International Journal of Non-Linear Mechanics 46 (2011) 834–840

Contents lists available at ScienceDirect

International Journal of Non-Linear Mechanics

journal homepage: www.elsevier.com/locate/nlm

Non-linear analysis of structures using two-point method

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A R T I C L E I N F O

Article history:
Received 25 May 2010
Received in revised form
2 January 2011
Accepted 20 March 2011
Available online 30 March 2011

Keywords:
Non-linear analysis
Space trusses
Newton–Raphson method
Two-point method

A B S T R A C T

Non-linear algebraic equations must be solved by an iterative method, the non-linear equations being linearized by evaluating the non-linear terms with the known solution from the preceding iteration. The Newton–Raphson method, which is based on the Taylor series expansion and uses the tangent stiffness matrix, has been extensively used to solve non-linear problems. In this paper, a new Newton–Raphson algorithm is developed for analyses involving non-linear behavior. Our method, here named as a two-point method, is constructed as a predictor–corrector one, most frequently taking Newton's method in the first iteration. It should be noted that our concern in this research ignores the problem of passing limit points. The presented method incorporates the known information at each stage of the loading process to determine the subsequent unknown variables. Compared with the classic Newton–Raphson algorithm, it offers a strategy that can be deployed to reduce both the number of the iterations and the computing time involved in non-linear analysis of structures.

1. Introduction

The various types of space structures differ in their behavior under load, and so a different method of analysis must be used for each type. Space truss systems are one of the most popular forms of space frames. Nowadays, they provide an easy and economic method of roofing large areas. The lighter and more efficient these structural systems become, the more likely they are to have non-linear stability problems. Space trusses may suddenly collapse if their failure modes are not realized. These structures may be designed to maintain their integrity even after an initial inelastic failure: a progressive failure that redistributes loads, normally causing other members to fail until the total structure becomes unstable [1].

For accurate modeling of a progressive failure, the analysis method that can create a load vs. displacement response during instability is required. Methods that have been used involved creating finite element models that update their stiffness according to non-linear geometric response [1].

The analysis of geometrically non-linear structural problems has been a subject of interest for over three decades. The solution of a non-linear problem reduces to that of tracing a non-linear load–displacement path by solving a system of non-linear algebraic or differential equations. An abundance of procedures exists for attacking the non-linear equilibrium equations. These include the Newton–Raphson method, the modified Newton–Raphson procedure, the perturbation method [2], the self-correcting incremental procedure [2,3], the incremental stiffness procedure [2], the initial value approach [4] and many more.

The non-linear behavior of trusses has been investigated by other researchers using various analytical techniques. Saffari et al. [5] used a modified normal flow algorithm to study non-linear behavior in truss structures, Tabatabaei et al. [6] applied the Newton–Raphson iterative algorithm along the flow path normal in non-linear static analysis. Papadrakakis and Gantes [7] presented some procedures to truncate the Newton–Raphson method. Pina et al. [8] presented a formal solution of quasi-static for solving non-linear problems. Greco et al. [9] proposed a new geometric non-linear formulation for space truss analysis that uses nodal positions rather than nodal displacements. Tabatabaei and Saffari [10] studied large strain analysis of planar frames using normal flow algorithm. Thai and Kim [11] presented the large-deflection inelastic analysis of space truss structures including both geometric and material non-linearities. Papadrakakis [12] employed the dynamic relaxation scheme for the second-order and large deflection analysis of trusses. Bellini [13] suggested a new mathematical model to study snap-buckling problem. Kassimali and Parsi-Feraidoonian [14] studied the non-linear behavior of prestressed cable trusses. Inelastic post-buckling analysis of truss structures by the dynamic relaxation method investigated by Ramesh and Krishnamoorthy [15].

Of all numerical computation, systems of non-linear equations are perhaps the most difficult to solve. There are several approaches for finding solutions. For a non-linear problem, the solution of the non-linear set of equations normally takes up most

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doi:10.1016/j.ijnonlinmec.2011.03.008