

## 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

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

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

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

A solution of some equilibrium problems is presented in this paper consisting of power series  $\psi$  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  $\psi$  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  $\psi_i$  satisfy a given differential equation, then  $\psi$  will also satisfy the said equation. Therefore, if the series  $\psi_i$  are mutually independent and their sum forms a complete polynomial expression of degree  $n$ , then the elements  $\psi_i$  can be considered as a base for the

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