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NUMERICAL OPTIMIZATION OF THE EFFECT OF THE ASPECT RATIO ON THE DYNAMIC PERFORMANCE OF PLATES

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ABSTRACT

This paper intends to study, investigate and optimize the effect of aspect ratio such as width and height on the dynamic behavior of a plate in terms of frequency and mode shapes.The research involves simulating and building plate models using ANSYS software. Modal analysis is adopted to predict the dynamic behavior of the plate. MATLAB code is developed to estimate the natural frequency values mathematically. Numerical results are compared with mathematically calculated frequency values. A total of 25 ANSYS models are built. The study has investigated up to eight dynamic modes shapes. The effects of the aspect ratios are presented in this article. Increasing the width can slightly increase the natural frequency values however increasing the thickness can significantly increase the values of the natural frequency. The range of the width values was from 40, 45, 50, 55, and 60 mm. The range of thickness values was from 10, 15, 20, 25, and 30 mm. This effect was seen to take place more in flexural (bending) modes. Flexural, Lateral, torsional, and buckling mode types were observed during the modal analysis. The rank of these modes for each model was dependent on the width and height of the plate.

KEYWORDS: *Plates; Dynamics; ANSYS; Modal; Frequency, vibration modes.*

1. INTRODUCTION

Plate structures are essential building blocks that are widely used in a wide range of engineering applications, from mechanical systems to aeronautical and civil engineering. It is crucial to understand and improve the dynamic behavior of plates since it directly affects their stability, structural integrity, and overall performance. The aspect ratio, which is the ratio of a plate's length to its breadth and one of the important geometric elements controlling the dynamic properties of plates, is essential in defining the plate's vibrational response and overall dynamic performance.

Numerous studies on plate dynamics have been conducted, including inquiries into how aspect ratio affects several dynamic characteristics such as natural frequencies, mode shapes, damping ratios, and modal involvement factors. Numerous computer methodologies and numerical optimization techniques have been used to date to study the dynamic behavior of plates under various aspect ratios. These methods enable academics to effectively examine complex structural systems and provide knowledge on how engineers and designers may improve plate designs for better performance.

By providing a thorough numerical optimization analysis on the impact of aspect ratio on the dynamic performance of plates, this research seeks to support this continuing effort. This work aims to uncover the complex links between aspect ratio changes and important dynamic parameters using meticulous numerical simulations and optimization techniques, offering useful insights for the design and engineering of high-performance plate-based systems.

To build upon a strong theoretical foundation, this investigation incorporates significant work in the fields of plate mechanics, numerical optimization, and structural dynamics. The creation of the governing equations for plate dynamics at different aspect ratios is based on the classical theories of Timoshenko and Woinowsky-Krieger (Timoshenko and Woinowsky-Krieger 1959) on plate mechanics. Michell's (Michell 1904) and more recent (Svanberg 2002) efforts on numerical optimization methods, as well as research on structural optimization concepts, were used to construct the aspect ratio optimization framework.

There is a wealth of literature on the dynamics of plates under various loading and boundary conditions, which aids in understanding the complex interplay between the

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aspect ratio and dynamic properties. The vibrational behavior of plates is extensively discussed in the works of Leissa (Leissa 1973) and Meirovitch (Meirovitch 1986), while Reddy (Reddy 2004) investigates the mechanics of laminated composite plates and shells. Furthermore, early research by Zienkiewicz and Belytschko (Zienkiewicz 2000 and Belytschko 2014) served as the foundation for numerical techniques like finite element analysis (FEA), which is widely used in structural analysis.

The fields of structural analysis and numerical optimization have seen a revolution in modern engineering practices because of strong computer tools and software. This work makes effective use of the capabilities of top simulation programs, including Ansys (*Structural Analysis Software*, 2023), Abaqus (*Finite Element Analysis Software*, 2023), and COMSOL (*Multiphysics Simulation Software*, 2023), to carry out dynamic analysis and optimization methods. A robust and precise evaluation of the dynamic performance of plates under various aspect ratios is made possible by the inclusion of these software tools in numerical studies.

For the purpose of creating a methodical strategy for optimizing the aspect ratio of plates, the knowledge gleaned from earlier work on structural optimization and dynamic response assessments by Spyridon and Bendsoe (Spyridon 2023 and Bendsoe 2003) serves as an invaluable resource. We attempt to determine the ideal aspect ratio that optimizes certain performance metrics while taking into account realistic technical restrictions by using optimization techniques influenced by Michell's work on frame structures (Michell 1904).

This study adds something new and significant to the fields of plate dynamics and numerical optimization. By figuring out how aspect ratio affects the dynamic performance of plates, this study hopes to make it easier to design new, high-performance structures that can stand up to different kinds of loads and are more efficient and safer in a wide range of engineering applications.

With the use of a thorough analysis of the effects of numerical optimization, we hope to better understand the dynamic behavior of plates in this work. We aim to shed light on the complex interactions between aspect ratio fluctuations and important dynamic factors by using fundamental theories of plate mechanics, numerical optimization approaches, and cutting-edge computational tools. This introduction's extensive list of cited sources provides a wealth of knowledge that serves as a strong foundation for our research. The knowledge gained from this study is anticipated to enable engineers and designers to optimize the aspect ratio of plates for improved structural performance in a variety of engineering applications.

This examination uses finite element analysis (FEA), a popular numerical technique in structural mechanics, as the primary numerical simulation tool to accomplish the research goals (Belytschko 2014). By discretizing the plate domain into smaller components, FEA makes it possible to analyze complicated systems and their dynamic behavior with accuracy and efficiency. COMSOL, Abaqus, and other well-known commercial software programs that provide sophisticated structural analysis and optimization capabilities are used to conduct the simulations (COMSOL AB, 2021, Dassault Systèmes, 2021, Ansys, Inc, 2021).

Natural frequencies, which are crucial determinants of a plate's vibrational properties (Tran et al. 2021), are the study's first emphasis on basic dynamic factors. In order to comprehend how the quantity and distribution of natural frequencies change and to find possible resonances that could affect the plate's general stability and performance (Zhong et al. 2019), we adjust the aspect ratio. Additionally, mode shapes, which describe the plate's deformation patterns at certain frequencies, provide crucial information on the localization and distribution of energy inside the structure (Araujo et al. 2010). Our study investigates how modal patterns are influenced by aspect ratio and suggests designs that encourage more effective energy distribution.

In evaluating the dynamic performance of plates, taking damping into account is equally important (Reddy 2004). To understand how the structure's capacity to dissipate vibrational energy varies, various aspect ratios are explored using damping ratios, which measure the energy dissipation in the system (Wei et al. 2016). The interaction between damping and aspect ratio significantly affects a plate's resistance to dynamic loads and vibrations.

Along with natural frequencies and damping, modal participation variables are also looked at to figure out how different modes affect the plate's overall response (Al-Shammari et al. 2022). For engineering structures that display frequency-dependent behavior and need focused optimization of certain modes to achieve performance requirements, understanding these aspects is essential.

We use numerical optimization methods in the analysis in order to get the ideal aspect ratio for certain performance indicators (Svanberg 2002). The aspect ratio that produces the necessary dynamic properties is chosen using a variety of optimization approaches, including gradient-based and evolutionary techniques. The groundbreaking optimization research by Araujo et al. (Araujo 2010) and Akl et al. (Akl et al. 2000) as well as the works of Bendsoe and Sigmund on topology optimization (Bendsoe 2003) served as important references in the development of the optimization methods for aspect ratio selection.

This study aims to reveal the complex interactions between aspect ratio and the dynamic performance of plates in terms of flexural behavior via a combination of theoretical underpinnings, numerical simulations, and optimization techniques. This study's results have enormous potential for assisting engineers and designers in the optimization of plate structures for a variety of uses, including bridge decks, mechanical parts, and more. This publication offered a road map for every form of mode shape that can show up during a modal analysis. Different mode shape types were revealed in this study such as flexural, torsional, lateral, and buckling. This paper showed how the height and width dimensions of the plate could change the appearance rank of these mode shape types.

Finally, this study aims to make a substantial contribution to the area of plate dynamics and numerical optimization by thoroughly exploring the influence of aspect ratio on the dynamic performance of plates. This paper intends to provide significant insights and approaches for optimizing plate-based systems for improved performance and structural integrity in a variety of engineering applications by using a large number of influential references.

2. Boundary conditions, configurations, and dimensions

This study investigated a plate with a cantilever configuration. The boundary condition considered one end fixed while the other end kept free as shown in Figure 1. The length of the plate was 150 mm. The width of the plate had the values of 40, 45, 50, 55, and 60 mm while the height of the plate was in the range of 10, 15, 20, 25, and 30 mm. Different models with different width and height were built. Steel with density of 7850 Kg/m^3, modulus of elasticity of 200 GPa and poison's ration of 0.3 was selected. These dimensions and specifications are chosen for the purpose of this research only.

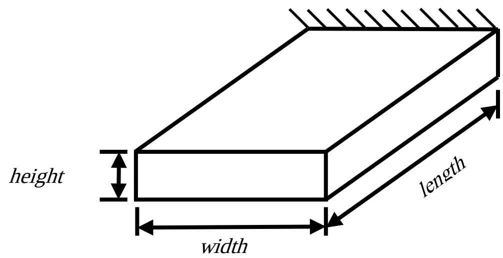

Fig.(1):-Layout of the cantilever plate

3. NATURAL FREQUENCIES AND MODE SHAPES

In this study, the natural frequency values and the behavior of the mode shape play an essential role to specify the effect of the plate dimensions on the flexural dynamic behavior of the plate.

Generally, the natural frequency is the rate at which an object oscillates naturally when exposed to initial excitation. The mode shape can be expressed as it is the shape of the deformation of that body at each natural frequency (Baqersad et al. 2014). Basically, all bodies have natural frequencies and accordingly have mode shapes as much as the level of the degree of freedom of these bodies. Knowledge of the system's natural frequencies is of importance where cases of intensive resonance can be avoided through several ways including shifting of the natural frequency to avoid resonance regions caused by any force vibration subjected to the system (Ewins 2009). Of course, the bulk natural frequency of any system can be derived from the equation of motion of that system.

4. FINITE ELEMENT MODELS

The finite element method is considered an essential technique to simulate the dynamic behavior of plates (Hughes 1987). Plate models with different dimensions and specific boundary conditions were selected. A total of twenty-five finite element models were built using the ANSYS software package. Figure 2 depicts the finite element model of a plate with a length of 150 mm, width of 40 mm, and height of 10 mm. The element type used is SOLID186 which is a 20 node-element with three degrees of freedom per node as shown in Figure 3. The meshing process included an element size of 4 mm for the body of the plate. Cantilever configuration was adopted for the finite element models. Model dimensions ranged from 10, 15, 20, 25, and 30 mm for the height and 40, 45,50, 55, and 60 mm for the width.

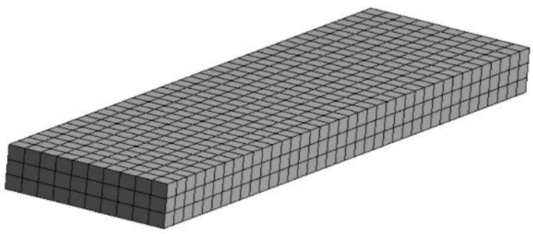

Fig.(2):- Finite element model of the plate

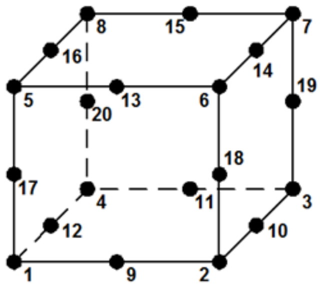

Fig.(3):- Element type of SOLID186 with 20 nodes

5. MODAL ANALYSIS

Modal analysis can be described as it is the method by which, the natural frequencies and the mode shapes of a mechanical system can be evaluated. This is considered an important characteristic in dynamic designs as the recorded natural frequencies and mode shapes are the equivalent values of the whole system (Clough and Penzien 1993). Generally, there are several methods to perform a modal analysis in practice such as subjecting a body to a single or multiple excitations and then, by acquisitioning the outputs, estimating the natural frequencies and mode shapes. The modal analysis adopts Eigen equations where the evaluated values of the natural frequencies present the Eigenvalues and the resulting mode shapes depict the Eigenvectors (Jurgen 1996). Modal analysis in the finite element method follows the Eigen equations as well, where the mechanical system undergoes free vibrations.

In this research, eight modes were simulated for each plate model starting from the lowest natural frequency. The plate adopted a cantilever configuration where one end was freed and the other end fixed. Free vibration test was chosen for the simulation. The resulting first eight natural mode shapes comprised flexural, torsional, lateral, and buckling modes. These modes are depicted in Figure 4. The classification of the resulting modes is listed in Tables 1, 2, 3, 4, and 5.

5.1 Mapping the mode shapes

The modal analyses performed for each plate model revealed that the rank of the first, second, and third flexural mode shapes among the eight generated mode shapes is not steady and is changeable according to the specific width and height of the plate model.

In light of the above, the plate model of width, height, and length of 40, 10, and 150 mm respectively (Table 1) has the 1st flexural mode ranked 1st and 2nd flexural mode ranked 3^{rd,} and 3rd flexural mode ranked 5th. While another plate model of width, height, and length of 45, 30, and 150 mm respectively (Table 2) has the 1st flexural mode ranked 1st and the 2nd flexural mode ranked 4^{th,} and the 3rd flexural mode ranked 8th.

A map for the different types of mode shapes, including flexural, torsional, lateral, and buckling, was able to specify and draw by recognizing the type and rank of each mode

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shape type for the different plate models.

Tables 1, 2, 3, 4, and 5 map the resulting different mode types and the rank of the flexural modes. Modal analysis is performed for eight modes as it was enough to visualize the third flexural mode shape. The following resea rch article will try to find the relationship between the mode type and the dimension of the plate.

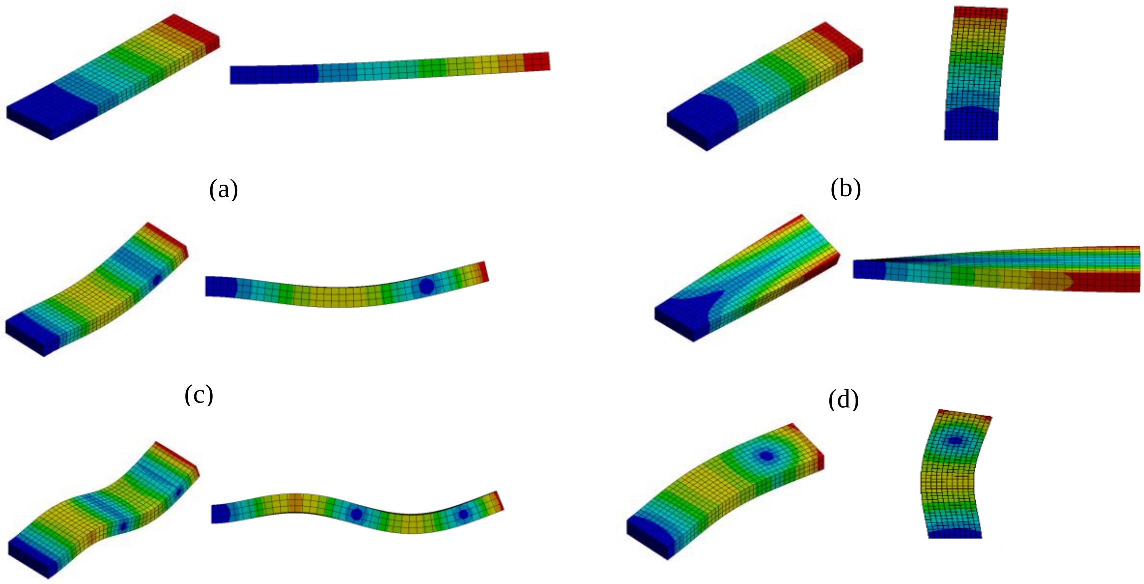

Fig.(4):- Mode shape types where (a) 1st flexural, (b) 1st lateral, (c) 2nd flexural, (d) 1st torsional, (e) 3rd flexural, and (f) 1st buckling

Table(1):- Map of mode shape types for plates with length 150 mm, width 40 mm, and different heights

Mode shape rank	Plate models				
	Width 40 mm Height 10 mm	Width 40 mm Height 15mm	Width 40 mm Height 20 mm	Width 40 mm Height 25 mm	Width 40 mm Height 30 mm
1	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st
2	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st
3	Flexural, 2nd	Flexural, 2nd	Torsion, 1st	Torsion, 1st	Torsion, 1st
4	Torsion, 1st	Torsion, 1st	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd
5	Flexural, 3rd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd
6	Lateral, 2nd	Buckling, 1st	Buckling, 1st	Buckling, 1st	Buckling, 1st
7	Torsion, 2nd	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd
8	Buckling, 1st	Torsion, 2nd	Torsion, 2nd	Torsion, 2nd	Torsion, 2nd

Table 2 Map of mode shape types for plates with length 150 mm, width 45 mm, and different heights

Mode shape rank	Plate models				
	Width 45 mm Height 10 mm	Width 45 mm Height 15mm	Width 45 mm Height 20 mm	Width 45 mm Height 25 mm	Width 45 mm Height 30 mm
1	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st
2	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st
3	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st
4	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd
5	Flexural, 3rd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd
6	Buckling, 1st	Buckling, 1st	Buckling, 1st	Buckling, 1st	Buckling, 1st
7	Lateral, 2nd	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd	Torsion, 2nd
8	Buckling, 2nd	Torsion, 2nd	Torsion, 2nd	Torsion, 2nd	Flexural, 3rd

Table (3):- Map of mode shape types for plates with length 150 mm, width 50 mm, and different heights

Mode shape rank	Plate models				
	Width 50 mm Height 10 mm	Width 50 mm Height 15mm	Width 50 mm Height 20 mm	Width 50 mm Height 25 mm	Width 50 mm Height 30 mm
1	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st
2	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st
3	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st
4	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd
5	Flexural, 3rd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd
6	Torsion, 2nd	Buckling, 1st	Buckling, 1st	Buckling, 1st	Buckling, 1st
7	Lateral, 2nd	Flexural, 3rd	Torsion, 2nd	Torsion, 2nd	Torsion, 2nd
8	Buckling, 1st	Torsion, 2nd	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd

Table(4):- Map of mode shape types for plates with length 150 mm, width 55 mm, and different heights

Mode shape rank	Plate models				
	Width 55 mm Height 10 mm	Width 55 mm Height 15mm	Width 55 mm Height 20 mm	Width 55 mm Height 25 mm	Width 55 mm Height 30 mm
1	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st
2	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st
3	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st
4	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd
5	Torsion, 2nd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd
6	Flexural, 3rd	Torsion, 2nd	Buckling, 1st	Buckling, 1st	Buckling, 1st
7	Lateral, 2nd	Buckling, 1st	Torsion, 2nd	Torsion, 2nd	Torsion, 2nd
8	Buckling, 1st	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd

Table(5):- Map of mode shape types for plates with length 150 mm, width 60 mm, and different heights

Mode shape rank	Plate models				
	Width 60 mm Height 10 mm	Width 60 mm Height 15mm	Width 60 mm Height 20 mm	Width 60 mm Height 25 mm	Width 60 mm Height 30 mm
1	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st	Flexural, 1st
2	Torsion, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st	Lateral, 1st
3	Lateral, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st	Torsion, 1st
4	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd	Flexural, 2nd
5	Torsion, 2nd	Torsion, 2nd	Lateral, 2nd	Lateral, 2nd	Lateral, 2nd
6	Flexural, 3rd	Lateral, 2nd	Buckling, 1st	Buckling, 1st	Buckling, 1st
7	Lateral, 2nd	Buckling, 1st	Torsion, 2nd	Torsion, 2nd	Torsion, 2nd
8	Buckling, 1st	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd	Flexural, 3rd

6. MATHEMATICAL COMPARISON

In this section, the natural frequencies of the cantilever plate models were calculated using the empirical formula developed by Blevins (Blevins 1979) based on his experiments on beams and plates. The material chosen was steel with a modulus of elasticity of 200 GPa, density of 7850 Kg/m^{3,} and poisons ratio of 0.3.

This section is devoted to comparing the natural frequencies obtained numerically using ANSYS with the natural frequencies calculated using Equation (1).

The equation to calculate the natural frequencies for different modes is presented below;

$$f_i = \left(\frac{\lambda_i^{\,2}}{2\pi}\right)\sqrt{\frac{EI}{mL^3}} \tag{1}$$

Where *i* is mode shape rank, λ is non-dimension frequency constant that depends on the rank of mode shape, *E* modulus of elasticity, *I* second moment of area, *m* mass, and *L* length of the plate.

λ values are 1.875, 4.694, 7.854, 10.995, and 14.137 used for modes 1, 2, 3, 4, and 5 respectively.

The empirical equation is designed to only estimate the flexural modes. Therefore, the first three modes calculated using the empirical equation will be compared to the first three flexural modes obtained from the ANSYS simulation.

A MATLAB code was developed to calculate the natural frequencies using Equation (1) and to generate the natural frequency values.

The comparison results are listed in Table 6 for a plate model of width, height, and length of 40, 10, and 150 mm.

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Table 6 Comparing numerical and mathematical flexural natural frequency values

Flexural mode	ANSYS frequency, Hz	Mathematical frequency, Hz	Error
1st flexural mode	365.880 (1st mode)	362.530 (1st mode)	0.92 %
2nd flexural mode	2245.00 (3rd mode)	2272.13 (2nd mode)	1.20 %
3rd flexural mode	6106.50 (5th mode)	6361.05 (3rd mode)	4.00 %

7. RESULTS AND DISCUSSIONS

The dynamic performance of a plate was investigated by performing modal analyses over eight modes. The plate was under a cantilever configuration. The width range of the plate was 40, 45, 50, 55, and 60 mm. The height of the plate ranged from 10, 15, 20, 25, and 30. The length was fixed at 150 mm.

The results show the effect of each plate's dimensions on the flexural natural frequency for the different mode shapes.

Basically, for each plate model, there were eight generated mode shapes with different mode types. These types included flexural, lateral, torsional, and buckling mode shapes. The rank and appearance of these mode shape types were affected by the dimensions of the plate. For example, a plate model with a width of 40 mm, height of 10 mm, and length of 150 mm has first, third, and fifth modes depicted as the flexural mode shape type. While first and second lateral modes appeared in the second and sixth modes respectively, first and second torsional modes appeared in the fourth and seventh modes respectively and buckling mode appeared in the eighth mode as listed in Table 1.

Figure 5 shows the behavior of the first natural frequency against a range of plate's width of 40, 45, 50, 55, and 60 for cases of plate's height of 10, 15, 20, 25, and 30 mm. Figure 5a presents the effect of increasing the width of the plate on the first flexural natural frequency for a plate's height of 10 mm. The same behavior was plotted in Figures 5b, 5c, 5d, and 5e but for plate height values of 15, 20, 25, and 30 respectively.

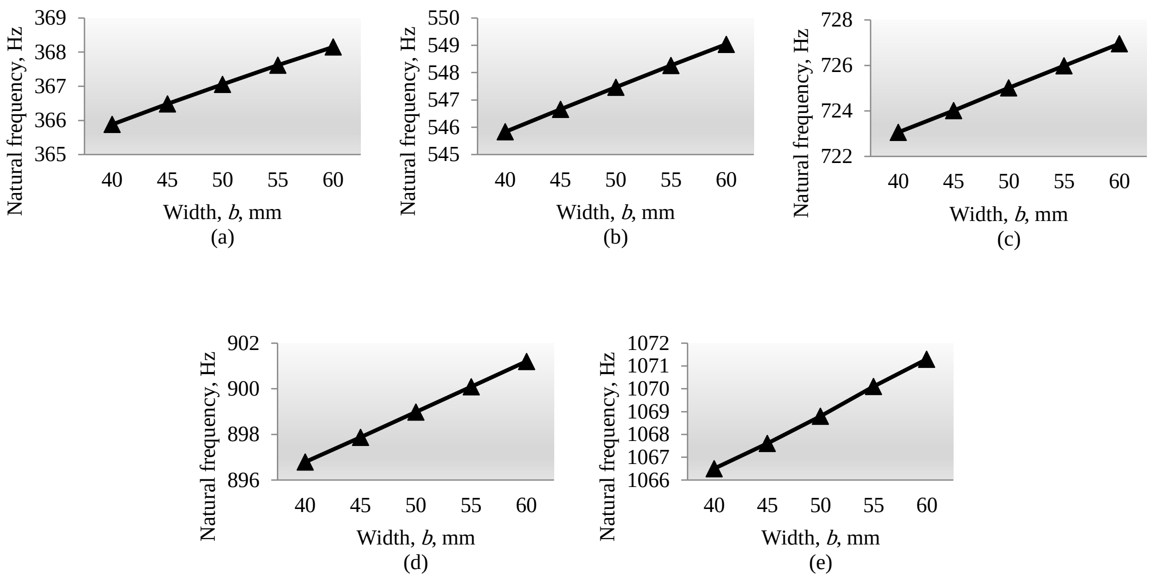

Fig.(5):- Effect of plate's width on the 1st flexural natural frequency at height of (a) 10, (b) 15, (c) 20, (d) 25, and (e) 30 mm

The results from Figure 5 indicate that increasing the width leads to an increase in the natural frequency slightly. This behavior is true for the selected plate's height values.

Examining the results shown above, indicate that the width has a slight effect on the values of the first natural frequency. This could be referred to as the basic equation of the natural frequency as shown in the equation below.

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m}} \quad (2)$$

where f is the natural frequency, k is the stiffness and m is the mass. The stiffness can be estimated through Equation (3),

$$k = \frac{3EI}{L^3} \quad (3)$$

where E is the modulus of elasticity, I is the second moment of area and L is the length of the plate. The second moment of area can be calculated through,

$$I = \frac{bh^3}{12} \quad (4)$$

Where b is the width of the plate and h is the height.

From the above equations, the natural frequency is affected by the square root of the width value. This can be considered as the reason for the slight effect of the width value on the natural frequency value.

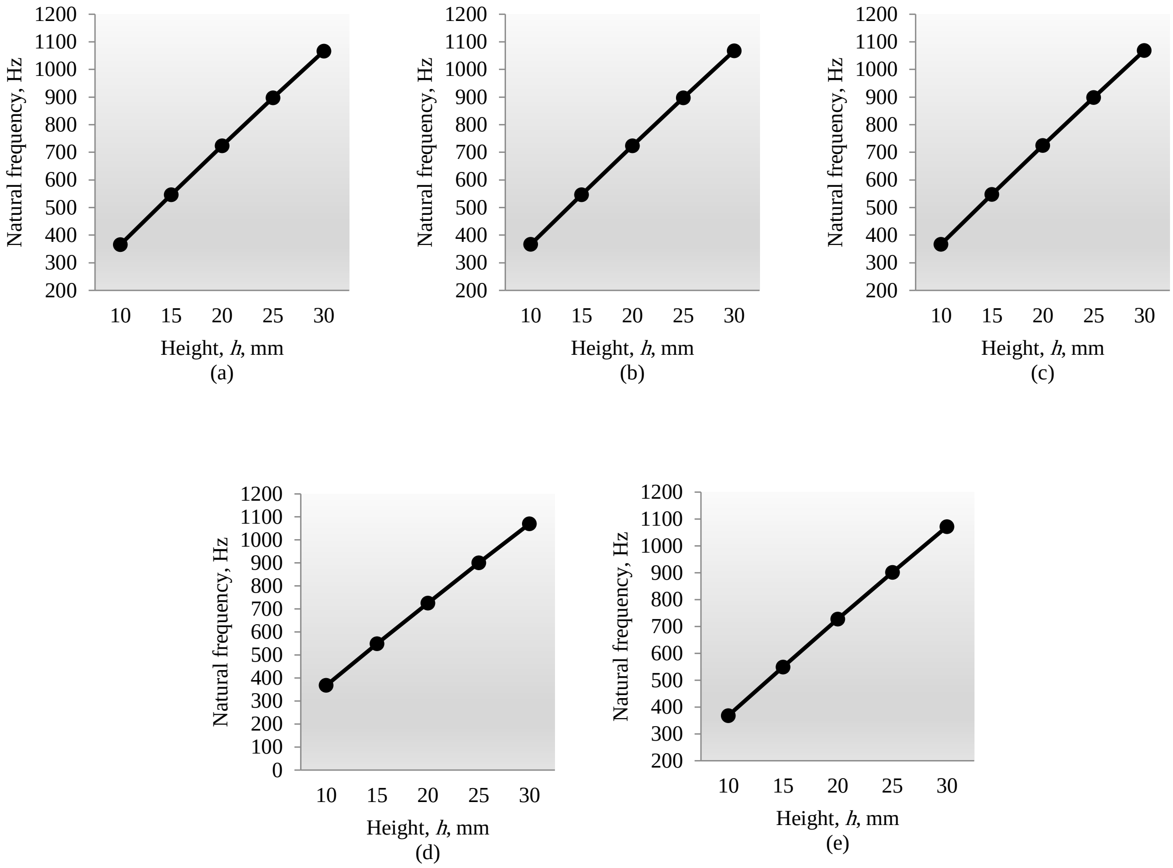

Fig.(6):- Effect of plate's height on the 1st flexural natural frequency at a width of (a) 40, (b) 45, (c) 50, (d) 55, and (e) 60 mm

Figure 6 presents the effect of the height of the plate on the behavior of the first flexural natural frequency at specific width values.

Exploring Figure 6a reveals that the effect of

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increasing the height from 10, 15, 20, 25 through 30 mm can significantly increase the value of the first flexural natural frequency at a width value of 40 mm and Length of 150 mm.

This behavior can be seen repeated in figures 6b, 6c, 6d, and 6.6e where the height is increasing from 10 mm to 30 mm with a step of 5 mm for each case and width values of 45, 50, 55, and 60 for Figures 6b, 6c, 6d and 6.6e respectively.

The reason for the significant effect of the height on the values of the natural frequency can be explained by returning to Equations 2, 3, and 4. The natural frequency is affected by the treble the square root of the height.

As Figures 5 and 6 represented the effect of width and height on the flexural first natural frequency respectively, Figure 7 represents the effect of the height on the first three flexural natural frequencies.

As this research is devoted to analyzing the flexural modes only, Figure 7 depicts the effect of the plate height on the first and second, and third flexural natural frequencies. The first, second, and third flexural modes had different ranks in each plate model therefore Tables 1, 2, 3, 4, and 5 were considered essential to specify the flexural modes in each model.

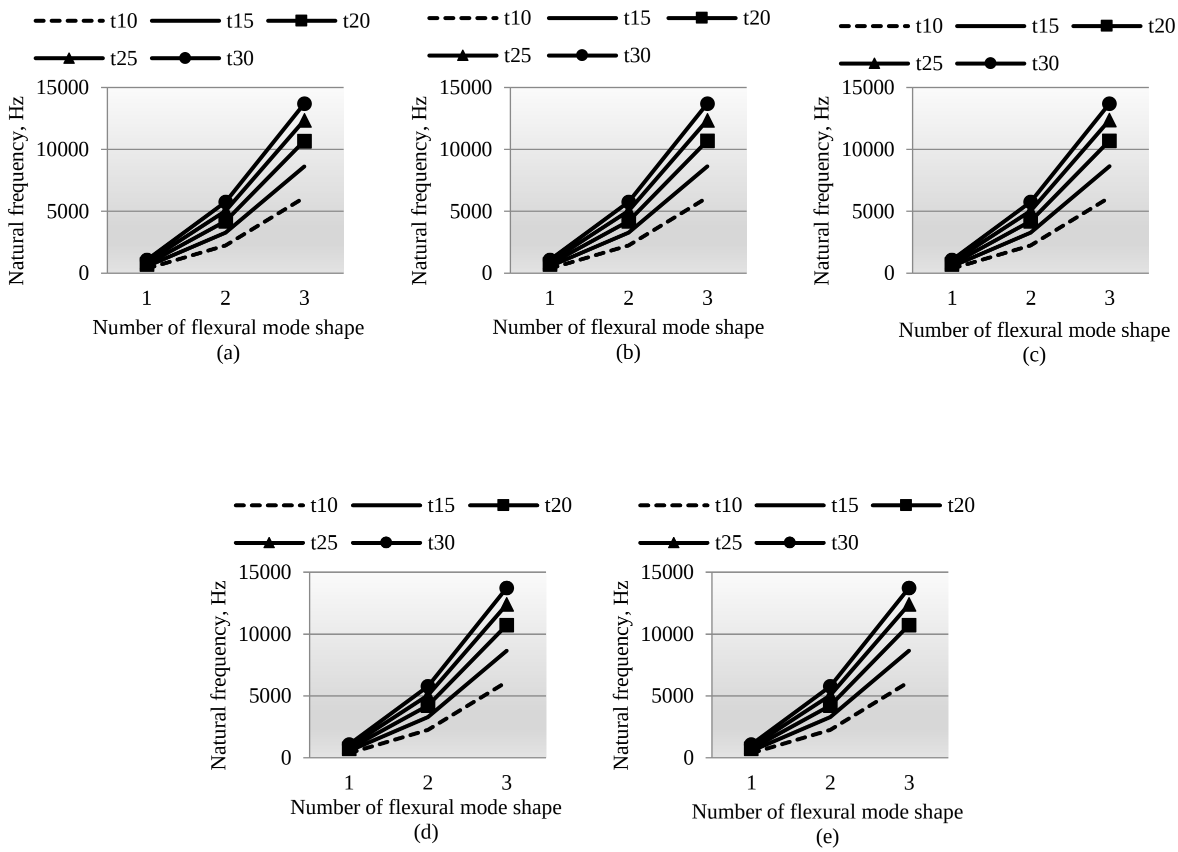

Fig.(7):- Effect of the plate height on the flexural natural frequency at a width of (a) 40, (b) 45, (c) 50, (d) 55, (e) 60 mm

The first, second, and third flexural modes had the rank of first, third, and fifth out of the total eight generated modes respectively for plate models of width 40 mm, height 10 mm, and length 150 mm. While the first, second, and third flexural modes had the rank of first, fourth, and eighth out of the total eight generated modes respectively for plate models of width 50 mm, height 25 mm, and length 150 mm.

Although this research focuses on the effect of the aspect ratio on the flexural modes only, however, this research shed light on the type of plate mode shapes. Where there were four main types observed as a mode shape. These types included flexural, lateral, torsional, and buckling mode shapes.

This research shows that, the rank of appearance of these different modes through the eight generated mode shapes differs and that they are affected by the dimensions of the plate. This research has presented a map for this behavior shown in Tables 1, 2, 3, 4, and 5.

8. CONCLUSIONS

The first three flexural modes of cantilever plate models were analyzed through modal analysis. Models of the plate with a width range of 40, 45, 50, 55, and 60 mm and heights of 10, 15, 20, 25, and 30 mm were built with a plate length of 150 mm. The effect of the aspect ratio against the flexural natural frequencies was examined and the research has summarized the following conclusions;

The height of the plate has a significant effect on the flexural modes where increasing the height lead to increasing the flexural natural frequency.

The effect of the width on the flexural frequencies was considered low compared to the effect of the height of the plate.

ANSYS was able to predict the different types of mode shapes. A comparison study was presented in this research to compare the mathematically and numerically obtained flexural frequencies.

Four main mode shape types were visually observed during the execution of the modal analysis. The type of these observed mode shapes ranged between flexural mode, lateral mode, torsional mode, and buckling mode.

The rank of the flexural modes among the eight tested modes was not fixed over the analyzed plate models. It was noticed that the aspect ratio affects the rank of all mode types including the flexural mode as shown in Tables 1, 2, 3, 4, and 5.

This research was able to furnish a map for the different mode types observed in this research where the total number of tested modes for each plate model was 8 modes.

Further comprehensive studies are suggested to correlate the dimensions of the plate with the rank of mode shapes with their different types including the flexural, lateral, torsional, and buckling modes.

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