

SOLUTION OF SOLID MECHANIC EQUILIBRIUM PROBLEMS BY POWER SERIES

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ABSTRACT

The paper presents the application of power series to the numerical solution of equilibrium problems in elasticity. Complete bases of power series that satisfy the differential equations are developed, first for unidimensional problems like the equilibrium of a beam on elastic foundation, second for the harmonic differential equation in two dimensions, with application to the Saint-Venant's torsion problem and, finally, for the biharmonic equation, which can be applied to plane elasticity problems as well as to the plate-bending problem. In the case of unidimensional problems the solution is exact, because the number of boundary conditions is equal to the number of parameters involved in the series expansion, whereas in the two-dimensional problems the solution satisfies exactly the differential equation but only approximately the boundary conditions. The approximation of the solution will depend on the number of points selected at the boundary. The method presented here can also be used for developing high-order finite elements of any number of nodes and boundary shapes using complete polynomial expansions that satisfy the differential equation. Selected practical applications are shown.

Keywords: *Beam on elastic foundation, biharmonic equation, boundary conditions, equilibrium problems, finite elements, harmonic equation, plane elasticity, plate-bending problem, power series, Saint-Venant's torsion problem*

1 INTRODUCTION

Equilibrium problems are defined by Crandall [1] as

$$L_{2\mu}(\psi) = 0 \quad \text{in } D \quad (1)$$

$$\text{with } B_{2\mu-1}^c(\psi) = 0, \quad c = 1, \dots, \mu \quad \text{at the boundary,} \quad (2)$$

where $L_{2\mu}(\psi)$ is a partial differential operator of order 2μ , containing only even partial derivatives, and $B_{2\mu-1}^c(\psi)$ are μ differential operators of order up to $2\mu - 1$.

A solution of some equilibrium problems is presented in this paper consisting of power series ψ that satisfy identically the homogeneous differential eqn (1) and approximately the boundary conditions in eqn (2). The collocation technique is used at the boundary in such a way that the boundary conditions are satisfied at selected points.

The approximation to the exact solution will depend on the degree n of the elements of the power series used.

2 POWER SERIES SOLUTION OF A DIFFERENTIAL EQUATION

Let ψ be a complete power series of degree n . Let also $\psi_i, i = 0, \dots, n$ be some incomplete power series of degree $\leq n$, such that

$$\psi = \sum_{i=0}^n \lambda_i \psi_i \quad (3)$$

If all series ψ_i satisfy a given differential equation, then ψ will also satisfy the said equation. Therefore, if the series ψ_i are mutually independent and their sum forms a complete polynomial expression of degree n , then the elements ψ_i can be considered as a base for the

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Hammond Morris,1897 Magnetic Fields of Force Hermann Ebert,1897 Practical Plane and Solid Geometry I.
Ulm,Olivier Coussy,2003 Intended for a first course in continuum mechanics and constitutive modeling at the senior undergraduate and the introductory graduate level the focus of this book is on a unified mechanistic approach that uses energy concepts for modeling a large range of engineering material behavior In the presentation 1D Think models lead to the development of various fundamentals of continuum mechanics such as deformation and strain momentum balance stress and stress states thermoelasticity and elasticity bounds plasticity and yield design Along these lines the bases for a common language among core disciplines in engineering sciences are developed in a mathematical yet eloquent manner The textbook evolved from lecture notes of a one semester course developed by the authors at the Massachusetts Institute of Technology as well as in France Germany and Brazil Key Features of the Book Parts I and II introduce the two pillars of continuum mechanics strain and stresses with a focus on geometrical and physical interpretation starting with the finite deformation theory Part III is dedicated to non dissipative material behavior with a focus on thermoelasticity and variational methods in elasticity as well as to its application in heterogeneous material systems Part IV starts with 1D plasticity introducing ideal plasticity hardening plasticity and associated energy transformations It is within the energy approach that the 1D Think models are extended to 3D introducing the notion of associated and non associated plasticity Finally the concept of plastic collapse is introduced leading to the development of the upper and lower bound theorems of limit analysis which form the basis of modern yield design for engineering structures and material systems The mathematical developments in each chapter are illustrated through a set of accompanying blackboard exercises of the subject matter a Training Set for recitation followed by a broad spectrum of worked exercises suitable for homework classroom assignments quizzes or take home examinations

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