Preface

The author is pleased to present Buckling and Post-buckling of Beams, Plates, and Shells. This book serves a wide range of readers, in particular, graduate students, PhD candidates, professors, scientists, researchers in various industrial and government institutes, and engineers. Thus, the book should be considered not only as a graduate textbook, but also as a reference book to those working or interested in areas of structural stability under mechanical and/or thermal loads.

The book is self-contained, so that the reader should not need to consult other sources while studying the topic. The necessary mathematical concepts and numerical methods are presented in the book and the reader may easily follow the subjects based on these basic tools. It is expected, however, that the reader should have some basic knowledge in the classical mechanics and theory of elasticity.

In the context of continuum mechanics, a structural element is either modelled by the elasticity theory or the flexural theory, where the latter theory is employed when the structure is thin and consequently lumped in the thickness direction. When such element is under loads producing compressive stress, the problem of stability becomes important. The most general type of elements falling into this category are beams, plates, and shells. The beam elements are either straight or curved, plates are either rectangular or circular, and the shells are cylindrical, spherical, and conical. This book covers the stability of all these structures. The applied loads may be either mechanical or thermal, where this book covers the stability of all the above structures under both mechanical and thermal loads. The structural element may be assumed to be made of homogeneous/isotropic material, or the functionally graded materials. Both types of material are discussed in this book. The structure may experience bifurcation phenomenon, snap through, or it may follow the post-buckling path, where these types of behavior are discussed in the book. The collection of materials in this book is therefore the most comprehensive, as of today, of the subject of structural stability. It covers all areas of structural type, loading type, and the material type.

The book contains 8 chapters, where the chapters cover the stability of all major areas of the flexural theory.

Chapter 1 gives a brief discussion on the concept of stability. A structure under loads that produce compressive stresses may loose its stability, provided that the compressive stresses bring the structure into a certain condition. The structural instability may be in form of bifurcation (buckling), snap through, and finite disturbance buckling which occurs when a structure reaches the bifurcation point and then a sharp drop of the applied load occurs before reaching to a stable post-buckling path. Proper examples are given in this chapter to familiar the readers with the concept of stability.

Chapter 2 deals with the stability of straight beams. The basic governing equations, such as the kinematical relations, the constitutive law, the equations of motion, and the stability of straight beams are first discussed and derived. Then, the stability of beams under the thermal and thermo-electrical loads are presented. Buckling and post-buckling of the piezo-FGM beams and FGMP beams are discussed in detail and the thermally post-buckling of beams on elastic foundation is presented in the following. The chapter concludes with the dynamic buckling of the FGM beams under thermal loads. By setting the proper value for the power law index, the results are reduced to those of the isotropic/homogeneous beams.

The third chapter presents buckling and post-buckling of the curved beams and rings. The basic governing equations are given and derived at the beginning of the chapter, and then the stability of arcs under external uniform pressure and external concentrated force are presented. Arcs under thermal force and axial force are discussed and closed form solutions are given for these types of loads. The buckling and post-buckling of rings under external pressure and thermal loads, employing the numerical method based on the general differential quadrature, are presented at the end of chapter. The material of the arcs and ring is assumed to be functionally graded, where by setting the proper value for the power law index, the results are reduced to those of the isotropic/homogeneous arcs.

Chapter 4 contains the stability of rectangular plates, which are frequently used in the engineering design problems. The basic governing equations, such as the kinematical relations, the constitutive laws, the equilibrium, and stability equations are presented and derived in the chapter and then the existence of bifurcation of rectangular plates is discussed. It is proved that the bifurcation path of the FGM rectangular plates under thermal loads depends upon the type of boundary conditions. Buckling of plates under thermal and in-plane compressive forces are discussed, and the thermal stability of the piezo-FGM beams and the beams on elastic foundation are given in the following. Closed form solutions are derive for each section. The effect of geometric imperfection on the stability of rectangular plates is then presented. The material of the plate is assumed to be functionally graded, where by setting the proper value for the power law index, the results are reduced to those of the isotropic/homogeneous rectangular plates.

The stability of circular plates is subject of the fifth chapter. The basic general governing equations are initially derived and presented. Thermal buckling of circular and annular plates under different plate theories are presented and the stability of circular plates on elastic foundation is discussed in detail, where closed form solutions are derived for the buckling loads. Thermal buckling and post-buckling of rotating circular plates and thermal buckling and post-buckling of geometrically imperfect circular plates are then presented at the end of chapter. Closed form solutions are derived whenever possible and the material of the plate is assumed to be functionally graded, where by setting the proper value for the power law index, the results are reduced to those of the isotropic/homogeneous plates.

Cylindrical shells, as a widely used element in many structural systems, is treated in the six chapter. The basic governing equations, including the kinematic and constitutive laws, the equilibrium, and the stability equations are discussed and derived. Then, the mechanical and thermal buckling loads of cylindrical shells are calculated and presented in closed form solutions. Thermal buckling loads for the piezo-FGM cylindrical shells for different types of temperature distributions which are mostly encountered in the engineering design problems are derived in closed form solutions. Dynamic thermal buckling and post-buckling of the piezo-FGM cylindrical shells is treated in the next section and the chapter concludes with the discussion of stability of cylindrical shells on elastic foundation.

Chapter 7 brings the stability problems of spherical shells as one of the naturally and inheritably stable structural element. Similar to the other chapters, it starts with the presentation of the basic governing equations. For this special type of shells, the behavior and nature of deep and shallow spherical shells are quite different. Thus, both theories of the deep and shallow spherical shells are derived and presented at the beginning of the chapter. Stability of isotropic/homogeneous spherical shells under the mechanical and thermal loads are discussed and closed form solutions are derived and the results are extended to those of the shallow and deep FGM shells. The effect of geometrically imperfection is discussed and the stability of piezo-FGM shells is derived and the effects of piezo-control on thermal buckling of the shallow and deep shells are shown in the next section. Buckling and post-buckling of the shallow piezo-FGM spherical shells concludes the chapter.

The stability of conical shells under the mechanical and thermal loading conditions are the subject of last chapter. The basic governing equations are derived and given at the beginning of the chapter. Buckling loads associated with the mechanical and thermal loads are discussed and the buckling of piezo-FGM conical shells under thermal loads is discussed at the end of chapter.

At the end of all chapters there are a number of problems for the students to solve. Also, at the end of each chapter, there is a list of relevant references.

The book is prepared over some 44 years of teaching the graduate courses and research of the graduate students. During this long period of time, the results of class work assignments and student research are carefully gathered and put into this volume of work. The author takes this opportunity to thank all his students who made possible to provide this piece of work.

The author's special thank is for his previous PhD student, Dr. Y. Kiani, now an assistant professor at Shahrekord University. His contribution to develop this work is outstanding. Many chapters of this book is prepared with detail comments and help of Dr. Kiani.

Tehran, Iran M. Reza Eslami
February 2017

Springer

http://www.springer.com/978-3-319-62367-2

Buckling and Postbuckling of Beams, Plates, and Shells
Eslami, M.R.
2018, XVII, 588 p. 249 illus., 29 illus. in color.,
Hardcover
ISBN: 978-3-319-62367-2