International Journal of Scientific & Engineering Research, Volume 7, Issue 10, October-2016
ISSN 2229-5518

Free Vibration Analysis of Delaminated Honeycomb Sandwich Composite Plates

Aryasree Madhukumar[1], A.S.Nisha.[2]

Abstract—A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components. Sandwich construction is one of the most valued structural engineering innovations developed by the composite industry. The present study aims on damage detection of sandwich plates based on free vibration analysis. To detect, localize and quantify the damage, modal parameters- frequency and mode shapes are used. ANSYS is used for the finite element analysis. An intact model is analyzed first and the results of the debonded one is compared with the intact one. It is observed that decrease in natural frequency of a debonded plate in comparison with that of an intact one gives an indication of the damage.Here a meaningful parameter called Modal Strain Energy Change Ratio (MSECR)is used to predict the position and extent of damage.

Index Terms—Delamination, Debond, Honeycomb Sandwich plates, Free Vibration, Natural frequency, Mode Shape, , Modal Strain Energy Change Ratio(MSECR)

1 INTRODUCTION

A sandwich structure is a special form of laminated composites. Sandwich structures consist of two thin, stiff and strong face sheets (skin sheets) attached to the top and bottom side of a thick, light weight, low modulus core. Generally face sheets are adhesively bonded to the core to obtain load transfer between the components. The faces will act together to form an efficient stress couple or resisting moment counteracting the external bending moment. The core resist shear and stabilize the faces against the buckling and wrinkling. The bond between the faces and the core must be strong enough to resist the shear and tensile stress set up between them. Sandwich constructions are used almost in every industrial sector ranging from buildings to aerospace applications because of their low density, high specific stiffness and strength. A sandwich structure with the core having the geometry of a honeycomb is called a honeycomb sandwich structure.

Damage can cause structural failure, and sudden failure during high load operation may lead to catastrophic consequences. Development of an early damage detection method for structural failure is one of the most important keys in maintaining the integrity and safety of structures. Damage can occur at several scales within the composite material and structural configuration. This ranges from damage in the matrix and fiber to broken elements and failure of bonded or bolted attachments. The extent of damage controls repeated load life and residual strength and is critical to damage tolerance. A major type of damage is delamination or debond.Strength and stiffness of honeycomb sandwich structure are reduced by the presence of debond.

- *AryasreeMadhukumar is currently pursuing masters degree program in structural engineering engineering in NSS College of Engineering, Palakkad, PH-9496723294. E-mail: aryasree392@gmail.com*
- *Nisha isAssistantProfessor of Civil department,NSS College of Engineering, Palakkad, E-mail: getmenisha@gmail.com*

The main objectives of this study is to carry out free vibration analysis in honeycomb sandwich plates.,analysing the response of a honeycomb sandwich plates by introducing delamination in it and identify the location and extent of damage using mode shape methods.

2 FINITE ELEMENT ANALYSIS

The modal analysis of a honeycomb sandwich plate is performed using finite element package ANSYS. The reliability of ANSYS for the delamination study of sandwich structures are accepted based on the previous studies in ANSYS. Composite materials are difficult to model because of their different orthotropic properties, therefore proper element types must be selected, layer configuration must be defined, failure criteria must be defined and lastly modeling and post-processing steps must bedone carefully. The most important characteristic of the composite materials is its layered configuration as mentioned before. The properties of the layers have to be specified individually. In the present study the honeycomb sandwich modelling is performed by ANSYS 16.2, and the debonding is modelled by a technique called cohesive zone modelling (CZM) technique.

In this study, composite sandwich structures were modeled by using elements SHELL181 for the core material and face sheet material as per suggestions for the sandwich structures in the ANSYS structural analysis guide.

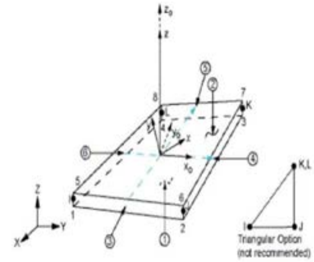

Fig 1: Shell 181 Geometry

The choice of face sheet and core materials depends heavily on the performance of the materials in the intended operational environment. A core material is required to perform two essential tasks; it must keep the faces the correct distance apart and it must not allow one face to slide over the other. It must be of low density. Almost any structural material which is available in the form of thin sheet may be used to form the faces of a sandwich panel.

Table I
Properties of Materials

Carbon Epoxy skin	
Modulus of elasticity, Exx	121 GPa
Modulus of elasticity ,Eyy=Ezz	8.6 GPa
Transverse shear modulus Gxy=Gxz	4.7 GPa
Transverse shear modulus Gyz	3.1 GPa
Poison's ratio ,ʋxy= ʋxz	0.27
Poison's ratio ,ʋyz	0.4
Density	1490kg/m3
Aluminium Honeycomb Core	
Poisson's ratio	0.3
Density	2770kg/m3
Modulus of elasticity	71GPa

3 Details Of The Model

Modelling of honeycomb sandwich plate is performed in ANSYS 16.2. Shell elements are used for modelling the face sheets and core. Honeycomb sandwich panel is modelled as a simple three layered shell model. Facesheets are modelled with a dimension of 400mm in length, 100mm in width and 0.5mm thickness. Honeycomb core is modelled with length of 400 mm, 100mm width and a height of 15 mm.

Analysis is carried out mainly for cantilevered boundary conditions with varying size of debonds , varying location of debonds .

Delamination in the honeycomb panels are introduced using cohesive zone modelling technique(CZM).Delaminated skin is modelled using cohesive zone element. Cohesive Zone technology models interface delamination and progressive failure where two materials are joined together. This approach introduces a failure mechanisms by gradually degrading the material elasticity between the surfaces. By integrating this method the separation mechanism of two surfaces can be simulated. Contact elements are introduced in the debonded region to prevent the overlapping and penetration of debonded skin with the core.

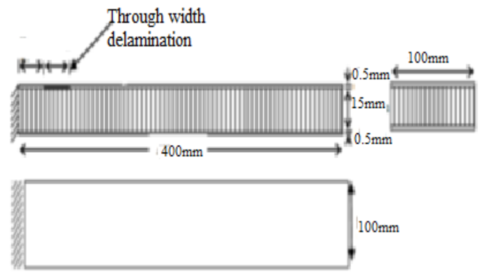

Fig 2.Configuration of Sandwich Cantilever Plate

Modal analysis is carried out for singly debonded plates. Cantilevered honeycomb sandwich plates are analyzed when debond is present in various positions and various sizes.

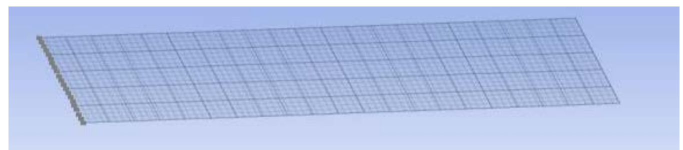

Fig3.Meshed Cantilever Honeycomb Sandwich Plate

The specimens used in the study are shown below:

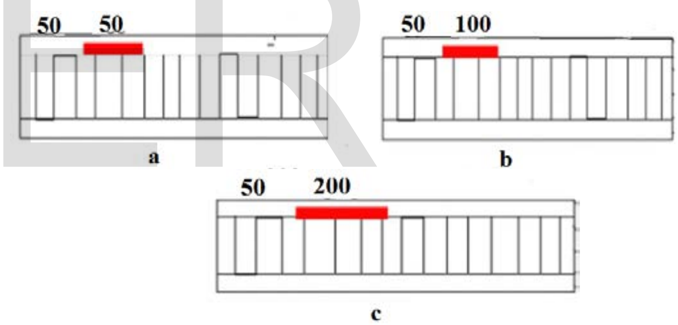

Fig 4. Variation in size of debond from fixed end

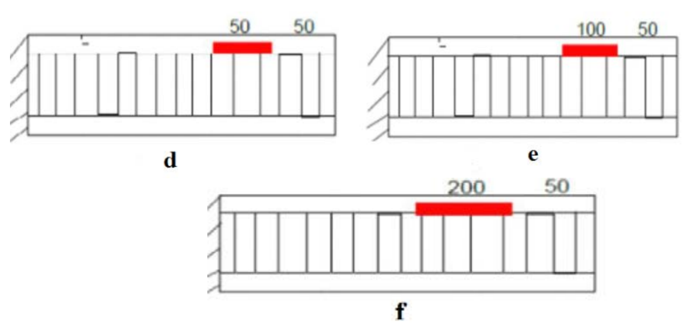

Fig 5 Variation in size of debond from free end

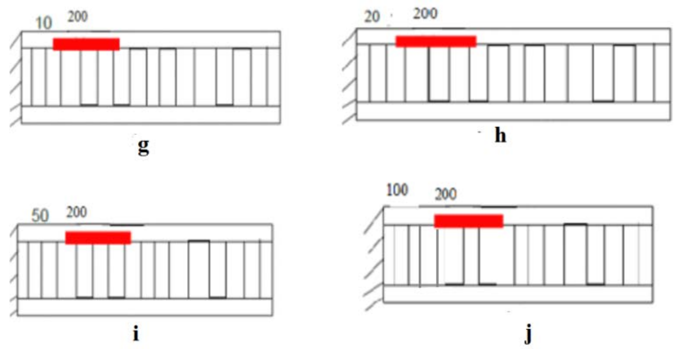

Fig 6: Variation in position of debond from fixed end

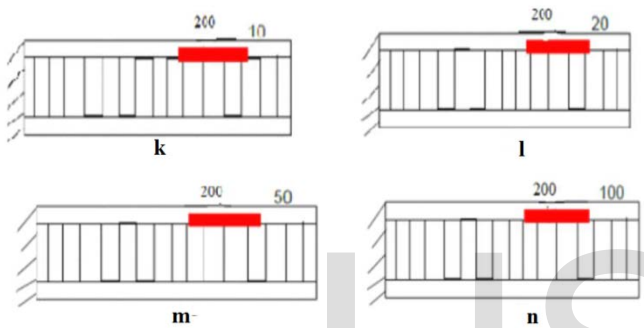

Fig 7: Variation in position of debond from free end

4 Results And Discussions

First four bending mode shapes of honeycomb sandwich plates and their frequencies are considered for the study. Strain energies are calculated from the analysis of plates using displacement results of the honeycomb sandwich plates. Frequencies of damaged plates is compared with intact plates for studying the effect of damage in honeycomb sandwich plates.

Table II

Natural frequency results of intact plate

Mode No	Intact (frequency in Hz)
1	122.2
2	749.07
3	1999.3
4	3641

Delaminated plates are modelled and analysed to compare their results with the intact plate.

Table III

Comparison of Frequencies of Debonded Plates (Having Variation InDebond Size from fixed end) With Intact Plate

Mode no	Frequencies in Hz			
	Intact	a	b	c
1	122.2	114.96	114.66	114.34
2	749.07	725.38	724.45	723.4
3	1999.3	1961.1	1959.6	1957.8
4	3641	3596.5	3592.9	3588.3

Table IV

Comparison of Frequencies of Debonded Plates (Having Variation InDebond Size from free end) With Intact Plate

Mode no	Frequencies in Hz			
	Intact	d	e	f
1	122.2	115.24	115.24	115.2
2	749.07	726.18	726.14	725.9
3	1999.3	1962.4	1962.2	1961.8
4	3641	3599.4	3599.1	3598.2

The results obtained for size varying set is compared with that of intact plates, and a reduction is seen in the frequencies of damaged plates. For debonds placed near to the fixed end more reduction in frequency(about 6%) is noted than that placed near to the free ends(5% reduction). It is observed that as the size of debond increases, frequency values shows reduction. When debond is placed far away from the fixed end reduction in natural frequencies are almost same. Largest reduction is observed for a debond of 50% plate length placed 50mm away from the fixed support.

Table V

Comparison of Frequencies of Debonded Plates (Having Variation In Position of Debond from fixed end) With Intact Plate

Mode No	Frequencies in Hz				
	Intact	g	h	i	j
1	122.2	113.34	113.37	114.34	115.05
2	749.07	720.4	720.51	723.4	725.44
3	1999.3	1952.4	1952.9	1957.8	1961
4	3641	3541.7	3566.4	3588.3	3596.9

The above table shows natural frequency results of honeycomb sandwich plates with debonds placed in different positions from the fixed end. Debond size is fixed as 50% of the plate length as it shown more reduction in frequency value in the previous sets. It is observed that significant reduction of about 7.3% is observed for debonds placed very near that is at 2.5% of plate length to the fixed end.

Table VI

Comparison of Frequencies of Debonded Plates (Having Variation In Position of Debond from free end) With Intact Plate

Mode No	Frequencies in Hz				
	Intact	k	l	m	n
1	122.2	115.22	115.22	115.2	115.05
2	749.07	726.03	726	725.9	725.44
3	1999.3	1962	1962	1961.8	1961
4	3641	3598.7	3598.6	3598.2	3596.9

The above table presents the natural frequency values of honeycomb sandwich composite plates with debonds placed at various positions from the free end. Reduction in value of frequencies is less that is about 5.7% for debonds placed closer to the free end. The effect of debonds placed far away from the fixed end is less compared to that placed near to the fixed ends.

4.1 Detection of Damage Location

Modal analysis has been carried out and extracted first four natural frequencies, but first mode frequencies are considered in the study since their effect is maximum and it is found that the results can be applicable to higher modes of vibration. It is noted from the results presented above that there is a decreasing trend in frequencies of the damaged honeycomb sandwich plate due to reduction in stiffness. But it is not possible to find the exact location of damage area in honeycomb plates by comparing only natural frequencies. Hence we use Modal Strain Energy Change Ratios(MSCER) for finding the location of damage areas. The displacement values of the specimen are plotted first and from which the strain energy values and change ratios is calculated.

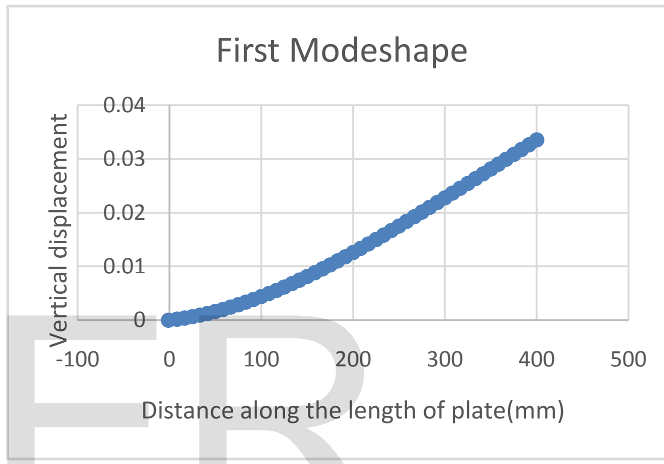

Fig.7: First Mode Shape of Intact CantileverHoneycomb Sandwich Plate

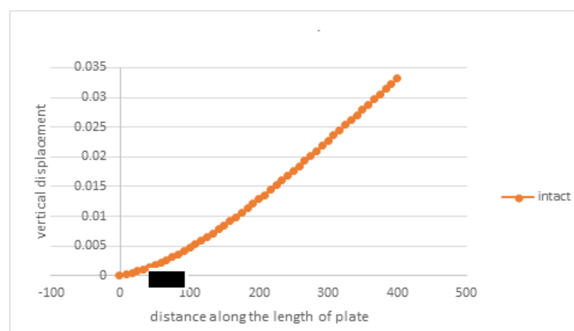

Fig.8: First Mode Shape of Damaged(a) Cantilever Honeycomb Sandwich Plate

It is difficult to understand the exact position of debond from the mode shape plot.Therefore it is essential to use a more sensitive method for obtaining the location of damage. Hence we use the Modal Strain Energy Change Ratio (MSECR) Method.

Modal strain energy of the element/region j for the mode i is given by

$$MSCE_{ii}^{d} = \{\emptyset\}_i^{d\,T}[K]_i\{\emptyset\}_i^{d} \qquad \text{Eqn (1)}$$

Where ∅ is the mode shape K is the stiffness.
Modal strain energy change ratio,

e MSECR plots of debonded plates are shown below.

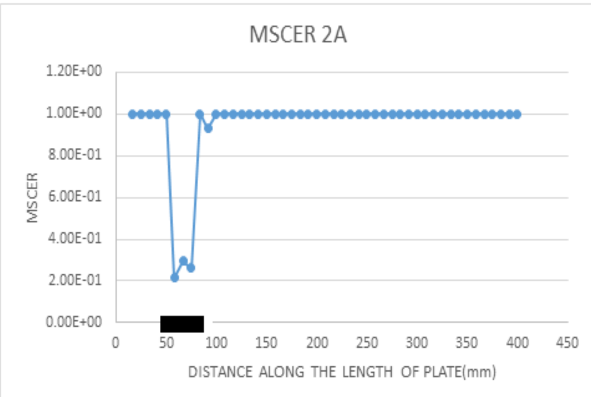

Fig.9: MSCER Plots For 50mm Debond Placed 50mm From Fixed End

Fig.10:MSCER Plots Of 100mm Debond Placed 50mm From Fixed End

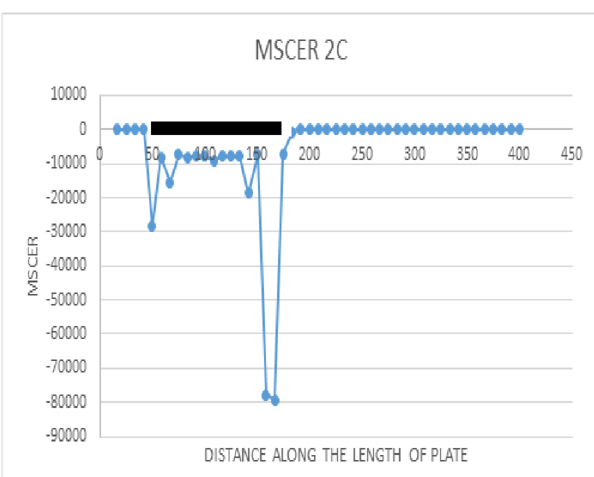

Fig.11: MSCER Plots of 200mm Debond Placed 50mm From Fixed End

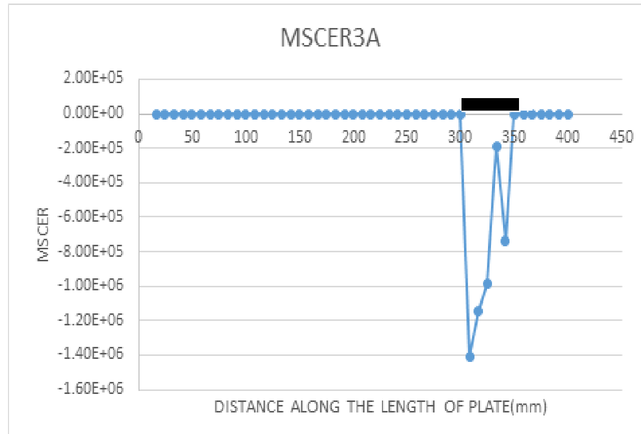

Fig.12: MSCER Plots of 50mm Debond Placed 50mm From Free End

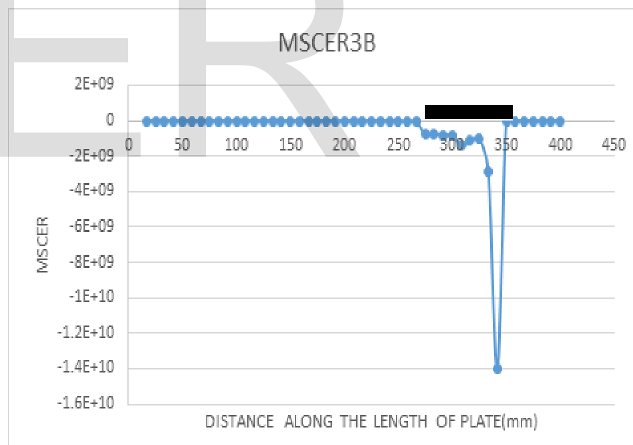

Fig.13: MSCER Plots of 100mm Debond Placed 50mm From Free End

$$MSECR = \frac{(\text{Modal strain energy of intact plate} - \text{Modal strain en}}{)/\text{Modal strain energy of intact}}$$

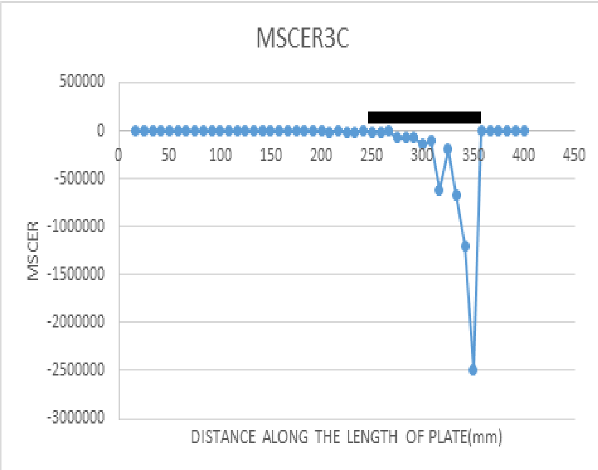

Fig.14: MSCER Plots of 200mm Debond Placed 50mm From Free End

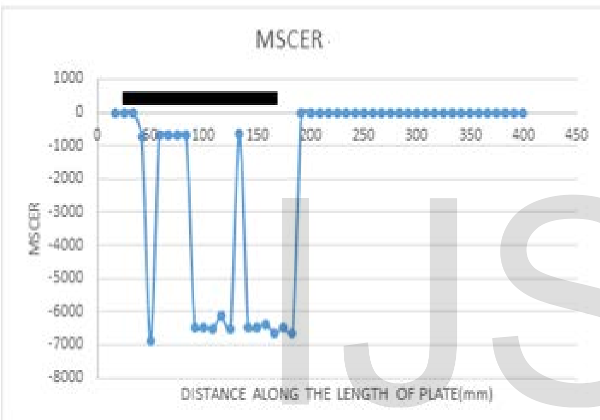

Fig.15: MSCER Plots of 200mm Debond Placed 10mm From Fixed End

Fig.16: MSCER Plots of 200mm Debond Placed 20mm From Fixed End

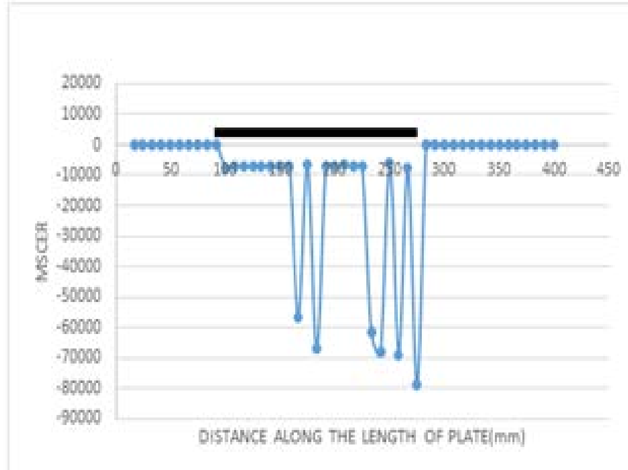

Fig.17: MSCER Plots of 200mm Debond Placed 100mm Away From Fixed End

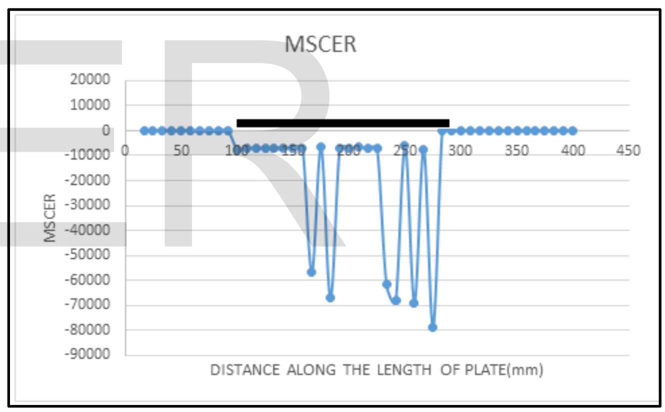

Fig.18:MSCER Plots of 200mm Debond Placed 50mm Away From Free End

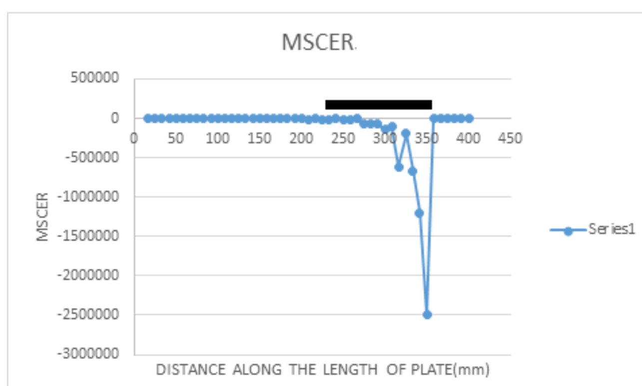

Fig. 19: MSCER Plots of 200mm Debond Placed 100mm Away From Free End

5 Summary And Conclusion

By evaluating the above results it is possible make the following conclusions:

- Reduction trend is noticed for natural frequencies of debonded sandwich plates when comparing with the intact sandwich plates.
- Significant reduction in natural frequencies is observed for debonds placed nearer to the fixed end.
- The effect of debonds placed very near to the free end is less compared to those placed near fixed end.
- It is observed that Modal Strain Energy Change Ratio Method gives the location and extent of damage more accurately when comparing with the mode shape plots.

References

[1] Alexander.J and et al; "Frequency Response of Composite Laminates at Various Boundary Conditions"; International Journal of Engineering Science Invention pp 11-15,2013

[2] DawariV.B, Vesmawala G. R.,"Structural Damage Identification Using Modal Curvature Differences "IOSR Journal of Mechanical and Civil Engineering.pp: 33-38 ,2009

[3] Elma Ekinovic and et al , "A Glance To A Mode Shape Based Damage Detection Technique", 17th International Research/Expert Conference"Trends in the Development of Machinery and Associated Technology ,2013

[4] Itishree Mishra &Shishir Kumar Sahu;"An Experimental Approach to Free Vibration Response of Woven Fiber Composite Plates under Free-Free Boundary Condition", International Journal of Advanced Technology in Civil Engineering, Vol-1, No-2, pp 2231,–5721,2012

[5] Luol.H and S. Hanagud,"Delamination modes in composite plates" , Journal of aerospace engineering ,Vol. 9,pp: 106-113,1996

[6] Manoj Kumar, "Experimental validation of modal strain energies based damage identification method for a composite sandwich beam", Composites Science and Technology,pp 1635-1643,2009

[7] Mehdizadeh M; "Vibration Based Analysis Of An Increasing Delamination In A Carbon/Epoxy Composite Structure", 3rd International Conference on Integrity, Reliability and Failure,2009.

[8] Nisha A S, Saraswathy B, "Dynamic Analysis Of Delaminated Sandwich Composites",International Journal Of Modern Engineering Resarch,vol 3,pp 172-177,2013.

[9] Pradeep K.R. and et al;" Modal strain energy change ratio for damage identification in honeycomb sandwich structures "Canadian journal of basic and applied sciences.,Vol 2,pp:10-24. ,2014

[10] Wang J.T.S ,Gibby J.A. , "Vibrations of split beams", Journal of Sound and Vibration ,pp: 491-502,1982

[11] Yusuf Arman and et al(2006) "Determination of critical delamination diameter of laminated composite plates under buckling loads",Journal of composite science and technology,vol: 66 , pp: 2945-2953