VECTOR METHODS OF SOLVING NONLINEAR EQUATIONS OF MOTION

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SUMMARY

In transient structural analyses, methods which generate the solution by processing vectors, rather than matrices, provide attractive computer solution algorithms. This paper, by examining the stability, accuracy, and efficiency of a variety of explicit vector methods evolves a new numerical integration procedure. The process is suited to transient analyses of finite element systems for linear or step-by-step nonlinear analyses.

The general approach is to examine characteristics of a Taylor series expansion of the solution. Thereby, the relation between methods with different orders of error and their numerical characteristics can be drawn in a consistent perspective. The paper examines stability from an analytical viewpoint and accuracy and efficiency from experimental data.

The growth of the stability boundary is determined as a function of the shortest resonant period and the order of the integration operator. The evaluation demonstrates the generally monotonic enlargement of the stability region and the increase in complexity of this boundary. These data define the maximum number of terms that can be used in the series as a function of the computer precision.

Accuracy contours are established by distilling data from integrations of equations of linear, discontinuous rheonomic, and nonlinear systems. Superimposing these contours on representations of the stability boundaries exhibits the problem classes in which stability or accuracy dictates choice of an acceptable time step. It is shown that stability can always be guaranteed when accuracy requirements are stringent.

Calculation counts of analyses for studies demonstrate the advantage of using two distinct solution strategies: one for linear systems and the other for nonlinear.

The strategy for linear systems centers around adaptive choice of the solution algorithm to suit the problem, accuracy requirements, and computer precision. This strategy yields reductions in the number of calculations of an order of magnitude or more over methods in more general use. Experiments with a general purpose program in which the strategy is implemented, demonstrate that much of the projected economy can be realized in practice.

The strategy for nonlinear systems centers around adaptive choice of time steps to suit the nonlinear system, accuracy and stability characteristics. This strategy usually results in less than an order of magnitude reduction in calculations, compared with the method of central differences. Though the efficiency advantages in practical application of the strategy are better than projected, the principle advantage is in insuring solution accuracy.