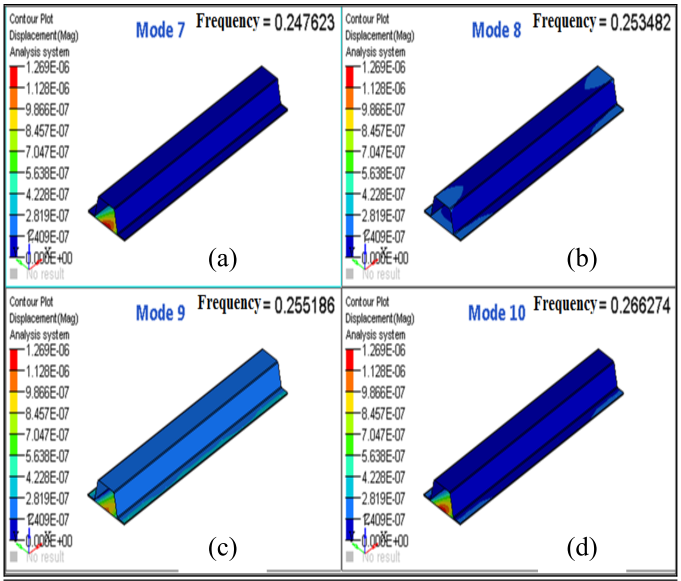
Frequencies: a) 245.127Hz b)252.264Hz
c) 272.450Hz d)272.677Hz

Figure 8. Frequency results of structure S1P3

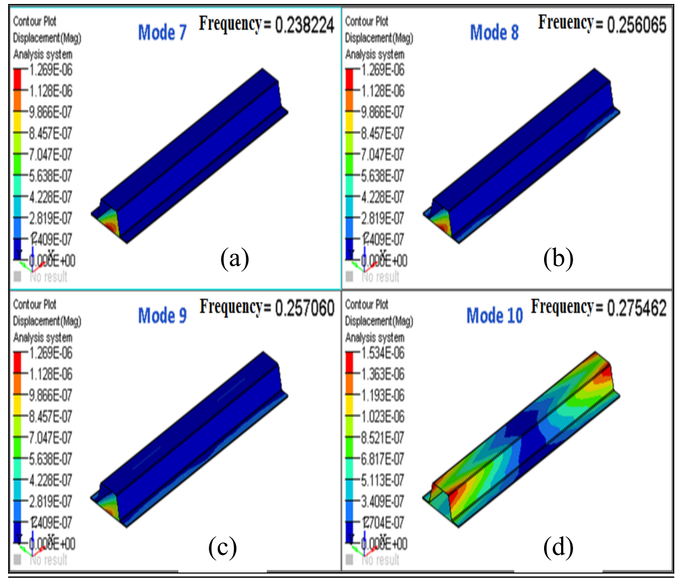


Frequencies: a) 275.249Hz b)282.271Hz
c) 284.363Hz d)287.074Hz

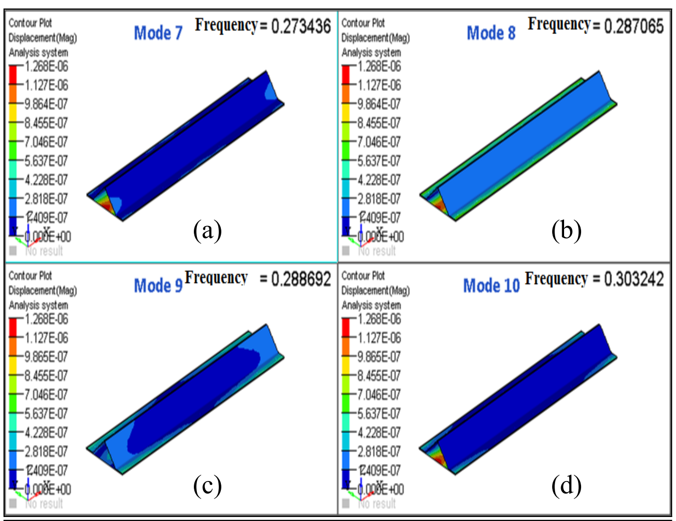
Figure 9. Frequency results of structure S2P1



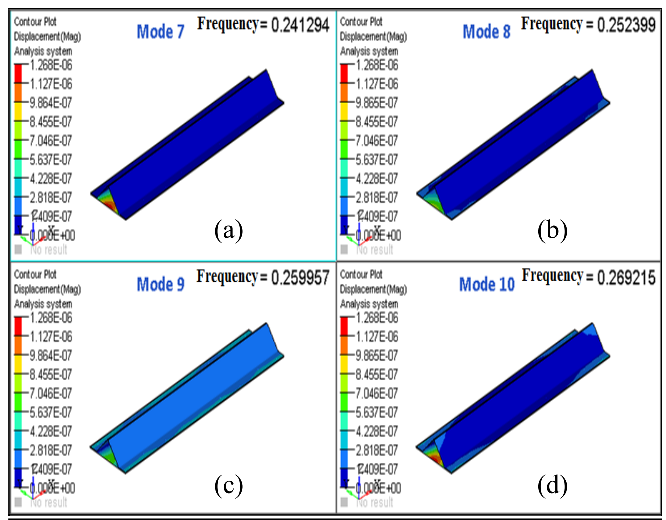
Frequencies: a) 247.627Hz b)253.482Hz
c) 255.186Hz d)266.274Hz
Figure 10. Frequency results of structure S2P2



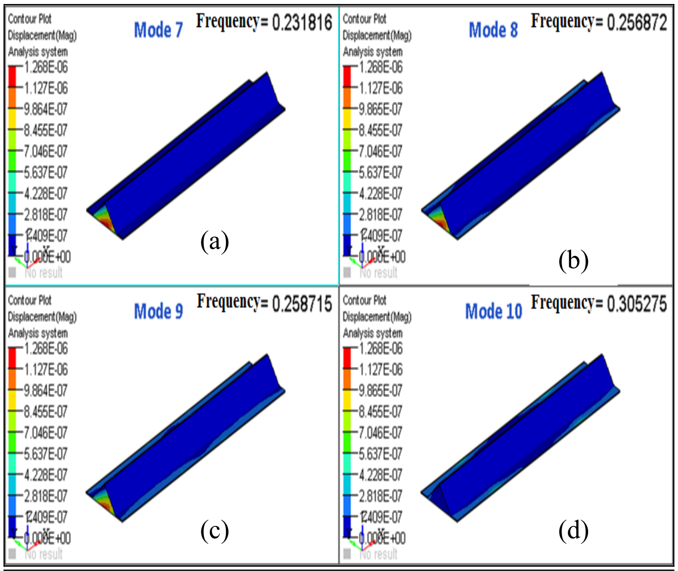
Frequencies: a) 238.224Hz b)256.065Hz
c) 257.060Hz d)275.462Hz
Figure 11. Frequency results of structure S2P3



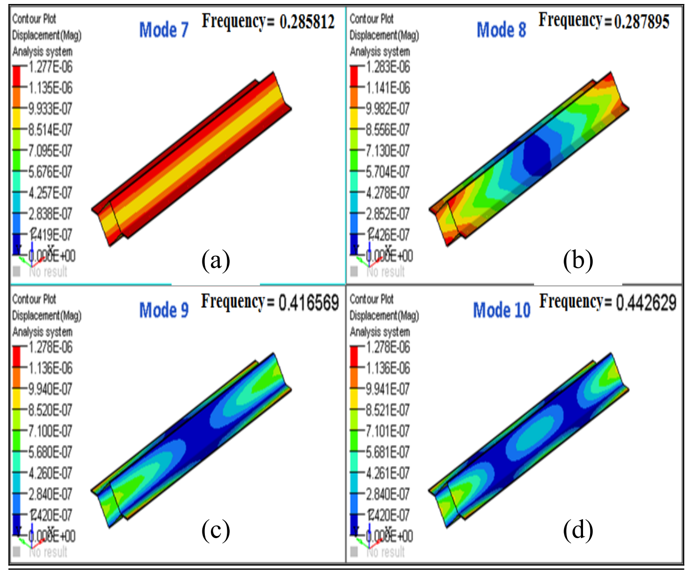
Frequencies: a) 273.436Hz b)287.065Hz
c) 288.692Hz d)303.242Hz
Figure 12. Frequency results of structure S3P1



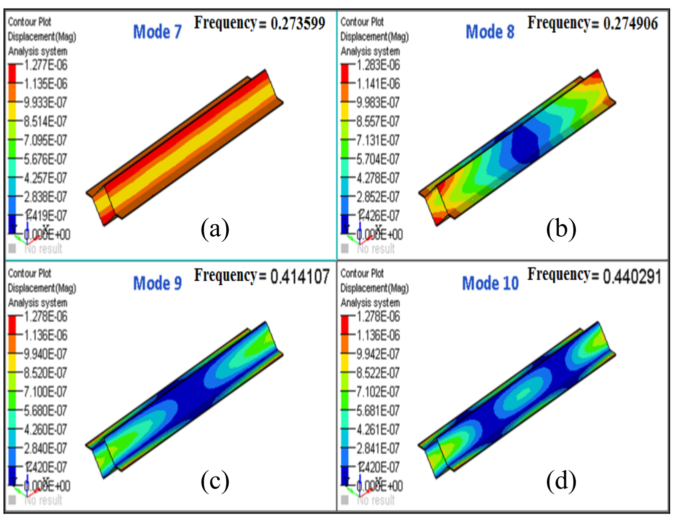
Frequencies: a) 241.294Hz b)252.399Hz
c) 259.957Hz d)269.215Hz
Figure 13. Frequency results of structure S3P2



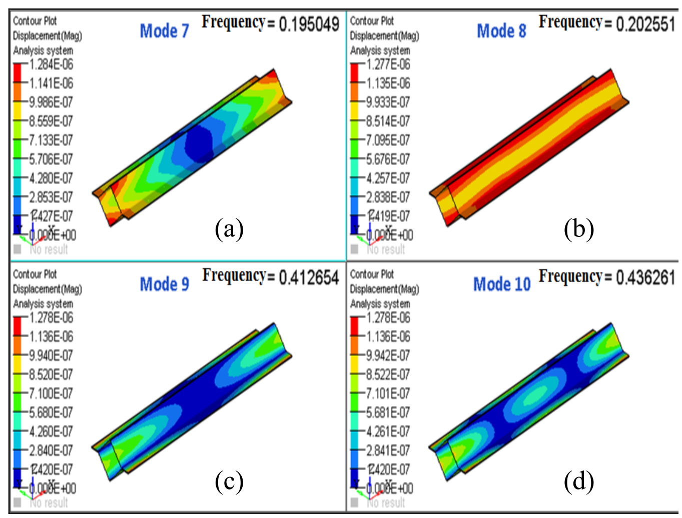
Frequencies: a) 231.816Hz b)256.872Hz
c) 258.715Hz d)305.275Hz
Figure 14. Frequency results of structure S3P3



Frequencies: a) 285.812Hz b)287.895Hz
c) 416.569Hz d)442.629Hz
Figure 15. Frequency results of structure S4P1



Frequencies: a) 273.599Hz b)274.906Hz
c) 414.107Hz d)440.291Hz
Figure 16.Frequency results of structure S4P2



Frequencies: a) 195.049Hz b)202.551Hz
c) 412.654Hz d)436.261Hz
Figure 17.Frequency results of structure S4P3

D. RESULTS OF MODAL ANALYSIS:

Table -02 Results of Modal Analysis

Structures	Frequencies in Hz			
	Mode 7	Mode 8	Mode 9	Mode 10
S1P1	226.650	230.701	268.247	269.715
S1P2	209.274	212.181	264.864	266.645
S1P3	245.127	252.264	272.405	272.677
S2P1	275.249	282.271	284.363	287.074
S2P2	247.623	253.482	255.186	266.274
S2P3	238.224	256.065	257.060	275.462
S3P1	273.436	287.065	288.692	303.242
S3P2	241.294	252.399	259.957	269.215
S3P3	231.816	256.872	258.715	305.275
S4P1	285.812	287.895	416.569	442.629
S4P2	273.599	274.906	414.107	440.291
S4P3	295.049	242.551	412.654	436.261

V. EXPERIMENTAL ANALYSIS:

Experimental modal analysis is very useful vibration analysis tool, providing an understanding of structural characteristics, operating conditions and performance criteria. For this study, modal testing conducted to free-free boundary condition for each structure. The structures are tested for one hammer point. The location for the impact is carefully chosen to get accurate results. The vibration response measured using FFT Analyzer system

Structures are made up of mild steel with nominal thickness of 0.7mm.The welding is carried out using spot welding machine has power of 10 KVA. The electrodes have a truncated conical shape with a flat circular contacting area of 5 mm diameter.

A. *EXPERIMENTAL SETUP:*

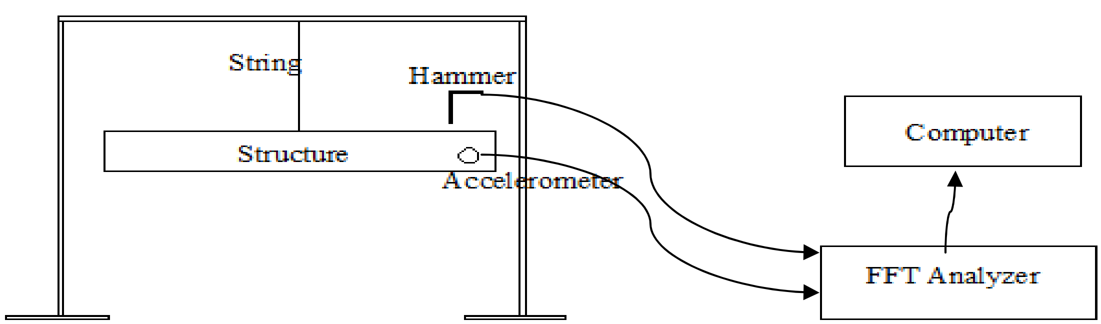


Figure 18. Experimental Setup

B.*GRAPHICAL EXPERIMENTAL RESULTS OF ALL STRUCTURES:*

Structure (S1P1)

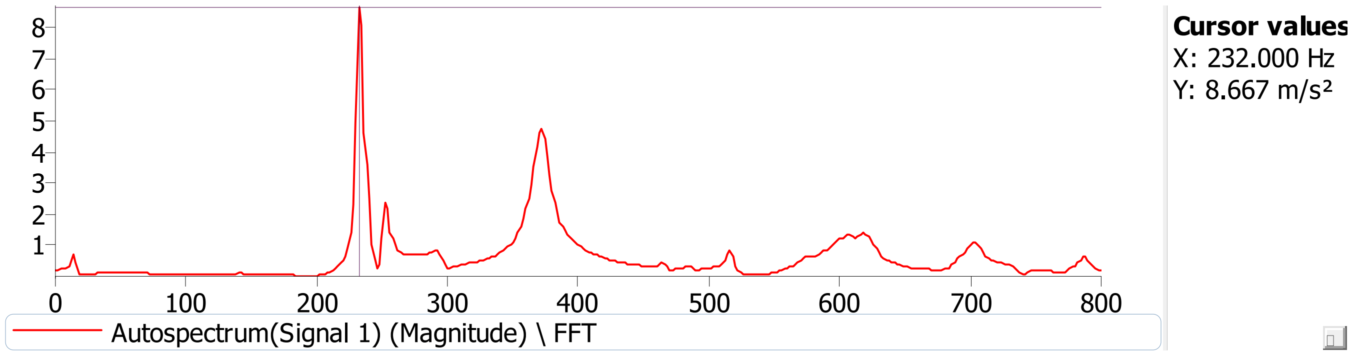


Figure 19. Experimental Result of Structure S1P1

Structure (S1P2)

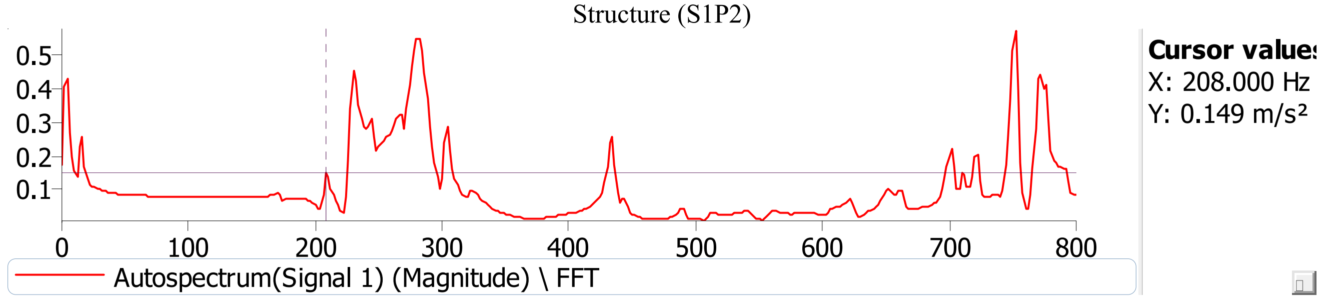


Figure 20.Experimental Result of Structure S1P2

Structure (S1P3)

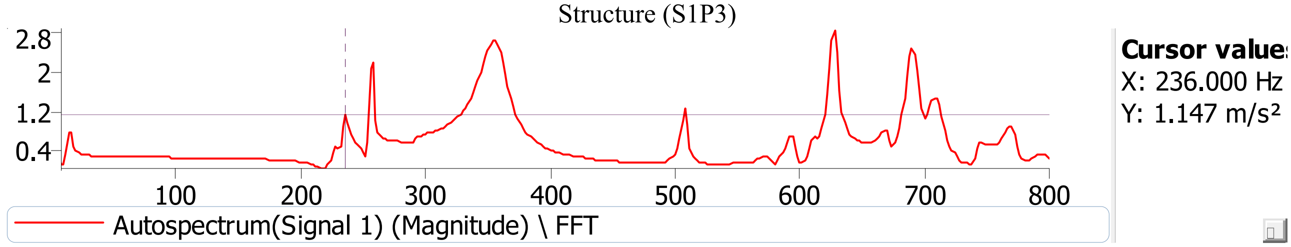


Figure 21.Experimental Result of Structure S1P3

Structure (S2P1)

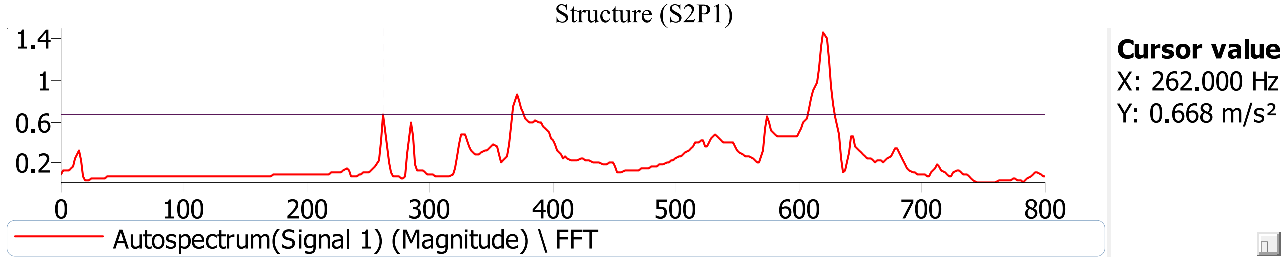


Figure 22.Experimental Result of Structure S2P1

Structure (S2P2)

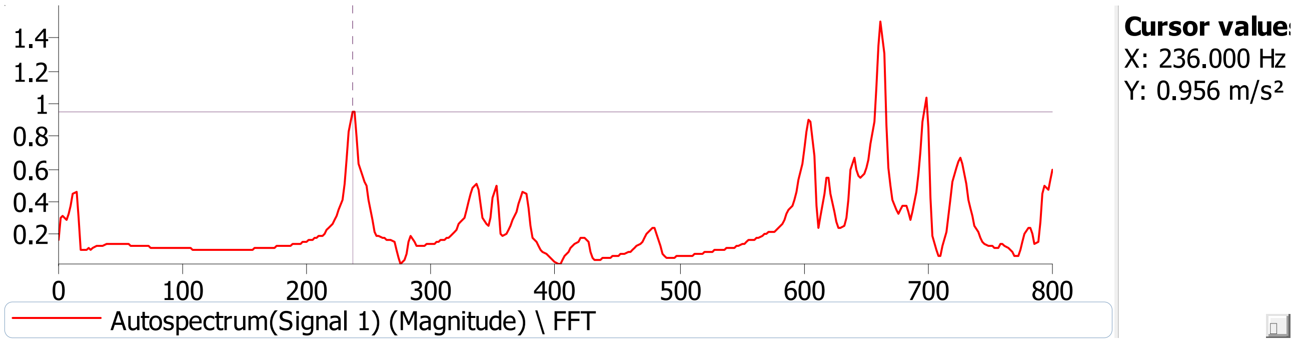


Figure 23.Experimental Result of Structure S2P2

Structure (S2P3)

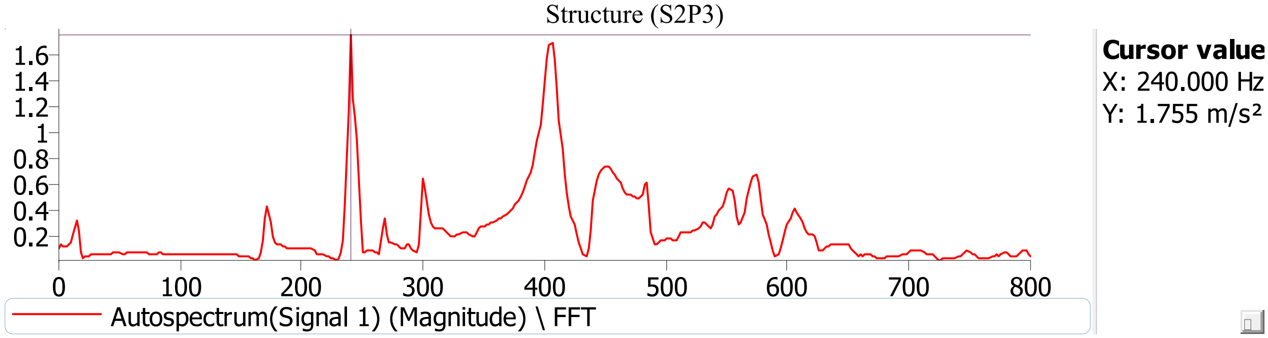


Figure 24.Experimental Result of Structure S2P3

Structure (S3P1)

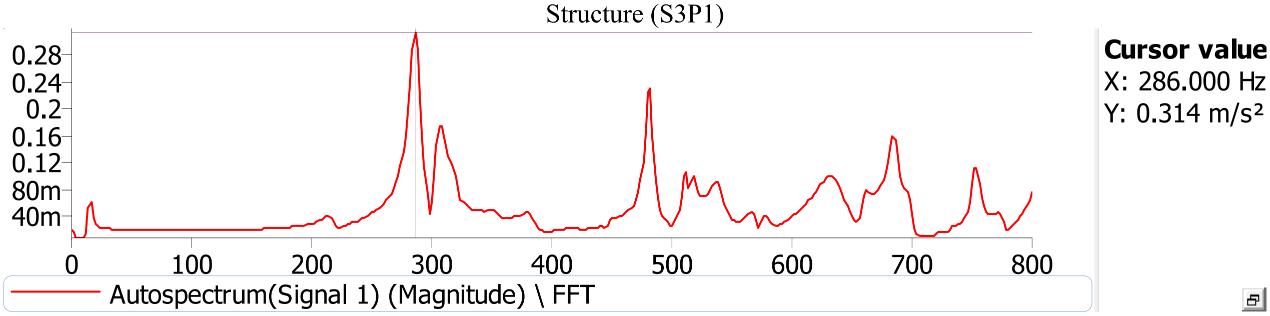


Figure 25.Experimental Result of Structure S3P1

Structure (S3P2)

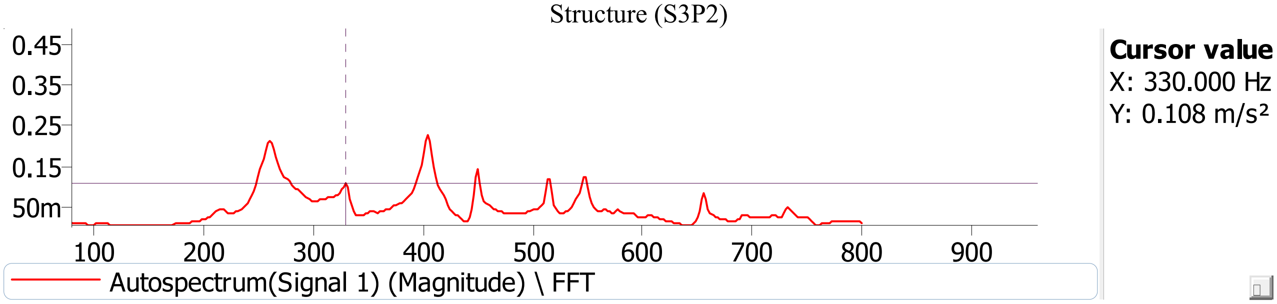


Figure 27.Experimental Result of Structure S3P2

Structure (S3P3)

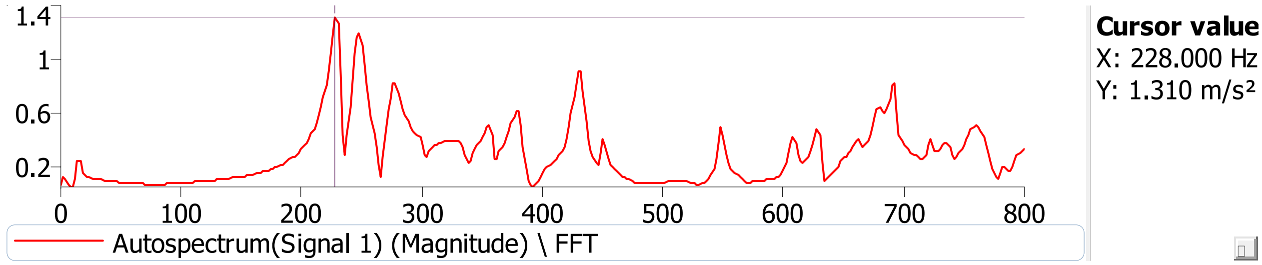


Figure 28.Experimental Result of Structure S3P3

Structure (S4P1)

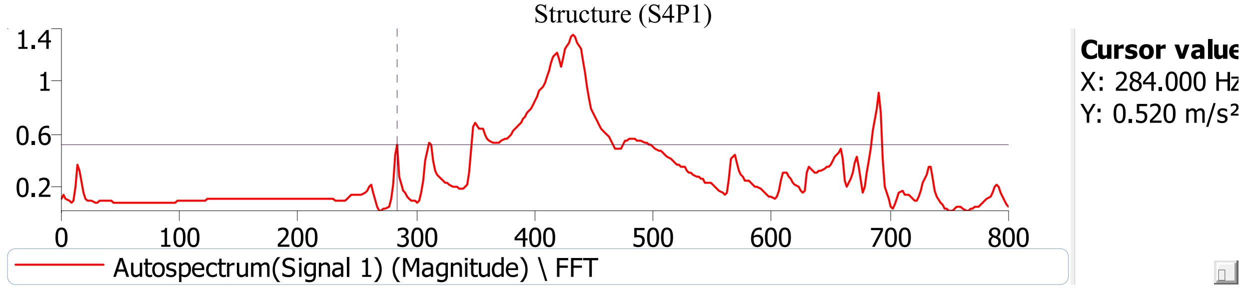


Figure 29.Experimental Result of Structure S4P1

Structure (S4P2)

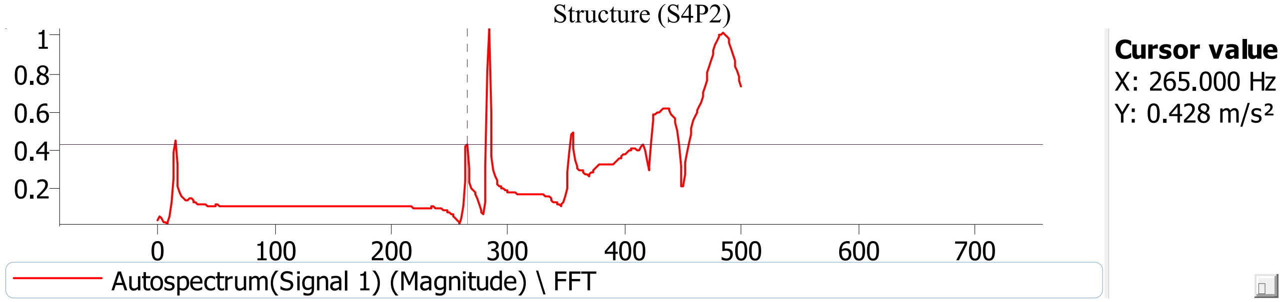


Figure 30.Experimental Result of Structure S4P2

Structure (S4P3)

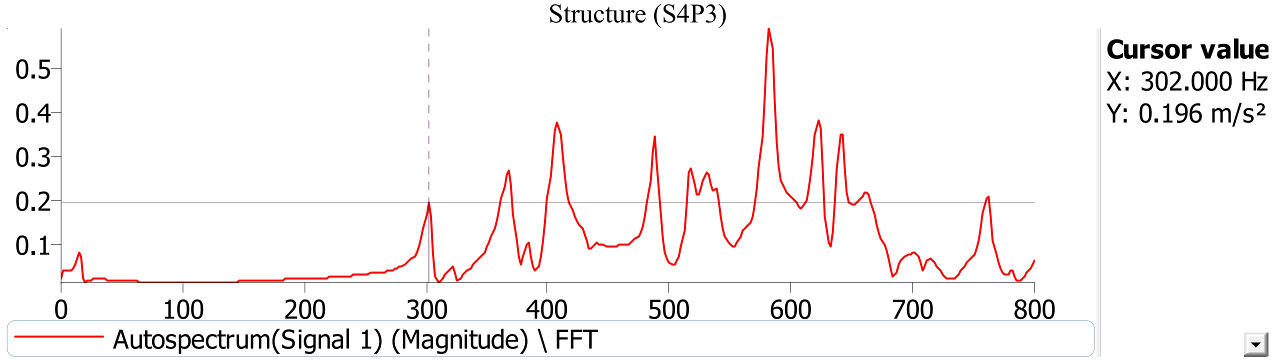


Figure 31.Experimental Result of Structure S4P3

Table -03 Results of Experimental Modal Analysis

Structures	S1P1	S1P2	S1P3	S2P1	S2P2	S2P3	S3P1	S3P2	S3P3	S4P1	S4P2	S4P3
Frequency (Hz)	232.00	208.00	236.00	262.00	236.00	240.00	286.00	260.00	228.00	284.00	265.00	302.00

VI. CONCLUSION

From the FEA and experimental study, following conclusions are made;

1. The natural frequency of seventh mode of vibration lies between 209 Hz to 295 Hz in FEA and it is 208 Hz to 302 Hz from experimental study

2. Experimental results back up the results of FEA study. Both the results are nearly same.

3. The observation made from both the studies that, the natural frequency is less for S1P2 structure and it is highest for S4P3 structure.

4. From the above FEA and experimental results, it is revealed that, the profile of stiffener and weld pattern having much more influence on natural frequencies of the structural model.

5. 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 structures having less frequency are useful for the application where high excitation frequency and the structures having high frequency are useful for the application where less excitation frequency.

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