A Novel Finite Element Method Based on a Nodal Integration Technique for Nonlinear Problems of Mechanics of Solids

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ABSTRACT

This paper is devoted to the development and assessment of a new finite element method for problems of nonlinear mechanics of solids (plasticity, viscoplasticity), based on a nodal integration technique. This method is similar to one proposed by Dohrmann et al. [1] which seems, to the authors' best knowledge, to have received little attention in spite of its potentialities. Its basic elements are: (i) evaluation of nodal strains through averaging, at each node, of the strains in elements containing it; (ii) evaluation of nodal stresses through application of the constitutive law at each node; (iii) calculation of relevant integrals through placement of the integration pojnts at the nodes. The potential advantages of such a method include notably (i) elimination of locking problems associated to internal constraints (since the points where these constraints are enforced coincide with those where the degrees of freedom are defined); (ii) easier postprocessing (since no extrapolations of quantities of interest from Gauss points to nodes are required); (iii) easier transfer of quantities in case of remeshing (since their definition at the nodes permits easy interpolation through shape functions). Its main disadvantage is a somewhat increased bandwidth of the left-hand-side matrix.

Our first aim is to examine the connection of this method, based on a classical meshing of the geometry, with some perhaps better known meshless technique, in which disjoint subdomains are associated to the discretization points and strains are evaluated through integration over their boundaries. It is shown that the method proposed in fact amounts to applying this technique with a certain choice of subdomains tied to the mesh.

Our second aim is to demonstrate the capabilities of the method through consideration of a significant problem of loading of a tensile notched specimen made of elastic-plastic material. Special attention is paid to the choice of the left-hand-side matrix used, with two options: exact tangent matrix or approximate classical finite-element matrix calculated through Gaussian integration.

REFERENCES

[1] Dohrmann C.R., Heinstein M.W., Jung J., Key S.W., Witkowski W.R. Node-based uniform strain elements for three-node triangular and four-node tetrahedral meshes. *International Journal for Numerical Methods in Engineering*, 2000; 47:1549–1568.