

Lecture 9: Stability of Elastic Structures

In lecture 8 we have formulated the condition of static equilibrium of bodies and structures by studying a small change (variation) of the total potential energy. The system was said to be in equilibrium if the first variation of the total potential energy vanishes. The analysis did not say anything about the stability of equilibrium. The present lecture will give an answer to that question by looking more carefully what is happening in the vicinity of the equilibrium state.

To illustrate the concept, consider a rigid body (a ball) sitting in an axisymmetric paraboloid, shown in Fig. (9.1).

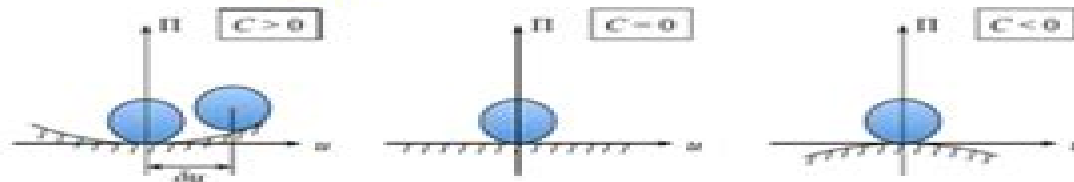


Figure 9.1: Illustration of stable, neutral and unstable equilibrium.

In the case of a rigid body the total potential energy is just the potential energy

$$\Pi = mgh = Cu^2 \quad (9.1)$$

where u is the horizontal displacement of the ball from the resting position. Let's calculate the first and second variation of the function $\Pi(u)$

$$\delta\Pi = \frac{\partial\Pi}{\partial u}\delta u = 2Cu\delta u \quad (9.2)$$

$$\delta^2\Pi = \delta(\delta\Pi) = 2C\delta u\delta u \quad (9.3)$$

At the origin of the coordinate system $u = 0$, so the first variation of Π is zero no matter what the sign of the coefficient C is. In the expression for the second variation, the product $\delta u\delta u = (\delta u)^2$ is always non-negative. Therefore, the sign of the second variation depends on the sign of the coefficient C . From Fig. 9.1 we infer that $C > 0$ corresponds to a *stable configuration*. The ball displaced by a small amount δu will return to the original position. By contrast, for $C < 0$, the ball, when displaced by a tiny amount δu , will roll down and disappear. We call this an *unstable behavior*. The case $C = 0$ corresponds to the *neutral equilibrium*.

One can formalize the above consideration to the elastic body (structure), where the total potential energy is a function of a scalar parameter, such as a displacement amplitude u . The function $\Pi(u)$ can be expanded in Taylor series around the reference point u_0

$$\Pi(u) = \Pi(u_0) + \left.\frac{d\Pi}{du}\right|_{u=u_0}(u - u_0) + \frac{1}{2}\left.\frac{d^2\Pi}{du^2}\right|_{u=u_0}(u - u_0)^2 + \dots \quad (9.4)$$

Stability Of Elastic Structures

Donald E. Carlson, R.T. Shield



Stability Of Elastic Structures:

Stability of Elastic Structures N.A. Alfutov, 2013-04-17 The subject discussed in this book is the stability of thin walled elastic systems under static loads The presentation of these problems is based on modern approaches to elastic stability theory Special attention is paid to the formulation of elastic stability criteria to the statement of column plate and shell stability problems to the derivation of basic relationships and to a discussion of the boundaries of the application of analytic relationships The author has tried to avoid arcane nonstandard problems and elaborate and unexpected solutions which bring real pleasure to connoisseurs but confuse students and cause bewilderment to some practical engineers The author has an apprehension that problems which though interesting are limited in application can divert the reader's attention from the more prosaic but no less sophisticated general problems of stability theory *An Introduction to the Elastic Stability of Structures* George J. Simitses, 1976 Stability of Elastic Structures H.H.E. Leipholtz, 2014-09-01 *Stability of Structures* Z. P. Bažant, Luigi Cedolin, 2010 A crucial element of structural and continuum mechanics stability theory has limitless applications in civil mechanical aerospace naval and nuclear engineering This text of unparalleled scope presents a comprehensive exposition of the principles and applications of stability analysis It has been proven as a text for introductory courses and various advanced courses for graduate students It is also prized as an exhaustive reference for engineers and researchers The authors focus on understanding of the basic principles rather than excessive detailed solutions and their treatment of each subject proceed from simple examples to general concepts and rigorous formulations All the results are derived using as simple mathematics as possible Numerous examples are given and 700 exercise problems help in attaining a firm grasp of this central aspect of solid mechanics The book is an unabridged republication of the 1991 edition by Oxford University Press and the 2003 edition by Dover updated with 18 pages of end notes *Stability of Elastic Structures* H.H.E. Leipholtz, 2014-05-04 **Theory of Stability of Continuous Elastic Structures** Mario Como, Antonio Grimaldi, 1995-06-29 Theory of Stability of Continuous Elastic Structures presents an applied mathematical treatment of the stability of civil engineering structures The book's modern and rigorous approach makes it especially useful as a text in advanced engineering courses and an invaluable reference for engineers W. T. Koiter's Elastic Stability of Solids and Structures Arnold M. A. van der Heijden, 2008-08-11 This book deals with the elastic stability of solids and structures It begins with fundamental aspects of stability relating the basic notions of dynamic stability to more traditional quasi static approaches The book is concerned not only with buckling or linear instability but most importantly with nonlinear post buckling behavior and imperfection sensitivity After laying out the general theory Koiter applies the theory to a number of applications with a chapter devoted to each These include a variety of beam plate and shell structural problems and some basic continuum elasticity problems Koiter's classic results on the nonlinear buckling and imperfection sensitivity of cylindrical and spherical shells are included The treatments of both the fundamental aspects and the applications are completely self contained This

book was recorded as a detailed set of notes by Arnold van der Heijden from W T Koiter's last set of lectures on stability theory at TU Delft

Theory of Elastic Stability Stephen P. Timoshenko, James M. Gere, 2009-06-22 The best available guide to the elastic stability of large structures this volume was co authored by world renowned authorities on engineering mechanics It ranges from theoretical explanations of 2 and 3 D stress and strain to practical applications such as torsion bending thermal stress and wave propagation through solids Equally valuable as text or reference 1961 edition

Dynamic Stability of Elastic Structures Subjected to Periodic Impulsive Loading Dusan Krajcinovic, 1968

Stability, Bifurcation, and Postcritical Behaviour of Elastic Structures Marcello Pignataro, N. Rizzi, A. Luongo, 1991-01-01 A comprehensive and systematic analysis of elastic structural stability is presented in this volume Traditional engineering buckling concepts are discussed in the framework of the Liapunov theory of stability by giving an extensive review of the Koiter approach The perturbation method for both nonlinear algebraic and differential equations is discussed and adopted as the main tool for postbuckling analysis The formulation of the buckling problem for the most common engineering structures rods and frames plates shells and thin walled beams is performed and the critical load evaluated for problems of interest In many cases the postbuckling analysis up to the second order is presented The use of the Ritz Galerkin and of the finite element methods is examined as a tool for approximate bifurcation analysis The volume will provide an up to date introduction for non specialists in elastic stability theory and methods and is intended for graduate and post graduate students and researchers interested in nonlinear structural analysis problems

A Translation of the Stability of Elastic Equilibrium Warner Tjardus Koiter, 1970 A general theory of elastic stability is presented In contrast to previous works in the field the present analysis is augmented by an investigation of the behavior of the buckled structure in the immediate neighborhood of the bifurcation point This investigation explains why some structures e g a flat plate supported along its edges and subjected to thrust in its plane are capable of carrying loads considerably above the buckling load while other structures e g an axially loaded cylindrical shell collapse at loads far below the theoretical critical load

Stability of Elastic Structures by Use of Catastrophe Theory Zsolt Gáspár, 1988

Structural Stability of Steel Theodore V. Galambos, Andrea E. Surovek, 2008-04-18 Practical guide to structural stability theory for the design of safe steel structures Not only does this book provide readers with a solid foundation in structural stability theory it also offers them a practical working knowledge of how this theory translates into design specifications for safe steel structures Structural Stability of Steel features detailed discussions of the elastic and inelastic stability of steel columns beams beam columns and frames alongside numerous worked examples For each type of structural member or system the authors set forth recommended design rules with clear explanations of how they were derived Following an introduction to the principles of stability theory the book covers Stability of axially loaded planar elastic systems Tangent modulus reduced modulus and maximum strength theories Elastic and inelastic stability limits of planar beam columns Elastic and inelastic instability of planar frames Out of plane lateral torsional

buckling of beams columns and beam columns The final two chapters focus on the application of stability theory to the practical design of steel structures with special emphasis on examples based on the 2005 Specification for Structural Steel Buildings of the American Institute of Steel Construction Problem sets at the end of each chapter enable readers to put their newfound knowledge into practice by solving actual instability problems With its clear logical progression from theory to design implementation this book is an ideal textbook for upper level undergraduates and graduate students in structural engineering Practicing engineers should also turn to this book for expert assistance in investigating and solving a myriad of stability problems

Stability of Structures Chai H Yoo, Sung Lee, 2011-05-12 The current trend of building more streamlined structures has made stability analysis a subject of extreme importance It is mostly a safety issue because Stability loss could result in an unimaginable catastrophe Written by two authors with a combined 80 years of professional and academic experience the objective of *Stability of Structures Principles and Applications* is to provide engineers and architects with a firm grasp of the fundamentals and principles that are essential to performing effective stability analysis Concise and readable this guide presents stability analysis within the context of elementary nonlinear flexural analysis providing a strong foundation for incorporating theory into everyday practice The first chapter introduces the buckling of columns It begins with the linear elastic theory and proceeds to include the effects of large deformations and inelastic behavior In Chapter 2 various approximate methods are illustrated along with the fundamentals of energy methods The chapter concludes by introducing several special topics some advanced that are useful in understanding the physical resistance mechanisms and consistent and rigorous mathematical analysis Chapters 3 and 4 cover buckling of beam columns Chapter 5 presents torsion in structures in some detail which is one of the least well understood subjects in the entire spectrum of structural mechanics Strictly speaking torsion itself does not belong to a topic in structural stability but needs to be covered to some extent for a better understanding of buckling accompanied with torsional behavior Chapters 6 and 7 consider stability of framed structures in conjunction with torsional behavior of structures Chapters 8 to 10 consider buckling of plate elements cylindrical shells and general shells Although the book is primarily devoted to analysis rudimentary design aspects are discussed Balanced presentation for both theory and practice Well blended contents covering elementary to advanced topics Detailed presentation of the development

Elastic Stability of Structural Elements NGR Iyengar, 2007-02 *Elastic Stability of Structural Elements* is designed for a one semester course for undergraduate graduate programmes in aerospace civil mechanical engineering and applied mechanics This well organized text discusses applications of both classical and

Analysis of the Static and Dynamic Stability of Elastic Structures Using the Finite Element Method Mohamed Hassan Gadallah, 1990

Structural Dynamics - Vol 1 Proceedings Editors, 2022-03-02 First published in 1991 This volume contains the proceedings of the first European Conference on Structural Dynamics Eurodyne 90 held at the Ruhr University Bochum FRG in June 1990 Volume one 169 9 covers impact dynamic stability soil dynamics

system identification earthquake engineering earthquake engineering R C structures and earthquake engineering for steel structures

Buckling of Structures B. Budiansky, 2013-03-08 This volume contains the written texts of the papers presented at a Symposium on Buckling of Structures held at Harvard University in June 1974 This symposium one of several on various topics sponsored annually by the International Union of Theoretical and Applied Mechanics IUTAM was organized by a Scientific Committee consisting of B Budiansky Chairman A H Chilver W T Koiter and A S Vol mir Participation was by invitation of the Scientific Committee and specific lecturers were invited to speak in the areas of experimental research buckling and post buckling calculations post buckling mode interaction plasticity and creep effects dynamic buckling stochastic problems and design A total of 29 lectures were delivered including a general opening lecture by Professor Koiter and there were 93 registered participants from 16 different countries Financial support for the symposium was provided by IUTAM in the form of partial travel support for a number of participants and also by the National Science Foundation the National Aeronautics and Space Administration and the Air Force Office of Scientific Research for additional travel support and administrative expenses Meeting facilities and services were efficiently provided by the Science Center of Harvard University and administrative support was generously provided by the Division of Engineering and Applied Physics of Harvard University The scientific chairman enjoyed the invaluable assistance of his colleagues Professors J W Hutchinson and J L

Scientific and Technical Aerospace Reports, 1990

Proceedings of the IUTAM Symposium on Finite Elasticity Donald E. Carlson, R.T. Shield, 2012-12-06 Although finite elasticity theory has its roots in the nineteenth century its development was largely neglected until the end of the Second World War Since then it has attracted a substantial amount of attention and considerable progress has been made both in our understanding of the basis of the subject and in its applications It occurred to me about three years ago that finite elasticity had reached a level of development at which an international symposium on the subject was overdue Accordingly with strong encouragement from Professor P M Naghdi and numerous other colleagues I submitted to the International Union of Theoretical and Applied Mechanics a proposal for their support of such a symposium to be held at Lehigh University during the period August 10 15 1980 The proposal received enthusiastic support from the International Union and an international scientific committee under my chairmanship consisting of Professors G Fichera Rome W T Koiter Delft L I Sedov Moscow and A J M Spencer Nottingham was assigned responsibility for the scientific program In constructing the program we aimed at as broad a coverage as possible of the many aspects of the subject on which significant progress is currently being made These range from theoretical studies of existence and uniqueness of solutions of the governing equations of finite elasticity theory to experimental studies of its application to such problems as tear resistance and friction in vulcanized rubbers

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