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Finite Element Analysis of Laminated Composite Plates with Circular and Square Openings

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Abstract: Laminated composites are widely used nowadays in variety of industrial areas like aerospace, marine structures, electrical appliances etc. Thorough study about the dynamic behaviour of such structures is necessary for the sound design of these structures since most of these structures are subjected to dynamic loading. In this paper, the dynamic analysis of such laminated composite plates with different types of openings and fibre orientations are done using ANSYS 17.0 software. The results are then compared in order to determine the most preferable shape of cut-out that can be used in a composite plate.

Keywords: Reinforcing phase, graphite epoxy composite, carbon aluminium composite, finite element analysis, free vibration analysis, ANSYS 17.0

I. INTRODUCTION

A laminated composite is an assembly of layers of composite materials which are joined together in order to attain specific desired properties. The two constituents of a composite are fibre and reinforcement. The reinforcing phase provides required strength and stiffness. The matrix provides proper fibre orientation and protects the layers from external abrasion etc. Nowadays the laminated composites in the form of plates are being widely used in many industrial areas including aerospace, marine structures, electrical appliances etc. In most cases these plates are provided with openings and are generally subjected to dynamic loads and the behaviour of these plates strongly depends on the vibrations, displacements etc. Hence, the study about the dynamic behaviour of the structure is necessary for the safe and sound design of the structures. Hence, the present study deals with the finite element analysis of graphite epoxy and carbon aluminium laminated composite plates with circular and square openings having different fibre orientations.

II. SUMMARY OF LITERATURE REVIEW

The dynamic behaviour of the plate is dependent on the orientation of the laminas in the laminated composite plate. Also, the behaviour of the plate alters when a hole is provided on the plate for various purposes. From the reviews, the following inferences can be drawn in general. By properly orienting the fibres in a laminated composite plate, the maximum deflection of the plate when it is subjected to loading can be reduced significantly. For single layer composite plates subjected to uniform uniaxial external loading, the strength of the plates are highly dependent on the fibre orientation angle. Also, it was noted that the boundary conditions of the plate plays an important role in the free vibration of plates with openings. When openings are provided on composite plates, stresses and deformations of steep gradient are induced around these openings. The strength of the plates is considerably decreased by the circular holes and in-plane deflection and stresses are lesser for larger size of cut-outs. Further, it was noted that the best location for opening is at the extreme edges of the plate. And some general conclusions made from the reviews are that the frequency increases with an increase in the number of layers, modulus ratio of the plate and angle of lamina; but it decreases with increase in aspect ratio, thickness ratio, cut-out size and distance between cut-outs.

III. METHODOLOGY

A. Analysis of Graphite epoxy composite Plate

Graphite epoxy composite plates are used increasingly for numerous applications. The graphite epoxy composite have many advantages including low weight, high structural stiffness etc and hence the use is increasing rapidly.

1) Details of the plate: The graphite epoxy composite for modal analysis is prepared by using shell 181 element of the ANSYS 17.0 software. The analysis is done using rectangular plate of dimension 3000mm X 2000mm with overall thickness of the plate 20mm. The dimension details of the plate is as shown in the table I.

TABLE I DETAILS OF THE PLATE

Parameter	Value
Length of plate	3000 mm
Width of plate	2000 mm
Total thickness of plate	20 mm
Thickness of each layer	4 mm
Total number of layers	5 nos
Diameter of circular opening	500 mm
Edge of square opening	500 mm
Orientations considered	0/0/0/0/0, 30/0/30/0/30, 45/0/45/0/45, 90/0/90/0/90
Mesh size adopted	50 mm

IV.RESULT AND DISCUSSIONS

A. Modal response of the plates

Modal analysis is the free vibration analysis of laminated composite plate which is carried out inorder to obtain the frequency of vibration of the plates in Hz. The results are obtained for different modes of vibration. Modal responses of the graphite epoxy laminated composite plates with no opening, circular opening and square openings of various fibre orientations i.e. 0° , 30° , 45° and 90° are shown in table 2.

TABLE 2 FREQUENCIES (Hz) OF GRAPHITE EPOXY COMPOSITE PLATES

Type of opening	Modes	Orientations			
		0/0/0/0/0	30/0/30/0/30	45/0/45/0/45	90/0/90/0/90
No opening	1	38.821	32.783	26.763	18.658
	2	47.581	43.894	40.549	34.686
	3	70.469	67.611	63.86	39.372
	4	104.82	86.009	66.892	58.236
	5	105	90.677	79.246	61.19
	6	107.3	96.844	88.957	76.731
Circular opening	1	37.487	31.861	26.881	19.269
	2	47.934	44.232	39.957	32.574
	3	72.499	67.878	60.61	45.358
	4	77.172	69.391	63.149	52.142
	5	88.026	83.485	78.578	60.788
	6	102.27	97.038	91.06	73.502
Square opening	1	37.961	31.705	25.902	19.725
	2	46.571	42.46	38.438	32
	3	68.944	62.464	57.399	46.702
	4	79.397	70.98	63.275	52.23
	5	83.862	80.914	76.478	61.201
	6	99.465	91.535	85.302	72.277

The frequency curves showing the variations of frequencies for each orientations of respective plate openings are as shown in figure 1.

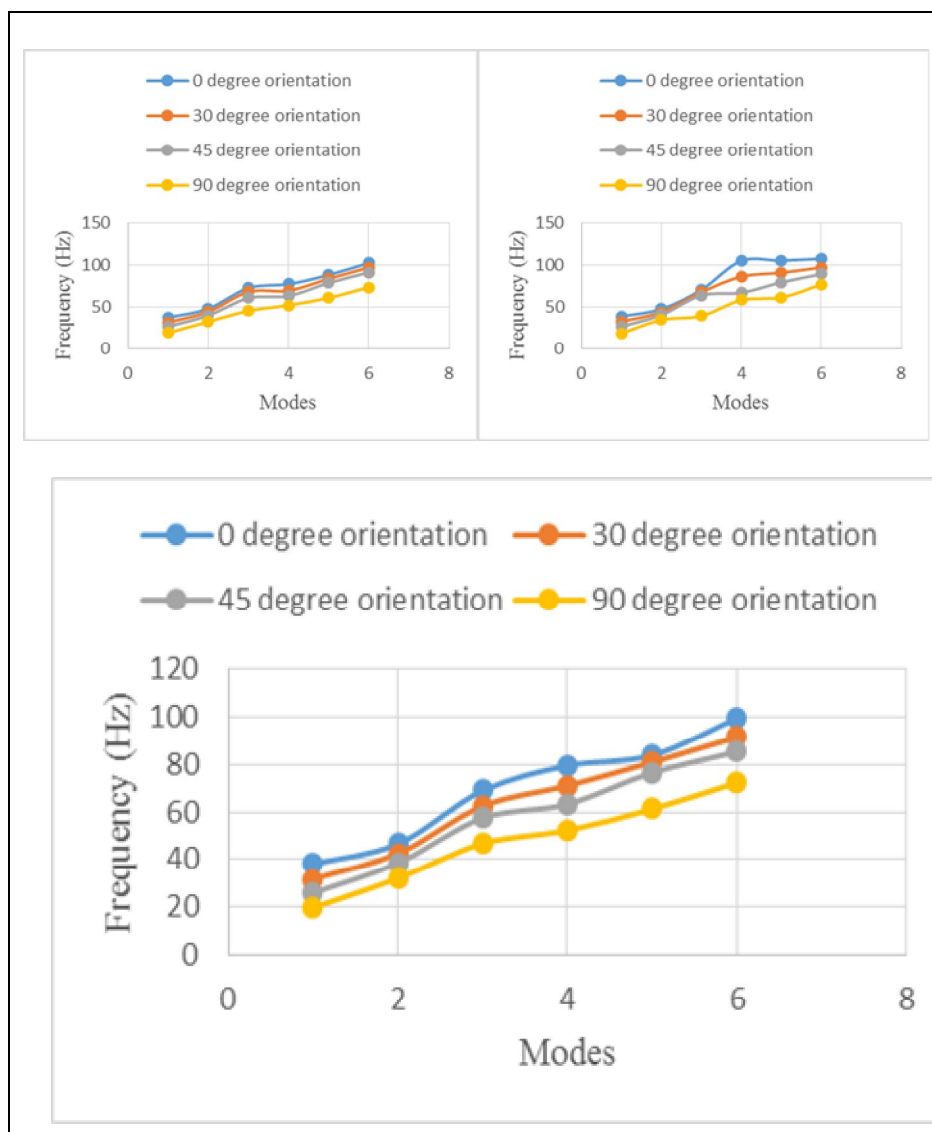


Fig. 1 Modal responses of graphite epoxy laminated composite plates without opening, with square opening and circular opening

From the frequency responses shown in the table and curves, it can be concluded that the frequency of vibration of the plates decreases with increase in the orientation angle of the plates. From the above results, the frequencies of the plates increased when opening is provided on the plate. So, plates without openings is preferable. But obviously, it is not possible to avoid an opening on the composite plate whenever it becomes necessary. So, on comparing the results obtained for a square and a circular opening, the frequency values of circular opening is slightly smaller than that of square opening. But the difference is very smaller, hence it can be concluded that the square and circular openings have almost same effect on the dynamic behaviour of a laminated composite plate.

B. Analysis of Carbon Aluminium Composite Plate

1) *Details of the plate:* The Carbon Aluminium composite for modal analysis is also prepared by using shell 181 element of the ANSYS 17.0 software. The analysis is done using rectangular plate of dimension 3000mm X 2000mm with overall thickness of the plate 20mm. The dimension details of the plate is same as shown in the table I.

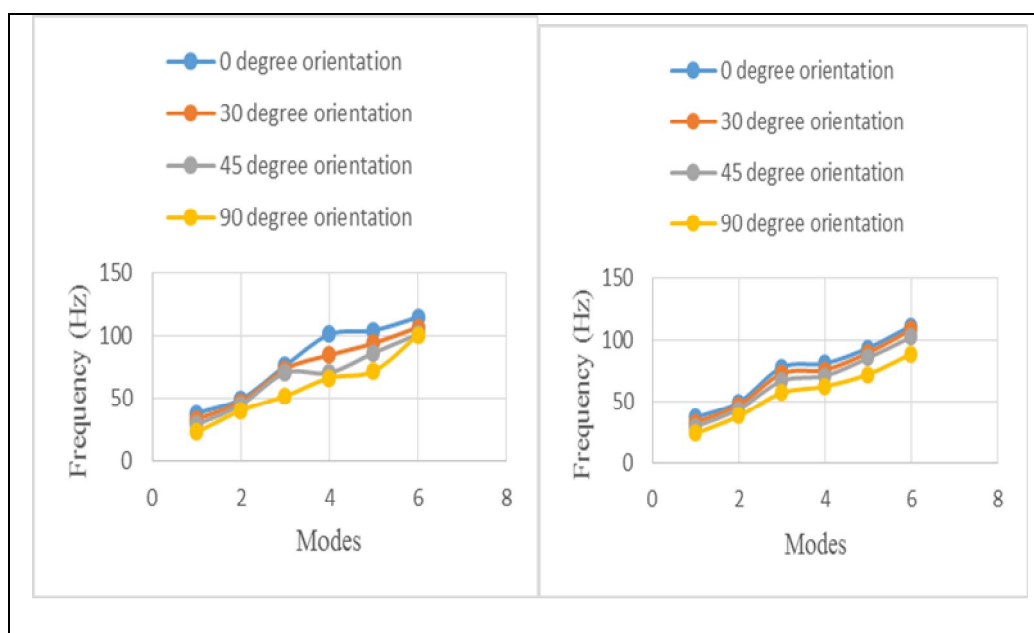
C. Modal Response of the Plate

Modal responses of the carbon aluminium laminated composite plates with no opening, circular opening and square openings of various fibre orientations i.e. 00, 300, 450 and 900 are shown in table 3.

TABLE 3
FREQUENCIES (Hz) OF CARBON ALUMINIUM COMPOSITE PLATES

Type of opening	Modes	Orientations			
		0/0/0/0/0	30/0/30/0/30	45/0/45/0/45	90/0/90/0/90
No opening	1	37.898	33.098	28.718	22.748
	2	49.175	46.934	44.623	40.003
	3	75.972	73.418	70.28	51.722
	4	100.82	84.486	70.338	66.409
	5	104.02	93.872	86.262	71.683
	6	114.58	106.54	100.99	100.49
Circular opening	1	36.83	32.866	29.316	23.989
	2	49.493	46.849	43.781	38.045
	3	77.848	72.837	66.897	57.031
	4	81.046	75.857	71.061	62.414
	5	93.396	89.642	85.37	72.195
	6	111.34	108.2	102.25	88.7
Square opening	1	37.422	32.836	28.839	24.174
	2	48.454	45.932	43.004	37.423
	3	73.637	68.624	64.437	57.587
	4	82.667	76.89	71.268	62.376
	5	89.758	87.38	83.729	72.574
	6	108.7	103.54	97.985	86.791

The frequency curves showing the variations of frequencies for each orientations of respective plate openings are as shown in figure 2.



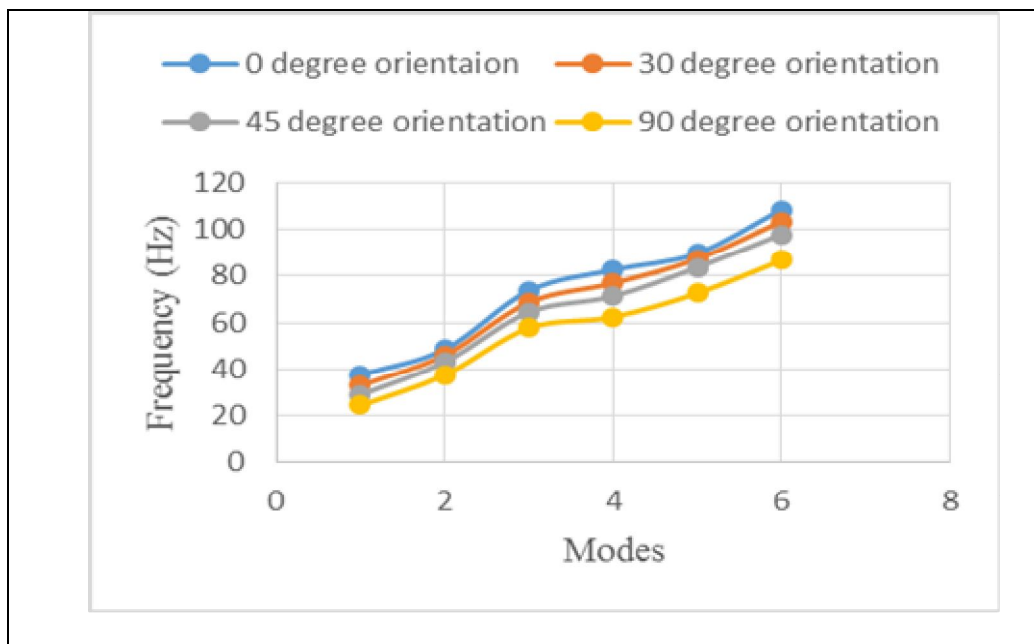
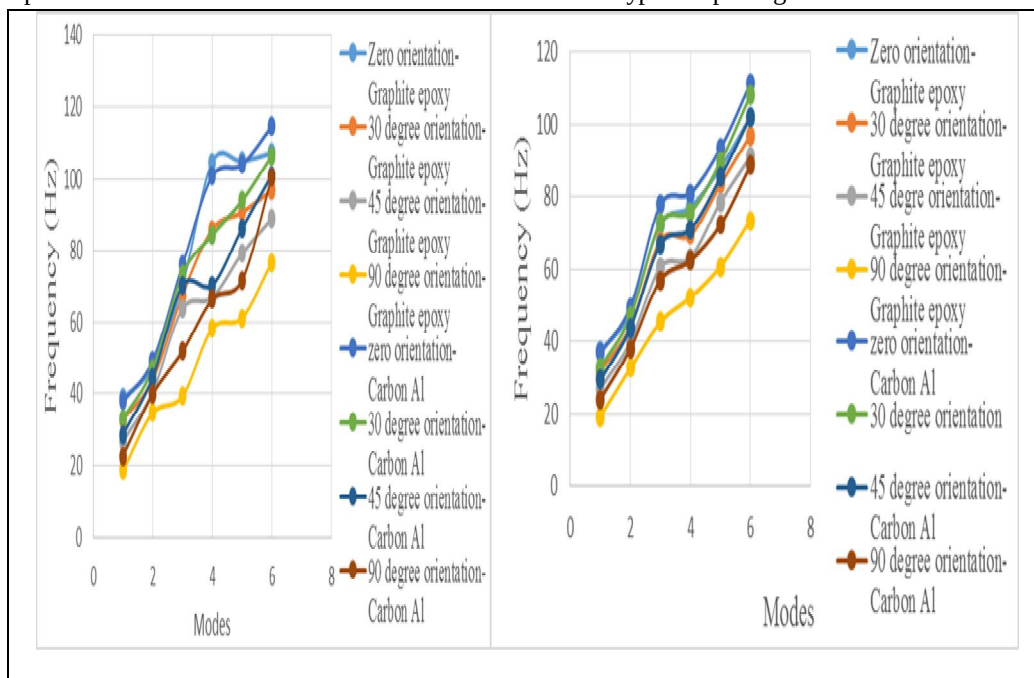


Fig. 2 Modal responses of carbon aluminium laminated composite plates without opening, with square opening and circular opening

From the frequency responses shown in the table and curves, it can be concluded that there is a decrease in frequency of vibration of the plates with increase in its orientation angles. Also, the frequencies of the plates with zero degree and 30 degree fibre orientation for circular opening is smaller than that of square opening and plate without opening. Hence, for a 0° and 30° fibre oriented plate, circular opening is the best preferable type of opening. But for the other orientations, circular as well as square openings have almost same effect on the dynamic behaviour of the laminated composite plate.

D. Graphite epoxy Vs Carbon aluMinium Composite Plate

From the obtained values of modal responses, a comparison can be made between the two types of composite materials selected for the study. The comparison curves are drawn for the two materials for each type of opening which are as shown in the figure 3.



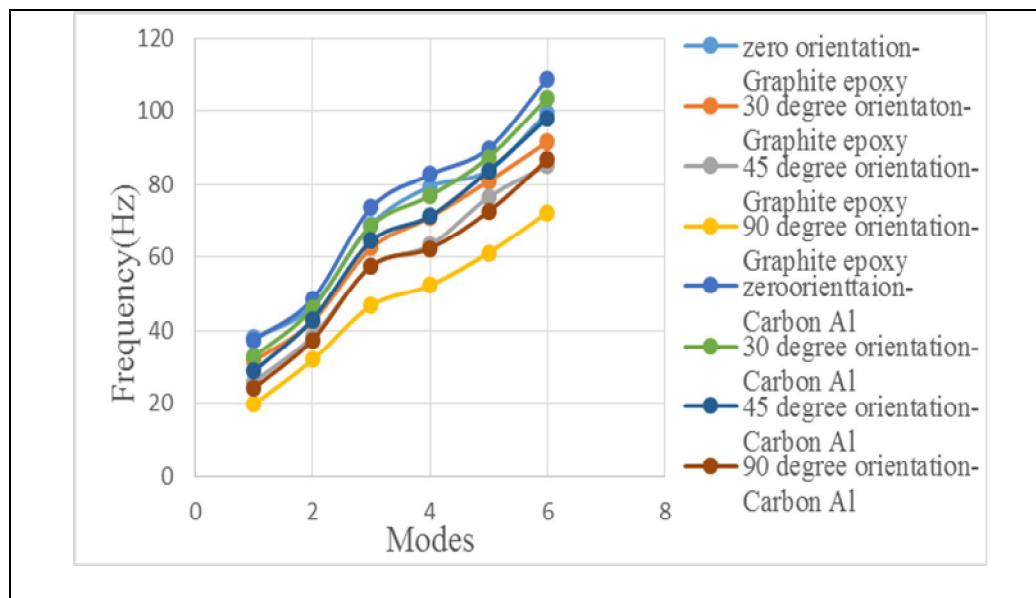


Fig. 3 Comparison of graphite epoxy and carbon aluminium laminated composite plates without opening, with square and circular opening

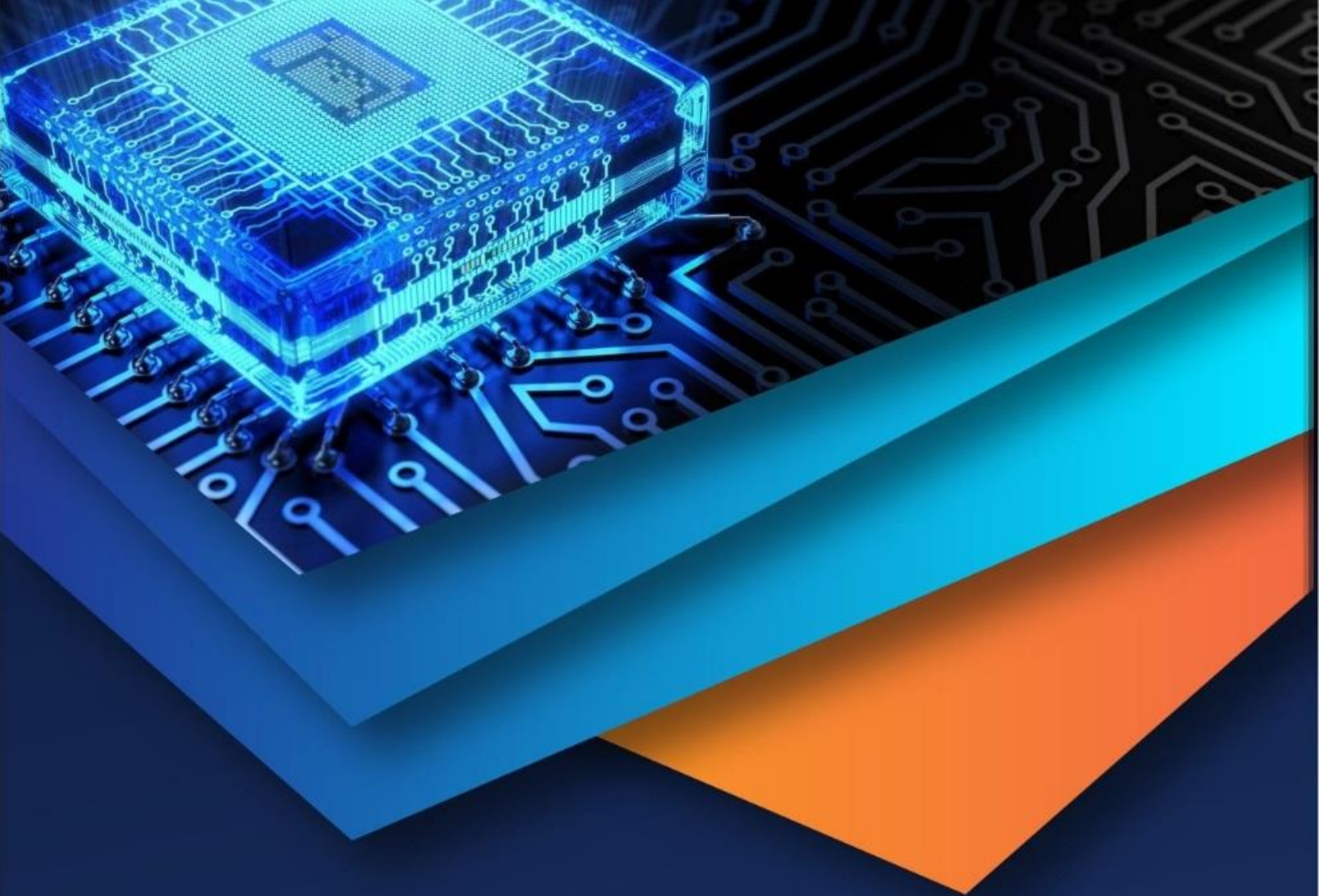
From the above curves, it is clear that the frequency of vibration for composite plates made of carbon aluminium composites are higher than that of graphite epoxy composite plates for all of the fibre orientations. Hence, graphite epoxy is the most recommended type of composite plate other than carbon aluminium.

V. CONCLUSION

For graphite epoxy composite plate, the frequency of vibration decreased with increase in the orientation angle and it increased when opening is provided on the plate. The frequency values of circular opening is slightly smaller than that of square opening, but since the difference is very smaller, it can be concluded that the square and circular openings have almost same effect on the dynamic behaviour of a graphite epoxy composite plate. Now for carbon aluminium composite, the frequency decreased with increase in orientation angles and circular opening is preferable for 00 and 300 fibre oriented plate. But for other orientations, circular as well as square openings have almost same effect on the dynamic behaviour. On comparing both the materials, graphite epoxy is the most recommended type of composite plate than carbon aluminium.

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