Experimental determination of mode shapes of a plate using speaker as excitation device

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Abstract. Experimental modal analysis is usually carried out in two methods, namely impact hammer method and shaker method. The limitation of both the methods is determination of mode shapes. Of course, the mode shapes are obtained using FFT analyser which is costly software. In this paper, however an attempt is made to determine the mode shapes of a plate experimentally using a speaker as excitation device. An experimental setup was prepared using a speaker to excite a plate at its central portion. An aluminium plate was mounted at its central portion and excited. Dust particles were sprinkled over the plate and when the excitation frequency matches the natural frequencies, the corresponding mode shape of the plate was obtained. The numerical modal analysis was carried out for the plate with proper boundary conditions using finite element analysis package ANSYS Workbench. The mode shapes obtained numerically and experimentally were compared and observed to be in good agreement.

1. Introduction

Vibrations occur in numerous mechanical and structural systems. In the event when vibration is uncontrolled, it can prompt to catastrophic circumstances. When the mechanical structure is forced to resonance vibration, at one of the natural frequency standing wave pattern are obtained. In eighteenth century, German researcher Ernst Chladni found that when a specific size of the board is at a specific frequency of vibration, because of wave reflection at the edge of a plate, it will deliver standing waves, forming nodes of no vibration and antinodes with huge vibration. As it is the vibration of a plane, the nodes are arranged in sections on the curves, forms Chladni pattern. Not all structures can be impact tested, however. For instance, structure with delicate surfaces cannot be impact tested. When impact testing cannot be used, FRF measurements must be made by providing artificial excitation with shaker. Shaker such as Electrodynamics shaker is used in the determination of mode shapes which cost more. So the speaker is used as an excitation device to determine the mode shapes which reduces the cost of the excitation device.

Xun Ma et al [1]. Experimental modal analysis and modal extraction experiment for the plate and it has the same results as of finite element analysis. H.R. Kemparaju et al [2]. The development of experimental setup to study the free vibration characteristics of the plate gives good results. A. E. Ikpe et al [3]. The Chladni patterns were obtained on the thin plate by acoustic excitation. The plate was analyzed using CATIA, ANSYS, and HYPERMESH, and the mode shapes and natural frequencies are obtained. P. H. Tuan et al [4] chladni nodal pattern for a thin plate was obtained using a mechanical oscillator. The resonant frequency was also measured experimentally by attaining the effective impedance of exciter. Owunna et al [5] The mode shapes and natural frequencies of the plate were determined using electromagnetic shaker.
Frequencies acquired by experimental analysis, the resonant frequency are obtained by varying impedance of the oscillator with the thin plate. Shridhar [6] the friction and adhesion present in the plate effects the formation of chladni patterns. This came to know by spatial autocorrelation analysis in investigating the effect of frictional forces and adhesion on the rate of pattern formation. Luo, Yan & Feng [7] introduces a simple approach to determine chladni patterns on an elastic plate by the optical lever method. In this method, mode shapes are acquired by integrating the slope distribution. Kaczmarek A et al [8] Mode of vibration for square plate which has built-in corners and inducted at the centre does not correspond to vibration modes for plates with free edges. Van Gerner et al [9] the inverse Chladni patterns are obtained on the plate when little particles are dispersed on the resonating plate. Xavier Escaler et al [10] utilized the Chladni procedure to obtain the mode shapes of the plate both in air and completely submerged in water.

The literature survey shows the researcher adopted different methods to determine the mode shapes of the plate. Some of the methods were time-consuming. Some researchers used electrodynamic shaker for mode shape determination which is costly. So, the main objective of the project is to determine the mode shapes of the plate using a speaker as an excitation device.

2. Methodology

2.1. Specimen details
An Aluminium square plate of size 305 x 305 mm and 1 mm thickness is taken for the modal analysis.

| Table 1: Properties of the specimen  |
|--------------------------------------|
| Young’s modulus                      | 70 GPA                  |
| Poisson’s ratio                      | 0.33                    |
| Density                              | 2720 Kg/m$^3$           |

2.2. Experimental modal analysis
An experimental setup is prepared so that plate can be excited at the centre by the speaker is as shown below in fig 3. Frequency of vibration is varied by the function generator. An aluminium square plate was fixed on the mounting plate of the excitation device using nut and bolts. The sound signals obtained from the function generator were supplied through an amplifier. When the plate starts vibrating due to excitation from the speaker the silica powder sprinkled periodically will start vibrating. At the place of the node, there is no vibration and silica powder settle there and at the place of antinodes where vibration is very high, the silica powder moves away from it towards nodes and settles there.

Fig 1: Experimental setup
This leads to the generation of nodal patterns which are the mode shapes of the plate. For the particular natural frequencies of vibration, corresponding mode shapes were thus obtained. These mode shapes obtained at different natural frequencies are recorded.

2.3. Numerical Modal Analysis

Numerical modal analysis of the aluminium square plate was done using ANSYS Workbench. The meshing of the plate was done using hexahedral elements. The plate was fixed at the centre and edges are free as shown in figure 3.7. The first eight mode shapes of the plate are extracted by carrying out numerical analysis utilizing ANSYS Workbench. The results obtained the numerical modal analysis are tabulated.

![Figure 2: Boundary Condition](image)

3. Results and discussion

Table 2 shows the comparison of the mode shapes of the plate. The first column of table shows the mode number. The second column in table shows the mode shape of the plate obtained from the numerical modal analysis. The third column of table shows mode shapes of the plate obtained from experimental modal analysis using the speaker as an excitation device.

| Mode Number | Numerical Modal Analysis | Experimental Modal Analysis |
|-------------|--------------------------|-----------------------------|
| 1           | ![Image](image)           | ![Image](image)             |
| 2           | ![Image](image)           | ![Image](image)             |
|   |   |   |
|---|---|---|
| 3 | ![Image](image3.png) | ![Image](image4.png) |
| 4 | ![Image](image5.png) | ![Image](image6.png) |
| 5 | ![Image](image7.png) | ![Image](image8.png) |
| 6 | ![Image](image9.png) | ![Image](image10.png) |
| 7 | ![Image](image11.png) | ![Image](image12.png) |
Table 2 shows the mode shapes of the plate obtained from numerical and experimental modal analysis. The mode shape of the plate acquire from experimental modal analysis were nearer to the mode shapes acquired from numerical modal analysis. Thus, by using the speaker as an excitation device the mode shapes of the plate of different boundary conditions can be determined, as mode shapes of the cantilever plate.

Table 2.1: Comparison of the Natural Frequencies

| Mode Number | Numerical Modal Analysis[Hz] | Experimental Modal Analysis[Hz] | % of Difference |
|-------------|-------------------------------|---------------------------------|-----------------|
| 1           | 38.8                          | 40.8                            | 4.90            |
| 2           | 39.5                          | 42                              | 5.95            |
| 3           | 42.2                          | 45.9                            | 8.06            |
| 4           | 44.1                          | 48                              | 8.12            |
| 5           | 64.2                          | 70                              | 8.28            |
| 6           | 104.2                         | 116                             | 10.17           |
| 7           | 105.2                         | 117.9                           | 10.77           |
| 8           | 150.4                         | 163.3                           | 7.89            |

Table 2.2 shows the comparison of natural frequencies obtained from numerical and experimental modal analysis. Comparisons of results give good agreement. Although results are closer there are some deviations. It was found that the deviation of the results is less than 11% as shown in table. These deviations between experimental and numerical modal analysis results may be due to density which was considered homogeneous during the numerical analysis of the plate. Using the speaker as an excitation device the cost of the excitation device can be considerably reduced.

4. Conclusion

In this paper, experimental modal analysis of the plate was conducted by fixing the plate at centre using the speaker as an excitation device. Numerical modal analysis of the plate was conducted by applying the boundary conditions using ANSYS Workbench. The comparison of results obtained from experimental and numerical modal analysis gives good agreement. The results obtained from experimental modal analysis were closer to the results obtained from numerical modal analysis. Thus, by using the speaker as an excitation device the mode shape of the plate with different boundary conditions can be determined, such as modes shape of the cantilever plate. By using speaker as an excitation device cost of the excitation device can be considerably reduced.
5. Reference

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