11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

# A CONSTRAINED LARGE TIME INCREMENT METHOD FOR A GRADIENT-ENHANCED DAMAGE MODEL

**B. Vandoren[1*], A. Simone[2] and L. J. Sluys[2]**

[1] Hasselt University, Faculty of Engineering Technology
Agoralaan Gebouw H, 3590 Diepenbeek, Belgium
bram.vandoren@uhasselt.be
[2] Delft University of Technology, Faculty of Civil Engineering and Geosciences
P.O. Box 5048, 2600 GA Delft, The Netherlands

**Key words:** *Constrained LATIN, Gradient-Enhanced Damage, Quasi-Brittle Failure.*

An important aspect when modelling quasi-brittle materials is a robust and efficient solution algorithm which can cope with highly non-linear behaviour such as snap-backs and bifurcations. An alternative to the widely used incremental-iterative Newton-Raphson algorithm is the non-incremental LArge Time INcrement (LATIN) method [1]. This algorithm differs significantly from conventional incremental methods since the whole loading process is iteratively calculated in a single time increment using two solution stages. In the local solution stage, stresses and strains verify the non-linear constitutive laws as well as a local search equation which searches for a new solution using the fields of the previous iteration. In the global solution stage, stress-strain couples are calculated which satisfy both structural equilibrium and a global search equation which searches for an improved solution using the stresses and strains of the local solution stage. In other words, the local and non-linear behaviour is separated from global and linear behaviour.

In the literature, LATIN algorithms are usually applied to elastoplastic hardening problems [2, 3]. In the few papers that investigate strain-softening problems using LATIN algorithms [4, 5], the softening behaviour is attributed to discontinuous and therefore local failure. In this contribution, the constrained LATIN algorithm developed in [6] will be applied to the continuous modelling of quasi-brittle failure. The problem is regularised using the implicit gradient-enhanced damage model [7] in which a modified Helmholtz equation is coupled to the standard equilibrium equation. Although coupled problems have been successfully modelled using the LATIN method [8], the implementation of a gradient-enhanced damage model in a LATIN framework is not straightforward since the non-linear constitutive behaviour can no longer be separated from the non-local (or global) behaviour. Special attention will therefore be devoted to implementation aspects of the algorithm. The performance of the proposed methodology is demonstrated by means of several numerical examples.

## REFERENCES

[1] P. Ladevèze. *Nonlinear computational structural mechanics. New approaches and non-incremental methods of calculation*. Springer-Verlag, 1999.

[2] Ph. Boisse, P. Ladevèze, and P. Rougée. A large time increment method for elasto-plastic problems. *Eur. J. Mech. A/Solids*, Vol. **8**(4), 257–275, 1989.

[3] E. Bellenger and P. Bussy. Plastic and viscoplastic damage models with numerical treatment for metal forming processes. *J. Mater. Process Technol.*, Vol. **80-81**, 591–596, 1998.

[4] J. Dolbow, N. Moës, and T. Belytschko. An extended finite element method for modeling crack growth with frictional contact. *Comput. Methods Appl. Mech. Engrg.*, Vol. **190**, 6825–6846, 2001.

[5] R. Ribeaucourt, M.-C. Baietto-Dubourg, and A. Gravouil. A new fatigue frictional contact crack propagation model with the coupled X-FEM/LATIN method. *Comput. Methods Appl. Mech. Engrg.*, Vol. **196**, 3230–3247, 2007.

[6] B. Vandoren, K. De Proft, A. Simone, and L. J. Sluys. A novel constrained LArge Time INcrement method for modelling quasi-brittle failure. *Comput. Methods Appl. Mech. Engrg.*, Vol. **265**, 148–162, 2013.

[7] R. H. J. Peerlings, R. de Borst, W. A. M. Brekelmans, and J. H. P. de Vree. Gradient-enhanced damage for quasi-brittle materials. *Int. J. Numer. Meth. Engrg.*, Vol. **39**, 3391–3403, 1996.

[8] D. Dureisseix, P. Ladevèze, and B. A. Schrefler. A LATIN computational strategy for multiphysics problems: Application to poroelasticity. *Int. J. Numer. Meth. Engrg.*, Vol. **56**(10), 1489–1510, 2003.