Dynamic Analysis of Isotropic Plate

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Abstract- **This paper deals with the study of simply supported isotropic plates subjected to transverse dynamic loads. Thefinite element explicit formulation (ABAQUS/Explicit finite element code) is utilised for determining the responses of the plates. The transient and steady state responses are found out. The present results are compared with the available results along with the convergence studies. Various parameters such as thickness, aspect ratio and type of loading arechanged in order to understand the impact of dependent parameters which played a key role in altering the response of the plates.**

Keywords— Dynamic load, finite element, isotropic load, dynamic load

I. INTRODUCTION

When a structure is designed for static loading conditions, it is expected that all the loads that are acting on the structure either are permanent or the loads vary very slowly with time. However, it is possible that during the service life of the structure may be subjected to time dependent loads. These loads are known as dynamic loads example, earthquake, wind forces, tidal waves, vibrations from machines etc. A structure resists external forces by inertia and because the dynamic loads vary with time, the structure may not begiven time to mobilize the required amount of resistive forces. This could lead to catastrophic results even if themagnitude of the dynamic force is small. Hence it is essential to analyse any structure for dynamic loads.

As one of the fundamental aspect of structure numerous studies have been carried out to understand the behaviour of structures under dynamic loads. But since these loads vary with time, there is always a level of uncertainty in terms of the magnitude and direction in which they act, which essentially means that there is no end to the analysis in this field. Mallikarjuna and Kant(1988) studied the effects of finite element mesh, time step, lamination scheme on the transient response of multi-layered symmetrically laminated composite plate based on higher order displacement model theory.They found that the simple C^0 isoparametric formulation was efficient in predicting the transient response of composite plate.Kant*et al.*(1992) studied the same effects using higher order shear deformable theory of composite and sandwich plates. Ghosh and Sinha(2004)investigated the initiation and propagation of damages of laminated composite plates under forced vibrations and impact loads.

Su and Banerjee (2015)investigated the free vibration of functionally graded Timoshenko beam by developing the dynamic stiffness method. They related the amplitudes of forces and displacements at the ends of the beam in order to formulate the dynamic stiffness matrix. They generated a 6×6 frequency dependent dynamic stiffness matrix which is used to analyse the functionally graded material which was found to be efficient and accurate. Nefovska-Danilovic and Petronijevic (2015)generated a computer program to examine the free vibration and dynamic response analysis of isotropic plates with arbitrary boundary conditions. They verified the results with the available literature and successfully concluded that the model performed accurately even though the numbers of variables were significantly reduced.

In the current study, a simply supported square plate is analysed for different type of loading condition and the response of the plate is observed for variation in the thickness and aspect ratio of the plate.

II. THEORY AND FORMULATIONS

The linear dynamic analysis is performed using the finite element software ABAQUS/Explicit. It solves the equation of motion(dynamic equilibrium equation), which can be written as,

$[M]\{\ddot{x}\} + [C]\{\dot{x}\} + [K]\{x\} = \{F(t)\}$ -------------------(1)

Where,

$\{\ddot{x}\}$ - Global acceleration vector

$\{\dot{x}\}$ - Global velocity vector

$\{x\}$ - Global displacement vector

$\{F(t)\}$- Force vector

$[C]$ - Damping matrix

$[K]$- Stiffness matrix

$[M]$ - Mass matrix

In the present study the damping effect is neglected, so the dynamic equation of equilibrium Eq. (1) becomes,

$[M]\{\ddot{x}\} + [K]\{x\} = \{F(t)\}$ -------------------------------(2)

Equation (2) is solved for all analysis and the results are reported in the next section.

III. RESULTS AND DISCUSSION

First the convergence and validation study is carried by taking some reported results from the literature. Then the proposed study is discussed and the results are reported.

A. Convergence and Validation study:

The analysis was carried out in ABAQUS/Explicit on a square isotropic simply supported plate(Fig.1), subjected to uniformly distributed load. The load is applied instantaneously upto 360 microseconds and the responses are reported upto the same time. The material properties and other parameters taken are as follows:

a = b = 25cm; h = 5cm; ν = 0.25; E = 2.1 X 10^6 N/cm^2; ρ = 8 X 10^{-6} Ns^2/cm^4; q = 10 N/cm^2; Δt = 5 μs.

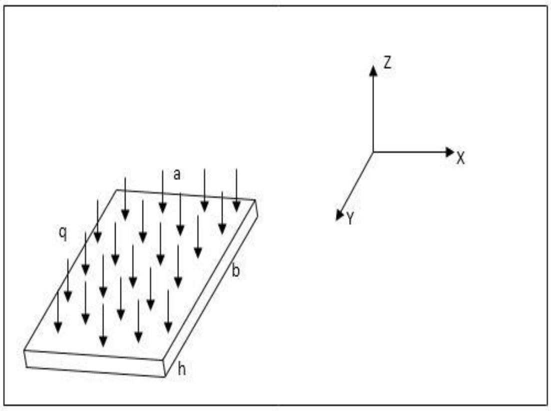

Fig.1 Model of the plate analysed in Abaqus 6.10-1

The dynamic analysis is performed by ABAQUS/Explicit considering different mesh sizes and the results are plotted in Fig.3.The element type is taken as S4R.S4R means a 4-node doubly curved thin or thick shell, reduced integration, hourglass control, finite membrane strains. It is seen from the figure that the results with 8×8 mesh sizes is almost converged. To validate the analysis further the results are compared with finite element results ofMallikarjuna and Kant(1988). In the reported results of Mallikarjuna and Kant(1988), it is found that the central displacements are shown in cm(w×1000). In the present study these are found to be in cm(w×10^{-3}). The results of Mallikarjuna and Kant(1988) with cm(w×10^{-3}) and the present results with 8×8 mesh size is plotted in Fig.2. It is found that the results are matching well.

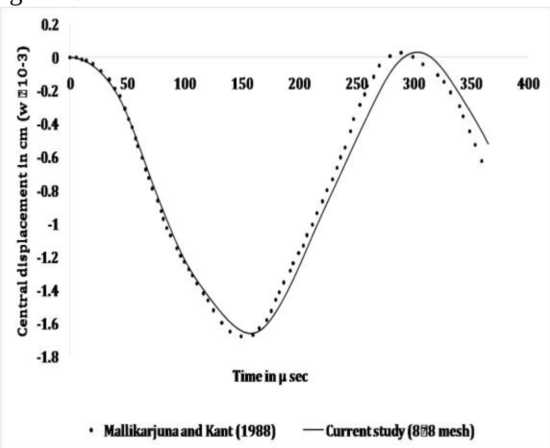

Fig. 2 Convergence and validation of the model

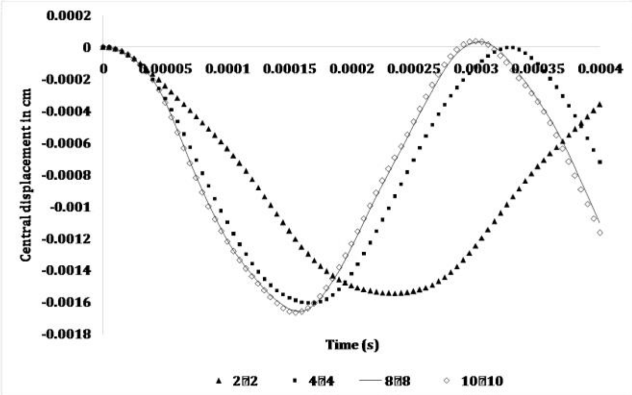

Fig. 3 Central displacement of isotropic plate with different mesh sizes

B. Proposed study

The plate taken in the convergence and validation study is considered in this case with uniformly distributed load with two functions(Fig.4). The effect thickness and the aspect ratio on dynamic behaviouris studied.

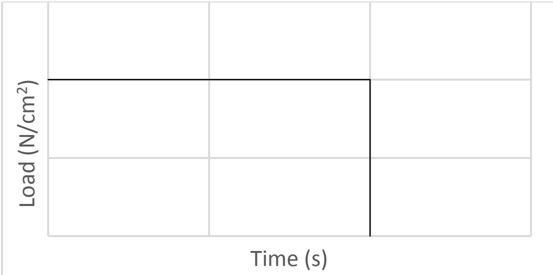

Fig. 4(a) Rectangular loading

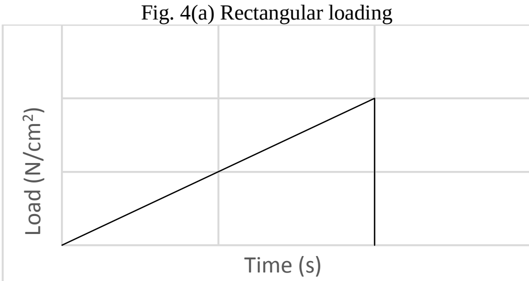

Fig.4(b) Triangular loading

Effect of loading functions

The square isotropic simply supported plate is subjected to rectangular and triangular loading (Fig.4). In order to observe the steady state response of the plate, the load is applied till 400 μs and response is recorded till 4000μs. The results are shown in Fig. 5 and Fig. 6.

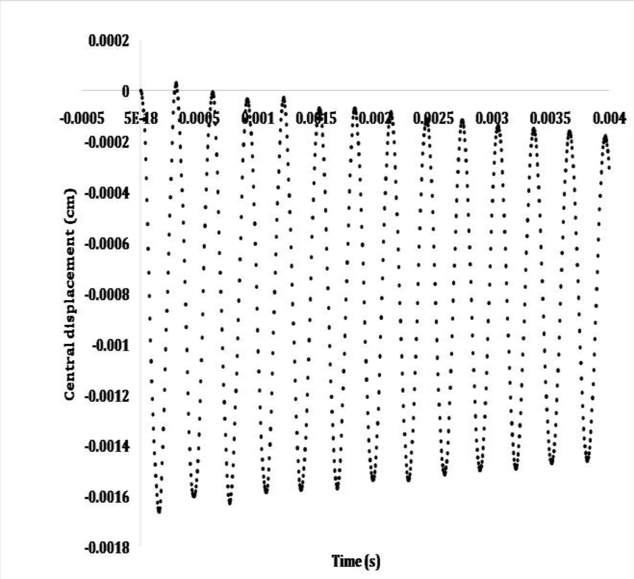

Fig. 5 Central displacement of isotropic plate with Rectangular loading

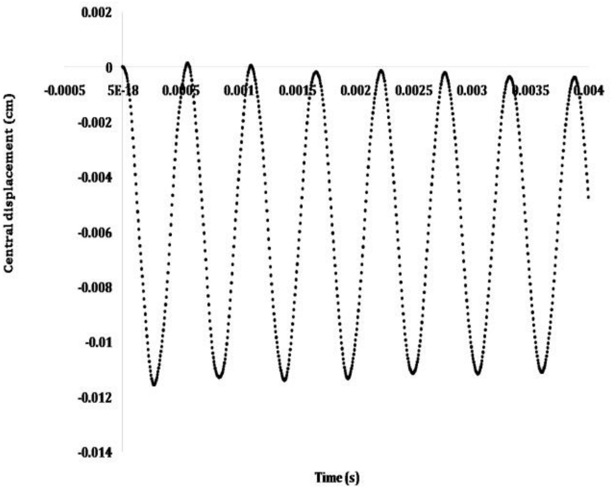

Fig. 6 Central displacement of isotropic plate with Triangular loading

It can be seen that the loading function completely alters the response of the system.

Effect of thickness

Further, the thickness of the plate is reduced to 2.5cm, 1.25cm and 0.625cm and subjected to rectangular loading. The load is applied till 400 µs and response is recorded till 4000µs. The results are plotted in Fig.7 – Fig.10.

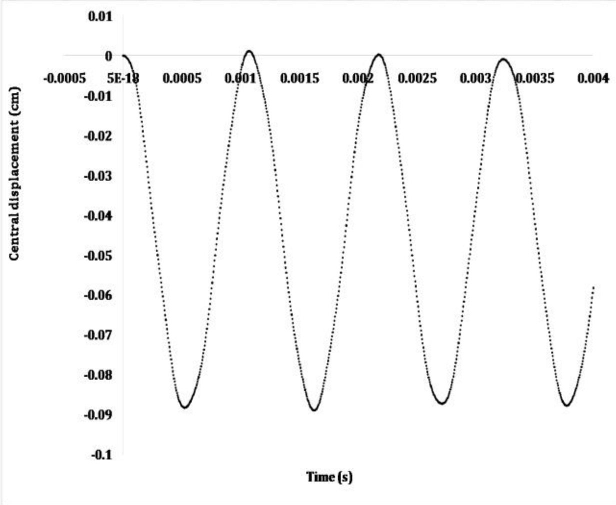

Fig. 7 Central displacement of isotropic plate with 2.5cm thickness

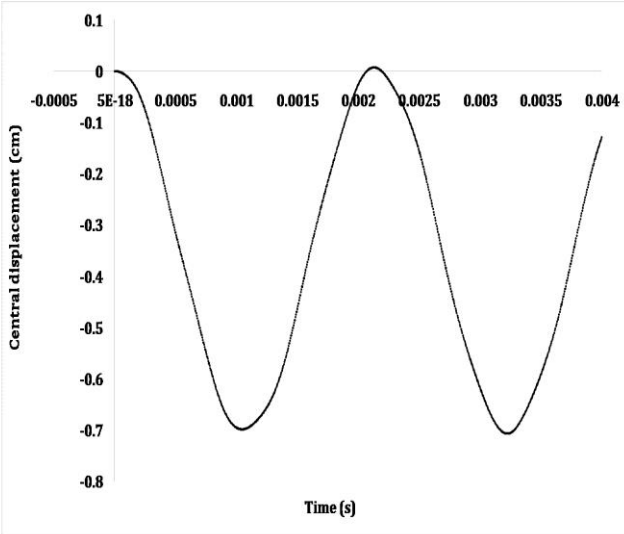

Fig. 8 Central displacement of isotropic plate with 1.25cm thickness

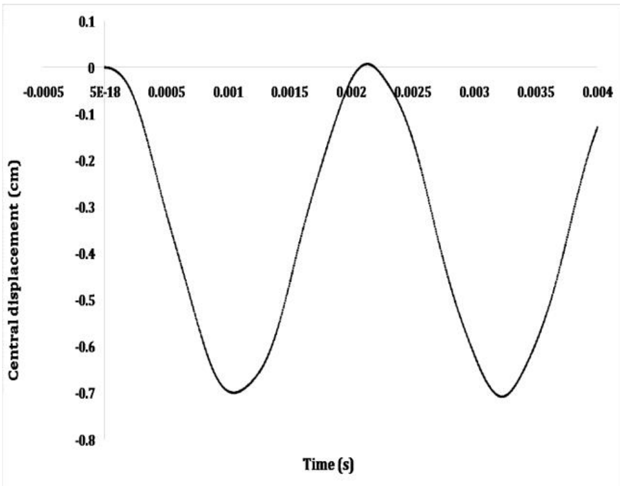

Fig. 9 Central displacement of isotropic plate with 0.625cm thickness

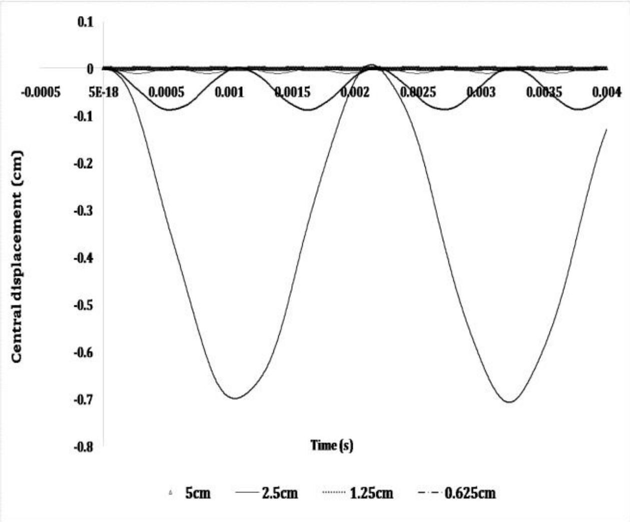

Fig. 10 Central displacement of isotropic plate with various thicknesses

Combining the 4 graphs won't help much because when the thickness is halved, the response increases by a factor of approximately 8.

3.2.3 Effect of aspect ratio

The aspect ratio is calculated as b/a. $a$is kept constant and b is increased. The thickness of the plate is 5cm and the plate is subjected to rectangular loading. The plate with aspect ratio 2,3,4,5 and 6 is considered and responses are recorded. The load is applied till 400 µs and response is recorded till 4000µs. The results are plotted in Fig. 11 and Fig. 12.

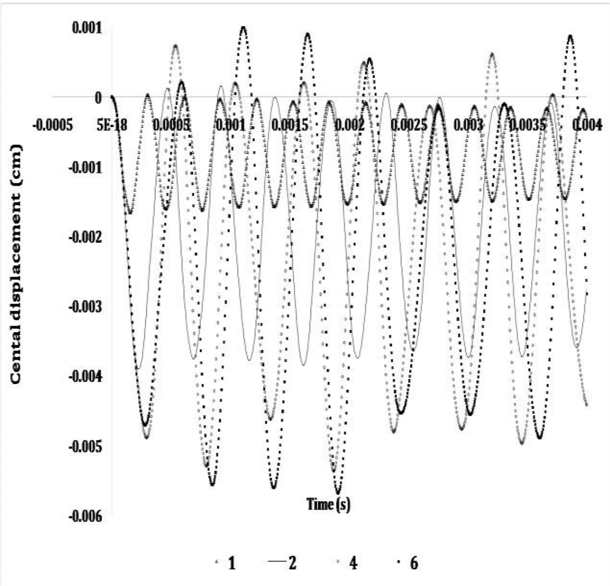

Fig. 11 Central displacement of isotropic plate with various aspect ratios

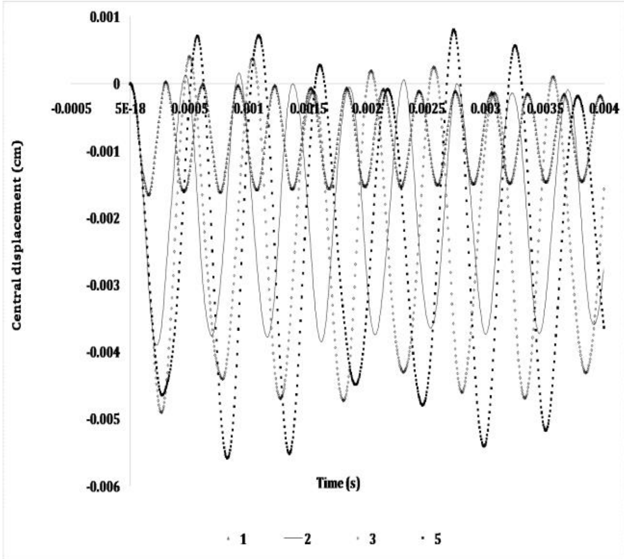

Fig. 12 Central displacement of isotropic plate with various aspect ratios

The results of aspect ratio 1, 2, 4 and 6 are plotted in Fig. 11 and the results of aspect ratio 1, 2, 3 and 5 are plotted in Fig. 12. Two separate plots are used as the one single graph will become overcrowded and interpreting the results is difficult. It can be seen from the two figures that the increase in the aspect ratio alters the frequency of the responses and after certain aspect ratio, the results do not vary much.

IV. CONCLUSION

The conclusions of the study can be summarised as:

1. The linear dynamic analysis of simply supported square isotropic plate subjected touniform transverse loading is carried out using ABAQUS/Explicit, version 6.10-1.
2. Initially the convergence and validation study is carried out, taking examples from available literature based on different mesh sizes.
3. The change in transient response of the plate when subjected to rectangular and triangular loading is noticeable and it is also observed that the maximum displacement is very less in triangular loading compared to rectangular loading.
4. In steady state response of the two loading conditions, it is observed that the decay in response is prominent in rectangular loading. After the load is removed, the amplitude is decaying slowly even without the consideration of damping because of the combined effects of stiffness and mass of the plate.
5. With decrease in the thickness of the plate, the frequency of the response reduces and the amplitude of the response increases.
6. The plate with aspect ratios 5 and 6 showed almost same response. With increase in aspect ratio, the frequency of the response reduces. The frequency of response of aspect ratio 1 is twice that of plate with aspect ratio 5 and 6.

ACKNOWLEDGEMENT

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