Load rate as a material model parameter

I. Kožar

Department for Computer modelling of materials and structures, Faculty of Civil Engineering, University of Rijeka, Radmile Matejčić 3, 51000 Rijeka, Croatia, ivica.kozar@gradri.uniri.hr

In the dynamic analysis of materials and structures, the load rate is usually applied after the discretization of the model. As a result, the left and right sides of the equation are treated separately. This can lead to a loss of insight into the structure/ material behaviour or even to incorrect results. In the approach presented, the structure, material, and loading are analysed together as a nonlinear dynamic system. The resulting equations are a system of nonlinear differential algebraic equations (DAE). Thus, the material and loading parameters are coupled and their mutual interaction can be analysed [1].

In previous work, the material model consisted of a series of Maxwell cells [2] or Kelvin cells [3]. The Maxwell model is used to describe fluid materials and the Kelvin model is used to describe solid materials. Here, the Burgers material model is proposed [4] because it can assume the behaviour of either the Maxwell or Kelvin model depending on the parameters. Since the model parameters can be changed during the analysis, it can represent complex phenomena such as solidification or melting, etc.

Dynamic analysis is required to study the rate behaviour of a material. It is possible to simulate a force- or displacement-driven experiment. In the first case we have Neumann boundary conditions and in the second case Dirichlet boundary conditions. We use a displacement controlled model since this provides a unique relationship for our softening material. The sudden loading is simulated with the impact loading, but the periodic loading with different frequencies is also needed to analyse the material response. The amplitudes of the two types of loading are kept equal.

The Burger model is a combination of the basic Maxwell and Kelvin material models in such a way that, given a suitable choice of material parameters, one can obtain either one of the basic models or a combination of them. We could say that the basic models represent the two limits and the model behavior lies somewhere between these two extremes. In each material cell, we have four parameters: the Maxwell elastic modulus and viscous damper, and the Kelvin elastic modulus and viscous damper. The external variable of the cell is its strain/displacement. There are also three internal variables: elastic and viscous strains in the Maxwell part and strain in the Kelvin part of the model. The evolution model of the internal variables is assumed to be nonlinear. For the elastic moduli, we have relationships that are used in the microplane material model. Each material cell can be without (viscous model) or with a mass (dynamic model).

Structural models include a larger number of material cells, limited only by computer capacity. Therefore, methods for automatic generation of DAE need to be developed. In this work, a matrix formulation is used that takes into account the different properties of the Maxwell and Kelvin components of the Burger model. The response of the structure is evaluated using phase diagrams, spectrograms, and power spectral density (PSD) diagrams.

References

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