A Mixed Strain/Displacement Finite Element Formulation Suitable for Fracture Computation in Large-Deformation Coupled CFD/CSD Blast and Impact Problems – COMPLAS XIII

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ABSTRACT

Theoretical modelling and computational resolution of the strain localization process up to structural failure remained an open challenge in computational solid dynamics (CSD). To date, most attempts to model discontinuities with standard local approaches produce non-physical solutions, which are fully determined by mesh resolution and orientation. Cervera et al. (see [1]) showed this must be due to the poorly numerical approximation that is obtained if irreducible formulations are used (standard displacement formulations). The previous statement may be simply explained by taking into account that in irreducible formulations, the strain, which is the variable of most interest for fracture prediction, are obtained by differentiation of the fundamental unknowns (the displacement field). Hence, if linear (or tri-linear) FE are used, the strain field has a theoretical convergence of order O(h) in L2-norm (h is the mesh size). Therefore, the strain field has zero point convergence order (in $L\infty$-norm), which means that even though the mesh resolution is improved, point values do not converge. Since point strains and/or stresses (values at integration points) are used to predict material damage and element fracture, it is of no surprise that localization bands strongly depends on the mesh size and orientation. Contrariwise, when using the strain and displacement fields as primary variables of the formulation, the added accuracy and convergence seems to be enough to satisfactorily solve the mentioned mesh dependency problem (see [1] and references therein).

Herein an explicit, strain/displacement, large-deformation FE formulation to deal with strong coupled CFD/CSD (computational fluid dynamics/computational solid dynamics) problems is presented. It is widely known that, if standard equal interpolation is used for the spatial discretization of both fields, strain and displacement, the scheme locks and produces meaningless and not stable results since the inf-sup condition is not fulfilled. However, equal continuous FE functions are highly desirable from a computational point of view. Hence, to circumvent the severe restrictions imposed by such an inf-sup condition, in this work the weak forms of the mixed strain/displacement solid dynamic equations are obtained by a variational multiscale stabilization (VMS) approach. Time discretization of the final continuous forms is achieved by an explicit Newmark scheme, and the spatial one by using Q1/Q1 standard functions. Several VMS methods were developed in [1] for the small-deformation static solid equations, and successfully applied to localization problems: Totally physical and mesh independent solutions were obtained where the standard displacement formulation failed miserably.

Finally, the CSD approach is loosely coupled with the widely tested CFD code FEFLO to solve real blast and impact problems (see [2]). Several benchmark cases and real applications will be presented.

REFERENCES

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[2] S O. Soto, J. Baum and R. Löhner, “An efficient fluid-solid coupled finite element scheme for weapon fragmentation simulations”, *Engr. Fracture Mech.*, Vol 77, 549-564, (2010).