AUTOMATIC DERIVATION OF COMPLEX MATERIAL MODELS

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Main objective of the presentation is to provide theoretical background and to show practical applications of automatic generation of numerical codes by symbolic approach. Emphasis will be given to direct and sensitivity analyses in non-linear continuum mechanics where straightforward use of CA systems leads to the exponential growth of derived expressions. An approach called Simultaneous Stochastic Simplification of numerical code and implemented in the *Mathematica* package *AceGen* [1], [3] overcomes the problem of expression growth by combining several techniques: symbolic algebra system *Mathematica*, automatic differentiation, automatic code generation and theorem proving.

One of the problems that represent major challenge for the CA approach is the derivation of efficient non-linear finite elements involving finite strains and multi-surface plasticity in combination with advanced treatment of incompressibility at element level. The approach will be demonstrated on derivation of low-cyclic fatigue damage model [4]. The model considers isotropic and kinematic hardening or softening with description of material damage. It leads to the system of 28 nonlinear evolution equations per material point that are coupled with the global equilibrium equations. The model is incorporated into the three-dimensional, 8 noded, brick element and the incompressibility is treated by the deviatoric-volumetric split of deformation gradient combined with the Taylor expansion of the element shape functions. Efficient and accurate numerical solution of the corresponding coupled non-linear system of equations requires quadratically convergent numerical procedure. Various exceptions such as singularities and implicit dependencies make CA based description of the model even more difficult. Direct use of CA system in this case leads to the catastrophic expression growth that can be controlled by the use of advanced techniques implemented in *AceGen* package. The derivation of a consistent tangent matrix for the model of that complexity would be extremely complicated if the standard approach is used.

References

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