Scientific Workshop for PhD students UET-VNU

NONLINEAR DYNAMIC RESPONSE AND VIBRATION OF IMPERFECT SHEAR DEFORMABLE FUNCTIONALLY GRADED PLATES SUBJECTED TO BLAST AND THERMAL LOADS

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Introduction

Functionally Graded Materials (FGMs), which are microscopically composites and made from mixture of metal and ceramic constituents, have received considerable attention in recent years due to their high performance heat resistance capacity and excellent characteristics in comparison with conventional composites. FGMs are the proper selection to use as structural components operating in ultrahigh-temperature environments and subjected to extremely high thermal gradients, such as aircraft, space vehicles, nuclear plants, and other engineering applications.

Figure 1. Applications of FGMs.

In recent years, buildings and critical infrastructures across the globe have become more vulnerable to extreme dynamic explosion and impact loads due to increased terrorist activities, accidental explosions, proliferation of weapons, and so forth. As a result, blast loads and their impact on the safety and performance of structures have received considerable interest.

Goals of research

This investigation presents an analysis of the nonlinear dynamic response and vibration of imperfect FGM thick plates subjected to blast and thermal loads resting on elastic foundations. The material properties are assumed to be temperature-dependent and graded in the thickness direction according to a simple power-law distribution in terms of the volume fractions of the constituents.

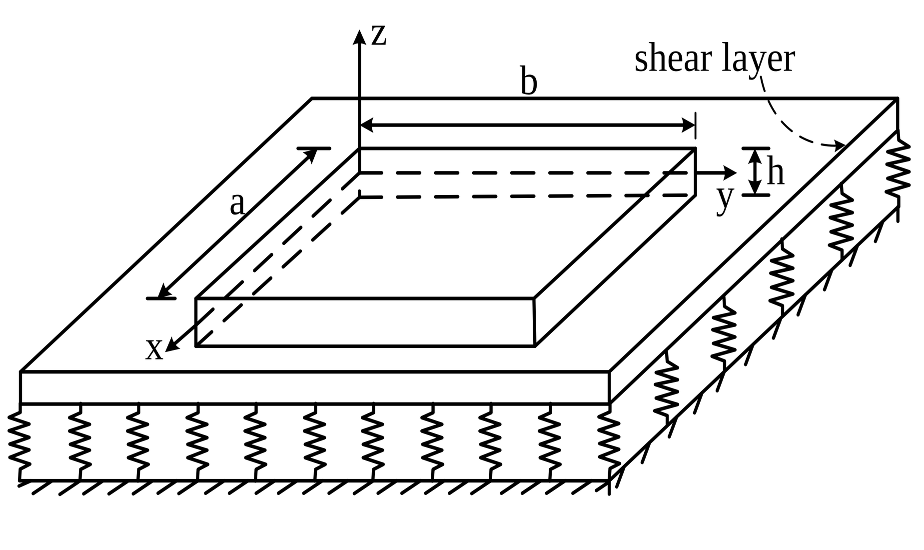

Figure 2. Geometry and coordinate system of FGM plate on elastic foundations.

Method to be used

The problem is posed in terms of stress and deflection functions. Governing equations account for the effects of geometrical nonlinearity, initial imperfection. Then these equations will be solved by Galerkin method and fourth-order Runge – Kutta method. Numerical result is given and compared with the one of other author.

Basic equations

In the present study, higher-order shear deformation plate theory is used to derive the governing equations and determine the nonlinear response of FGM thick plates.

Basic equations

The blast load is a short–term load and is generated by an explosion or by a shock-wave disturbance produced by an aircraft flying at supersonic speed, or by a supersonic projectile, rocket or missile operating in its vicinity. It can be expressed as [2]:

$$p(t) = 1.8 Ps_{max}\left(1 - \frac{t}{T_s}\right) exp\left(\frac{-bt}{T_s}\right),$$

where the "1.8" factor accounts for the effects of a hemispherical blast, Ps_{max} is the maximum (or peak) static over-pressure, b is the parameter controlling the rate of wave amplitude decay and T_s is the parameter characterizing the duration of the blast pulse.

Numerical results

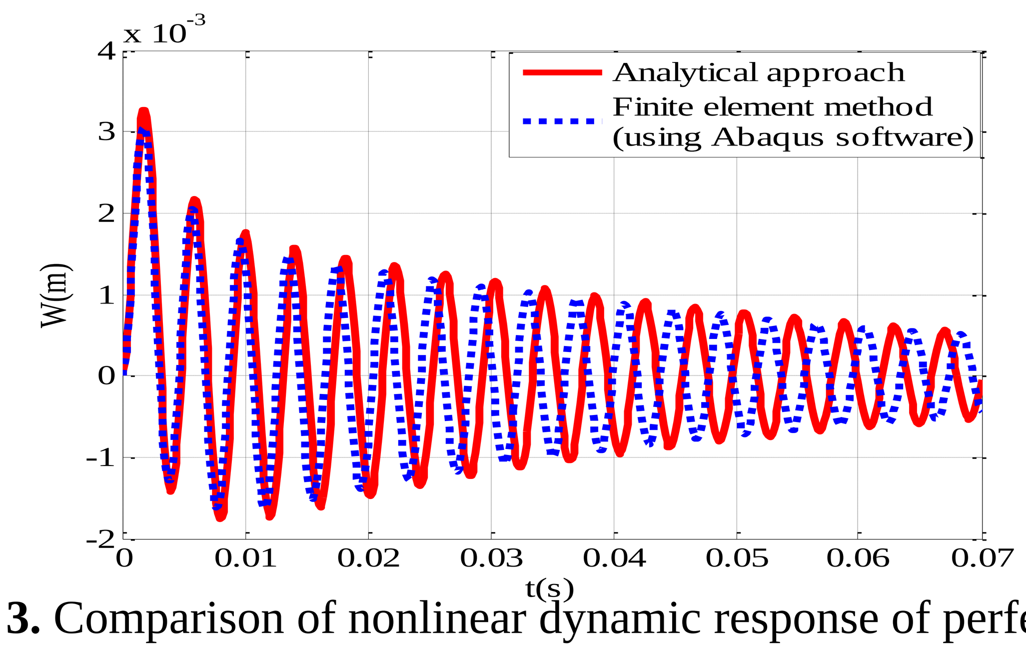

Figure 3. Comparison of nonlinear dynamic response of perfect FGM plate without elastic foundations subjected to blast load.

In order to verify the accuracy of the proposed formulation, Figure 3 shows the comparison of nonlinear dynamic responses of the FGM plate (*b/a=1, b/h=20*) without elastic foundations subjected to blast load in this paper based on the analytical approach and the results according to finite element method using Abaqus software. As can be seen, a good agreement is obtained in this comparison.

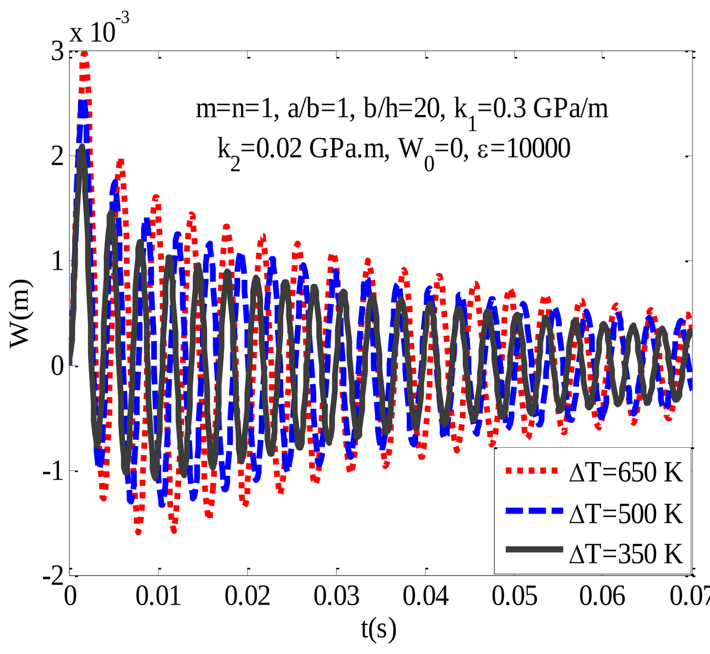

Figure 4. Effects of temperature increment on the nonlinear dynamic response of the simply supported FGM plate.

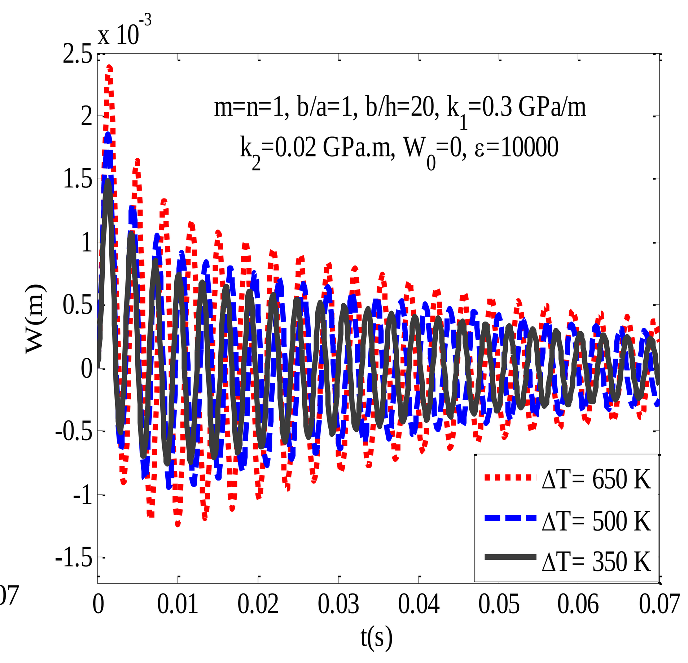

Figure 5. Effects of temperature increment on the nonlinear dynamic response of the FGM plate with two edges simply supported and two edges clamped.

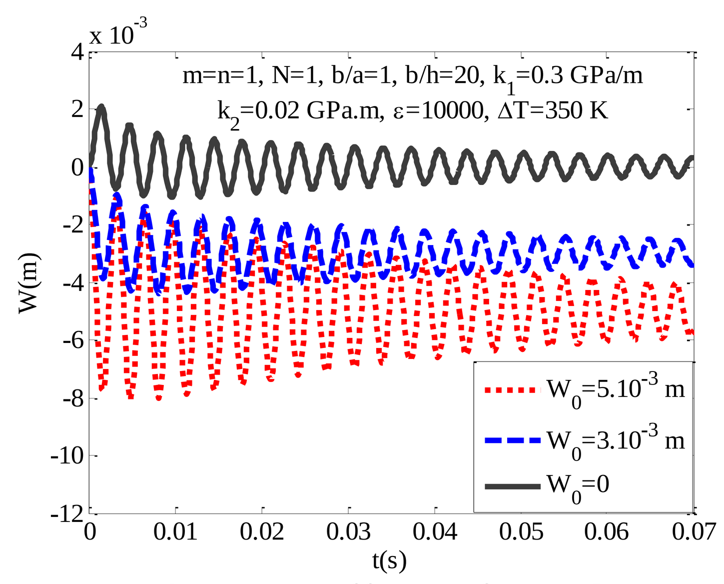

Figure 6. Effects of initial imperfection on the nonlinear dynamic response of the simply supported FGM plate.

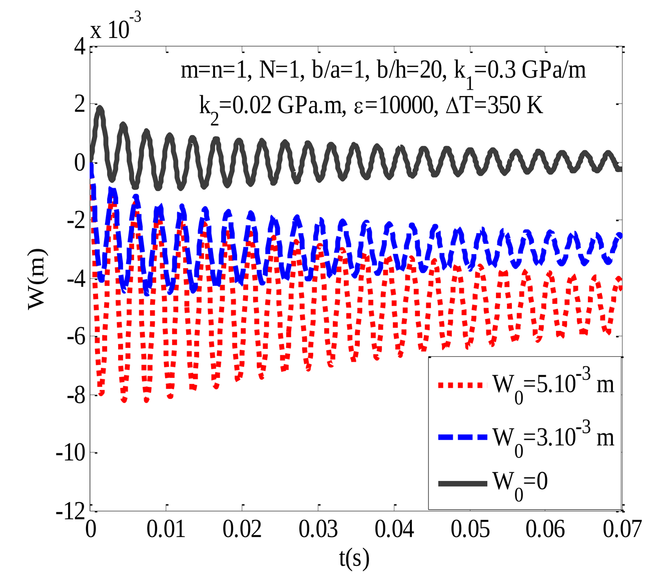

Figure 7. Effects of initial imperfection on the nonlinear dynamic response of the FGM plate with two edges simply supported and two edges clamped.

Figures 4 and 5 show the effects of temperature increment, on the nonlinear dynamic response of the simply supported FGM plate and the FGM plate with two edges simply supported and two edges clamped. As expected, an increase in temperature increment leads to a rise of the absolute value of the FGM plate amplitude. The results also show that the absolute value of the simply supported FGM plate is higher than the FGM plate with two edges simply supported and two edges clamped.

Numerical results

The influences of initial imperfection with amplitude W_0 on the nonlinear dynamic response of the simply supported FGM plate, and the FGM plate with two edges simply supported and two edges clamped are shown in Figures 6 and 7, respectively. As can be observed, the reduction of the amplitude of the initial imperfection leads to the decrease of the absolute value of the FGM plate amplitude fluctuation.

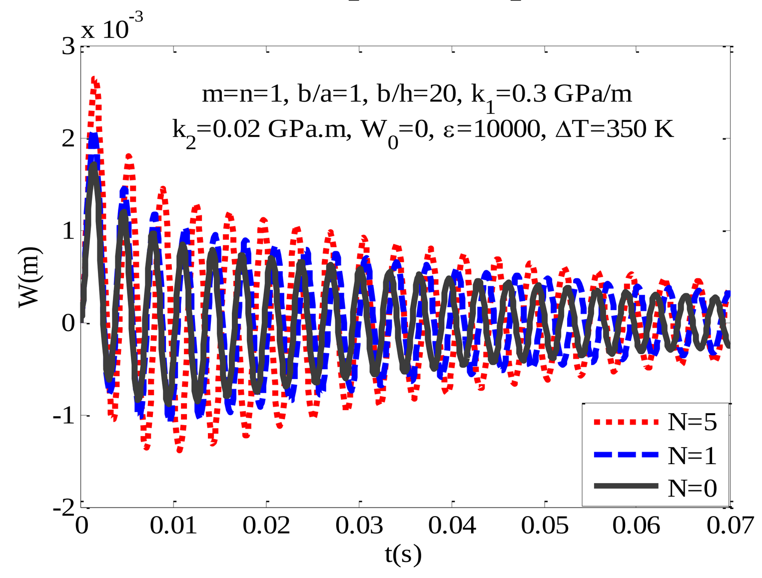

Figure 8. Effect of volume fraction index N on nonlinear dynamic response of the simply supported FGM plate.

Figures 8 shows the effect of volume fraction index, on the nonlinear dynamic response of the simply supported FGM plate and the FGM plate with two edges simply supported. As can be seen, the absolute value of nonlinear dynamic response amplitude of the FGM plate decreases when the power–law index decreases.

Conclusions

This study presents an analytical solution to investigate the nonlinear vibration and dynamic response of imperfect FGM thick plates resting on elastic foundations under blast and thermal loads using Reddy's higher–order shear deformation plate theory. Some special conclusions are obtained for the FGM plate subjected to blast and thermal loads:

- The temperature strongly influences the nonlinear dynamic response and vibration of FGM plates.
- The elastic foundations significantly enhance the load–carrying capacity of the FGM plates. In addition, the stiffness of the shear layer of the Pasternak foundation model has a more pronounced effect on the nonlinear dynamic stability of FGM plates than the modulus of the Winkler model.
- The geometrical dimensions affect considerably on the nonlinear dynamic response of the FGM plates.
- The initial imperfection increases the dynamic fluctuation amplitude of the FGM plates.

Publication


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