

Study The Free Vibration Analysis of Rectangular Thin Plate Using Finite Element Method

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Abstract: The current project effort uses the finite element approach to ascertain the natural frequencies of an isotropic thin plate. On the Kirchhoff plate theory was founded. The calculated frequencies were compared to those discovered using ANSYS's finite element analysis program and an exact Levy-type solution. For determining the natural frequencies of plates with rectangular cross sections, this methodology is helpful. The boundary conditions are taken to be unloaded and simply sustained. By applying fine meshing, we can obtain absolute results of frequencies from numerical results obtained from FEM with the prescribed boundary conditions, giving exact solutions, and ANSYS results by variation of plate thickness when no loads are applied to the plate to check and measure the free vibration of the plate and deformed shapes of the plate.

1.Introduction: Flat plate structures, such as the flooring of ships, buildings, airplanes, bridge decks, and enclosures around machinery, are vulnerable to dynamic stresses that are consistent with their plane. Flexural vibration arises as a result. Such structures can be investigated by decomposing the plate into a group of two-dimensional finite elements called plate-bending elements. These parts can be triangle-, rectangle-, or quadrilateral shaped. The commonly used and effective numerical approximation technique is known as the finite element method (FEM). With the finite

Each finite element possesses a displacement function. Every element in a network is connected to every other element, either directly or indirectly, utilizing shared interfaces like nodes or boundary lines. One may predict the behavior of a specific node in terms of the characteristics of every other element in the structure using the stress/strain characteristics of the material that makes up the structure. Each node's behavior is described by a combined set of algebraic equations, which are best written using matrix notation. The structural analysis finite element approach enables the designer to find stress and vibration, and here, finite element analysis is carried out using Kirchhoff plate theory. Finite element analysis was used to calculate the stiffness and mass matrices. By resolving the eigenvalue puzzle, these matrices are utilized to determine the natural frequencies of rectangular plates. The free vibration analysis of any thin rectangular plate structure can be successfully applied to the current method, according to the numerical results of the simply supported rectangular plates. The natural frequencies parameter error changes and remains constant as the thickness of the rectangular plate constructions increases.

Here, finite element analysis is carried out using Kirchhoff's plate theory. Finite element analysis was used to calculate the stiffness and mass matrices.

2.Literature Survey:

2.1 Ramu and Mohanty [1] for isotropic thin plates, a powerful numerical method based on Kirchhoff plate theory is presented, along with experimental experiments. By applying simply supported boundary conditions to the plate and formulating the FEM using Kirchhoff plate theory and the software Ansys, the author performed the analysis of a thin plate to determine the three different types of stresses operating on the plate.

2.2 Sonawane and Talmale [2] provided a powerful numerical method for simulating the dynamic response of a single rectangular cantilever plate and validating the results through tests in the laboratory.

2.3 Werfalli and Abobaker [3] to better understand the natural frequencies of isotropic thin plates, supply a partial third-order polynomial equation and the conditional mesh size.

2.4 Mansour, Loghmani, and Mostafa [4] gave an analytical answer for determining the natural frequencies of free vibration of a Kirchhoff plate with four corners that are only weakly supported, along with some boundary constraints.

2.5 Subhransu Mohan Satpathy and Praveen Dash [5] create the free cantilever beam's motion equations. Using ANSYS 14.0, the natural frequency of the continuous beam system will be determined for various beam variables. Further comparison of the outcomes will be done by testing involving cantilever beamfree vibration. These findings allowed for a comparison of the Euler-Bernoulli parameters.

3.Methodology:

In this chapter, the introduction and a clear description of the method are used. The small deflection theory of plates attributed to Kirchhoff is based on the following. For the Kirchhoff-love plate theory, we have some assumptions are given below.

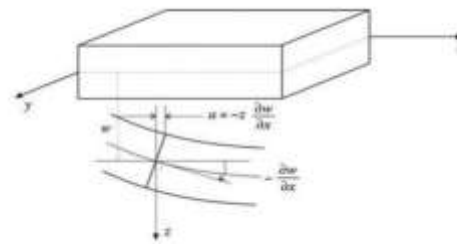


Figure-1: Deformed shape of thin plate.

Based on Kirchhoff's assumptions at any point due to a small rotation.

Displacement in the x direction

$$U = -Z \alpha x = -Z * (\text{---}).$$

The in-plane normal stresses and shear stress are acting on the edges of the plate as shown in the stresses varying linearly in the Z-direction from the mid-surface of the plate. Although transverse shear deformation is neglected, transverse shear stresses are present. Through the plate thickness, these stresses are varying quadratically.

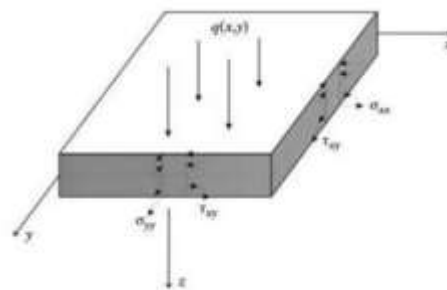


Figure.2 Stress-induced on a thin plate.

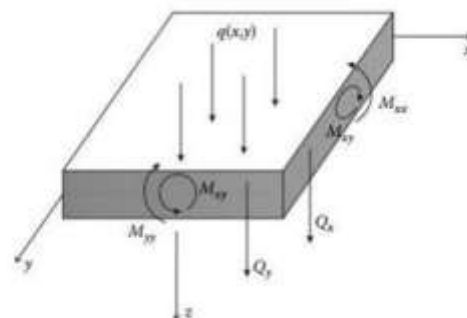


Figure.3 Momentum and strain in thin plate.

4. FEM Modelling:

Modeling of a single rectangular simply supported plate was done with the help of CATIA software. A finite element model of the beam is constructed In Ansys (R22) computational modal analysis is performed to generate natural frequencies and mode shapes. The material parameter is taken from the nomenclature. Boundary conditions are simply supported with no load applied finite element analysis (FEA) of specified objects is carried out to obtain necessary parameters and the specimens are to be tested in the software to analyze the dynamic response of the specimen at simply supported beam condition and to get the natural frequencies and mode shapes. Solving a practical problem by FEA involves learning about the program, preparing a mathematical model, discretizing it, doing the calculations, and checking the results.

The three major methods for resolving complex engineering problems are analytical techniques, experimental methods, and numerical methods. Although analytical methods are precise, they are limited to simple geometries. Experimental techniques can produce precise results, but they are expensive and frequently not financially viable. Finite element analysis, which provides reliable engineering solutions, can be used to numerically solve engineering problems. The numerical methodology of finite element analysis is exceedingly versatile and comprehensive.

5.ComputerAnalysis: The thin plate is the length-to-width ratio is always less than or equal to 0.01 thickness then it is called the thin plate. The Vibration analysis of the thin plate is done in the Ansys R22 in an open Ansys workbench in this lot of modules are available for vibration analysis to select the modal.



The analysis then has four options visible engineering data, geometric data, modal analysis, and setup first we have to select engineering data in this we have to add the type of material for analysis like aluminum we can set the young's modulus and poisson ratio adds the desired material to engineering data then click geometric data if we from Catia or Solid works save it to the Ansys extension by click import from the system or we can manually.

A user may start by defining the dimensions of an object, and then adding weight, pressure, temperature, and other physical properties. Finally, the Ansys software simulates and analyzes movement, fatigue, fractures, fluid flow, temperature distribution, electromagnetic efficiency, and other effects over time.

The total deformation will be visible click duplicate on total deformation then we can see the mode and apply how many modes are required to checkup we can gain the frequencies of the plate then we can select which deformation is used for check click on the selected mode.

Property	Value	Unit
Material Field Variables	Table	
Density	7950	kg m ⁻³
Isotropic Secant Coefficient of Thermal Expansion		
Coefficient of Thermal Expansion	1.2E-05	C ⁻¹
Isotropic Elasticity		
Derive from	Young's M...	
Young's Modulus	2E+11	Pa
Poisson's Ratio	0.3	
Bulk Modulus	1.6607E+11	Pa
Shear Modulus	7.6923E+10	Pa

Figure 5: Properties of aluminum.

Meshing of Plate:

Generate after modeling is completed click modal analysis in this select the type of material click geometry select geometry and the select surface of the plate click meshing a lot of options are visible like a bar, tetra, and quad we click the bar, and divide into 10 X 7 apply.

Mesh size =10 x 7

Nodes=88, Elements=70.

The Mesh bar type then gives boundary conditions to the plate click modal insert the boundary conditions like simply supported then select all four sides of the plate and click to apply to boundary condition. After applying boundary conditions click solutions and insert total the meshing various types like core, fine, and medium is used for exact solutions depending on the conditions. We used these different sizing used like tetra and suard are used to get mesh in Ansys for modal analysis after meshing select the analysis setting select maximum modes to find the natural frequency and then choose solution click to inspect and insert the deformation the total deformation will be visible click duplicate on total deformation then we can see the mode.

6. Results and Discussions:

For the analysis of a simply supported rectangular plate, the following material properties are considered

Aluminum Youngs modulus $E=68 \times 10^9$ N/m.

Density =2500 kg/m³.

Poisson ratio = 0.34

Length of plate in x direction =0.60 m

Length of plate in y direction =0.40 m



Figure 6: For Thickness 0.00625 The Frequency Variation.

In the above figure, a bar graph has been drawn between modes and frequency for the thickness of 0.00625 m.

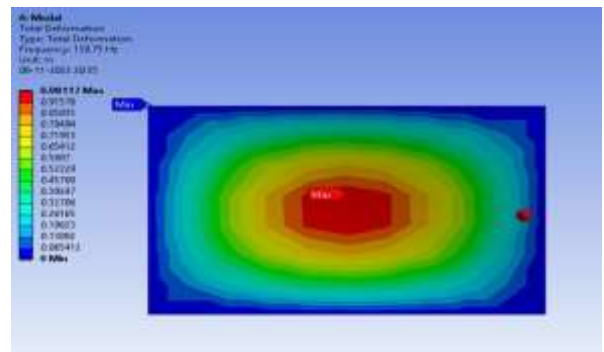


Figure 7: Modal Deformation.

In the above figure, the deformation of the plate at the first mode of frequency was given. The more deformation of the plate was at the center of the plate and we have a peak deformation point.

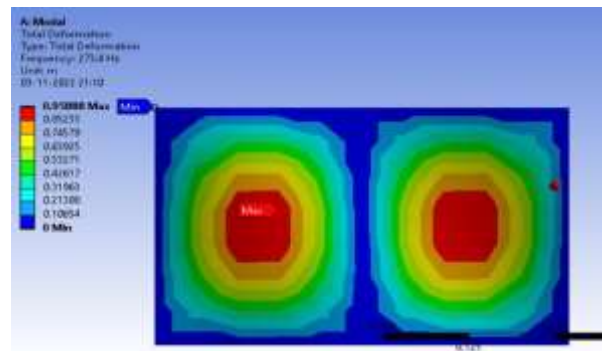


Figure 8: Next Modal Deformation.

In the above figure, the deformation of the plate at the second mode of frequency was given. The more deformation of the plate was at the two sides of the plate and we have two peak deformation points.

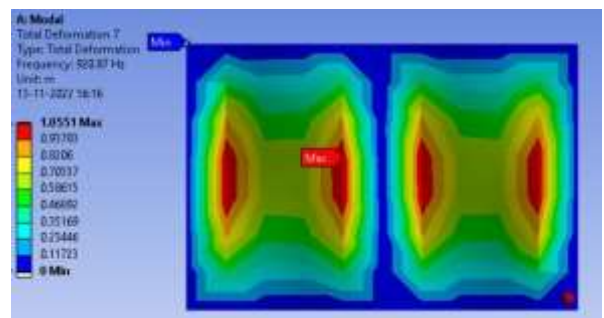


Figure 9: Next Deformation

In the above figure, the deformation of the plate at the seventh mode of frequency was given. We have four peak deformation points with the maximum value of deformation (1.0552) and with zero minimum.

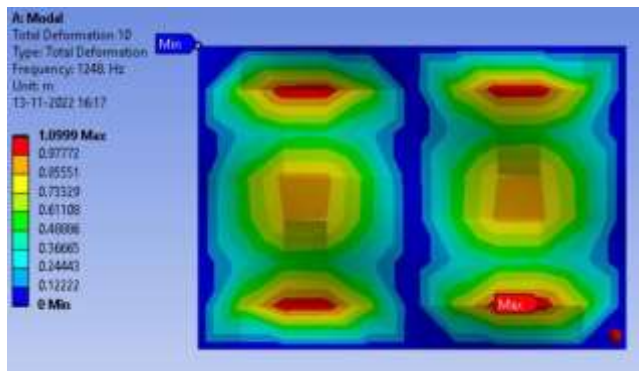


Figure 10: Next Modal Deformation.

In the above figure, the deformation of the plate at the tenth mode of frequency was given. We have four peak deformation points with the maximum value of deformation (1.0999) and with zero minimum. The ninth mode deformation chart and tenth mode graph look similar to the nearest deformation values.

7. Conclusion:

The finite element method is used for the analysis of a rectangular thin plate based on the Kirchhoff plate theory.

In this project, free vibration analysis has been carried out for a rectangular thin plate. By varying the thickness of the plate, it has been concluded that the frequency increases with the thickness of the plate.

The results showed that the current methodology solutions were very close to the exact solutions. An increase in the thickness of the plate does not affect the frequency parameter, but the results of natural frequencies increase with the thickness of the plate, and the natural frequency is varying according to the thickness of the plate.

8. Reference:

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