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Vibration Analysis of Functionally Graded Piezoelectric Actuators

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Preface

This book has evolved from the passionate desire of the author in using the modern concepts of piezoelectric materials for the design improvement of sensors and actuators. In this connection, the author took up his doctoral studies whose findings have resulted in this book. The initial focus here is on the basic theory, application, and drawbacks of piezoelectric materials. The types of deformation produced in piezoelectric materials due to different piezoelectric effects are reported briefly. Further, the concept of functionally graded material (FGM) used in the design of piezoelectric materials with graded properties is described. The engineering applications of functionally graded piezoelectric materials (FGPMs) are summarized thereafter. In the latter sections, the modal analysis of FGPM actuators is provided. Two types of actuator geometries are taken into consideration—first is beam, and the second is annular plate. The effects of various parameters on the natural frequencies are given in detail. A detailed account of a new numerical technique called the generalized differential quadrature (GDQ), adopted in this book, is also provided. An extension of this technique for the analysis of FGPM structures becomes an important endeavor. The overall focus is on the vibration analysis of FGPM actuators excited under the shear effect using the GDQ method.

This book is organized into seven chapters. Chapter 1 gives an overview of the book. Chapter 2 provides fundamentals of piezo-ceramics along with the associated constitutive equations. The applications and limitations of piezoelectric materials are also discussed. Chapter 3 provides a basic introduction to FGM, and the need of functionally graded piezoelectric material (FGPM) with the importance of shear effect. The applications of functionally graded piezoelectric materials explored in engineering are described in detail. Chapter 4 describes the differential quadrature (DQ) method adopted in this book. The advantages of the DQ method over other numerical methods are also discussed. The basic formulation of this method is given in detail. Chapter 5 presents the free vibration analysis of FGPM beam excited under the shear effect. The equations of motion are derived using the Hamilton principle. The generalized differential quadrature (GDQ) method is used to obtain the natural frequency of the beam. The results obtained by the GDQ method are compared with the results obtained from the finite element software

COMSOL. An exact analytical solution is obtained for the vibration analysis of FGPM beam excited under the shear effect. The effects of geometric parameters and volume fraction index on natural frequencies are reported. Chapter 6 presents the free vibration analysis of an FGPM annular plate excited under the shear effect. The GDQ method is once again used to obtain the natural frequency of the plate. The results obtained by the GDQ method are compared with the results obtained for a reduced case initially, and then, for FGPM annular plate, they are compared with the results obtained from COMSOL. The effects of geometric parameters and volume fraction index on natural frequencies are also investigated. Finally, Chap. 7 summarizes the major findings and important conclusions.

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