CHAPTER 7

CONCLUSION AND SCOPE FOR FUTURE WORK

7.1 Introduction

Functionally graded materials are characterized by gradual change in composition along the spatial coordinate resulting desired properties in the structure. They are composites of graded structures which can also be obtained in traditional and monolithic materials on the basis of a variety of microstructures formed during material processing. These materials do not have well distinguished boundaries or interfaces between their different regions as in the case of conventional composite materials. Because of this, such materials possess good chances of reducing mechanical and thermal stress concentration in many structural elements and thus advantageous compared to alloys and conventional composites, which can be developed for specific applications. The structure is not simply inhomogeneous, but this inhomogeneity is usually in one direction, typical for the entire volume of a material.

Functionally graded materials can be used at the interface to prevent the de-lamination. Moreover, these materials with ceramic-rich surface can be used to retain the required strength in high temperature applications. The FGMs find numerous applications in various sectors like aerospace, automobile and biomedical due to a number of exciting advantages. The behavior of the FGM in various circumstances as regards to main and parametric resonance need to be explored to cement its place as an advanced modern engineering material. In the present investigation an attempt is made to study the static and dynamic stability of FGM beams on different foundations and without foundation. The development of instruments for micro- and macrostructure design in functionally graded materials is a challenge for modern industry. On this path, mathematical modeling and numerical simulation are extremely helpful tools for design and investigation of functionally graded materials, which in fact, are typical representatives of knowledge-based multiphase materials.

In the present investigation, a mathematical model is developed to carry out the analysis on critical buckling, free vibration and parametric instability of functionally graded Timoshenko beam resting on variable elastic foundation. Hamilton's principle is used to derive the governing differential equation of the motion of the beam. The variation of material properties is considered as per sigmoid law along the thickness of the beam. Foundation stiffness varying linearly, parabolically and sinusoidally along the length of beam is considered for analysis. Finite element method is used for solution of the problem. The Floquet's theory is used for solution of parametric instability problem. The shape function for the element is formulated from the solution of static part of governing differential equation of motion of beam for better accuracy in result. The developed model is validated with bench mark results.

7.2 Summary of findings

The effect of various system parameters on dynamic stability behavior of FG Timoshenko beam has been studied using finite element method. A steel-alumina FGM beam with steel-rich bottom is considered for analysis. The important findings are outlined below:

7.2.1 Buckling of FGM beam on variable elastic foundation

A study on the critical buckling of functionally graded Timoshenko beam resting on variable elastic foundation is carried out and the observations are presented below:

- More the beam becoming slender lower is the buckling load of beam thereby justifying the Euler's theory of critical buckling.
- Sigmoid distribution of properties along the thickness of beam makes no effect on the static stability of the beam.
- The presence of foundation improves the static stability of the beam.
- There is a marked difference between the effect of interaction of foundation shear layer and the effect of foundation against transverse displacement of beam obtained from the investigation.
- The interaction of foundation shear layer ensures remarkable improvement in the static stability of the beam.
- The critical buckling load of sigmoid functionally graded Timoshenko beam increases with increase in foundation resistance against transverse displacement of beam.
- Increasing interaction of the shear layer of foundation causes significant improvement in the critical buckling load of beam.
- Variation of power index has no effect on the critical buckling load of sigmoid beam.

7.2.2 Free vibration of FGM beam on variable elastic foundation

The free vibration of functionally graded Timoshenko beam on variable elastic foundations is carried out and the important conclusions of the study is summarized below as:

- More the beam becoming slender higher is the frequencies of the beam.
- Increasing the value power index decreases the frequencies of beam thereby making it more prone to resonance.

- The presence of foundation increases the fundamental frequency of the beam.
- There is a marked difference between the effect of interaction of foundation shear layer and the effect of foundation against transverse displacement on free vibration of beam obtained from the investigation.
- The interaction of foundation shear layer ensures remarkable improvement in the fundamental frequency of the beam.
- Foundation resistance against transverse displacement of beam causes increase in its fundamental frequency.
- Effect of shear layer interaction of foundation with bottom surface of beam is more prominent as compared to that of foundation resistance against transverse displacement.
- Higher power index renders lower frequency of the sigmoid beam.

7.2.3 Parametric instability of FGM beam on variable elastic foundation

An investigation on the dynamic stability of functionally graded Timoshenko beam reveals that

- Increase in slenderness of beam makes it more prone to parametric instability.
- Increasing the value power index enhances the chance of parametric resonance.
- The presence of foundation improves the dynamic stability of the beam.
- The interaction of shear layer of the foundation with mating surface of the beam improves its dynamic stability more significantly as compared to interaction of the foundation with its transverse displacement.
- Increase in the value of foundation parameter reduces the chances of parametric resonance.
- The increase in steady part of the load remarkably enhances chances of parametric instability.
- The dynamic stability of sigmoid beam is enhanced as the foundation resistance against transverse displacement of beam.
- Foundation shear layer has more contribution in enhancing the dynamic stability of beam as compared to foundation resistance against transverse displacement.
- Higher foundation parameter renders the beam more prone to parametric resonance.

The parabolic elastic foundation gives better performance as far as the buckling, free vibration and dynamic stability of the sigmoid functionally graded Timoshenko beam is concerned.

7.3 Scope for future work

Present study explores some important aspects of the dynamic stability of functionally graded material beams. There are some other aspects of the beams which remain as open problems. The works that can be undertaken in future are presented here:

- In the present analysis the beams are modeled on the basis of first order shear deformation theory. Higher order shear deformation theory may be used to get precise results in case of thick beams.

- The specific resistance of elastic foundations in the process of interaction of shear layer with mating surface of the beam is assumed to be constant in the present study. But in practice this resistance may be variable along the length of the beams. This aspect of foundation may be taken up as a future work of research.

- Many rotating components like turbo machinery blades, blades rotors, propellers are subjected to external excitations and may fail due to dynamic instability. Turbine and pump blades are pre-twisted for functional purpose. These components can be modelled as rotating pre-twisted beams and can be considered as a future work for its analysis of parametric instability.

- Many components in nuclear power plant are used in high temperature environment and act as beams. The static and dynamic behavior of those components can be investigated as a future work. Moreover, the tapered beams can be considered for their parametric instability analysis.

- The dynamic behavior of FGM beams can be undertaken for analysis using higher order terms for strains to obtain accurate results.

- Sometimes the loading may be such that the structural components are stressed beyond elastic limit. Then the material behaves nonlinearly. In present study the beam materials are considered to be stressed within elastic limit. The study of dynamic stability of FGM beams considering material nonlinearity may be undertaken as a future work of research. Moreover, higher order stretching strain may be considered to include geometric nonlinearity.

- The results obtained need to be verified with experimental results. Therefore experimental analysis of dynamic stability of functionally graded material beams may be taken as a future work in order to validate the used computational method and obtained theoretical results.