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Development of a new calculation software for large deformation problems

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Abstract: This paper covers the development of a new stand-alone 3D finite element software package called "MSIM", which allows large deformation calculations as it occurs in the field of manufacturing technology. Since existing commercial software packages do need a lot of time to solve the highly nonlinear system of equations and do not often incorporate suitable elements as it is common in several forming processes, a new calculation program was implemented to remedy this deficiencies.
The first part of this work describes the development and the object-oriented implementation of the finite element program MSIM in C++, which is highly superior to commercial software packages with respect to calculation time and storage capacities. The parallelization of the assembly algorithm and the implementation of the solution algorithm for the highly nonlinear system of equations is one of the core issues. The second part focuses on the development of a novel solid-shell element and treats the locking phenomenon resulting from low order interpolation functions. The customized solid-shell element formulation is embedded in a static implicit total Lagrange formulation, which is able to deal with large deformations in accordance with the finite strain theory. For the constitutive relation, a hyperelastic material law was used in preparation to a further extension to a hyperelastic-plastic material behavior. Therefore, the determination of the elastic predictor gained from the right Cauchy Green strains, turned out to be a crucial step in hyperelasto-plasticity.
Several benchmark tests were performed to evaluate the computing speed of the new calculation program MSIM and the accuracy of these solid-shell elements in comparision to the results attained by the FEM-package ANSYS©.
The results obtained so far agrees satisfactorily by gaining a significantly reduced calculation time. The developed calculation program serves as an effective tool to predict the stress-distributions inside the material under large deformations. Furthermore, this calculation program provides the basis for further improvements and enhancements and thus serves as an effective tool for research and teaching.

REFERENCES

[1] Bathe K.J.: *Finite Element Procedures*, Prentice Hall, New Jersey, (1996).

[2] Bischoff M.: *Theorie und Numerik einer dreidimensionalen Schalenelement-formulierung*, Institut for Structural Mechanics, University of Stuttgart, Technical report, (1999).

[3] Crisfield M.A.: *Non-linear Finite Element Analysis of Solids and Structures*, Volume 1, John Wiley & Sons, (1996).

[4] Choi K., Im S.: Finite element simulation of welding processes using a solid-shell element, *Journal of Physics* (2009) **42**:1-17.

[5] Masud A., Tham C.L., Liu W.K.: A stabilized 3-D co-rotational formulation for geometrically nonlinear analysis of multi-layered composite shells, *Comput. Methods. Appl. Mech. Eng.* (2000) **26**:1-12.

[6] Sattinger V., Kainz A., Schörkhuber K., Aigner L., Zeman K.: Calculation of mechanical and thermal influences during coiling of hot strip, *Comput. Plasticity XII – Fundamentals and Applications* (2013) **1**:1186-1197.

[7] Schwarze M., Vladimirov N., Reese S.: Sheet metal forming and springback simulation by means of a new reduced integration solid-shell finite element technology, *Comput. Methods Appl. Mech. Eng.* (2011) **200**:454-476.

[8] Shabana A.A.: *Dynamics of Multibody Systems*, Cambridge University Press, (2010).

[9] Simo J.C., Miehe J.C.: Associative coupled thermoplasticity at finite strains: formulation numerical analysis and implementation, *Comput. Methods Appl. Mech. Eng.* (1992) **68**:1-31.

[10] Sousa R.J.A., Cardoso R.P.R., Valente R.A.F., Yoon J.W., Gracio J.J., Jorge R.M.N.: A new one-point quadrature enhanced assumed strain (EAS) solid-shell element with multiple integration points along thickness, Part II: Nonlinear applications, *Int. Journal for Num. Meth. Eng.* (2006) **67**:160-188.

[11] Wriggers P.: *Nichtlineare Finite-Element-Methoden*, Springer, (2000).

[12] Wriggers P.: *Computational Contact Mechanics, Second Edition*, Springer, (2006).

[13] Zhongqing Zhou, Thomson P.F., Yee Cheong Lam, Yuen D.W.: Numerical analysis of residual stress in hot-rolled steel strip on the run-out table, *Journal of Materials Processing Technology* (2003) **132**:184-197.

[14] O.C. Zienkiewicz and R.C. Taylor, *The finite element method*, 6th Edition, Elsevier, (2005).

[15] Intel Math Kernel Library: *Reference Manual*, September (2007).

[16] Intel Math Kernel Library: *User's Guide - Intel Math Kernel Library*, Version 10.3.