PERFORMANCE OF LAGRANGIAN FINITE VOLUME APPROACHES FOR LINEAR AND NONLINEAR SOLID MECHANICS ANALYSES

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Introduction

In the field of computational solid mechanics, the Finite Element (FE) method is ubiquitous; however, alternative approaches such as the Finite Volume (FV) method can provide viable alternatives in many applications. The attraction of the FV method may be attributed to its simple yet strongly conservative nature; additionally, the proliferation and relative success of the OpenFOAM library for computational fluid dynamics problem has led to a desire for equivalent solid mechanics procedures within the library.

In this work, the performance of recently developed Lagrangian FV procedures [1, 2, 3] for solid mechanics problems are examined. Specifically, two separate approaches are investigated with regard to accuracy and efficiency:

- a block coupled Lagrangian FV method for linear elasticity;
- a segregated Lagrangian FV method for metal forming analyses.

Methods

For the block coupled approach, a number of 2-D and 3-D benchmark cases are examined: Slender Cantilever in Bending; Out-of-Plane Bending of an Elliptic Plate (Fig. 1); and a Narrow T-Section Component Under Tension (Fig. 1). The accuracy and efficiency of the method is compared to a segregated FV solvers and to a commercial FE solver.

For the segregated large strain plasticity approach, the solver is strictly verified on a series of 1-D, 2-D and 3-D benchmark cases: Expansion of Thick-Walled Cylinder; Upsetting a Cylindrical Billet (Fig. 1); Crushing of a Pipe (Fig. 1); Necking of a Cylindrical Bar; and Flat Rolling of Wire; The predictions are compared with analytical solution and FE solutions.

Conclusions

The developed block-coupled and segregated methods are compared with benchmark solutions and commercial FE solvers; the efficiency and accuracy of the FV procedures are shown to be impressive relative to standard FE procedures. Accordingly, the new methods can be considered as a practical alternatives to standard FE methods for simulation of both linear and nonlinear problems in solid mechanics.

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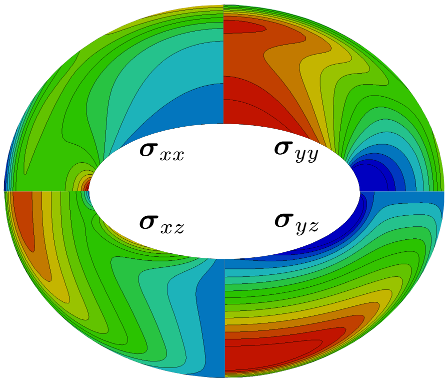
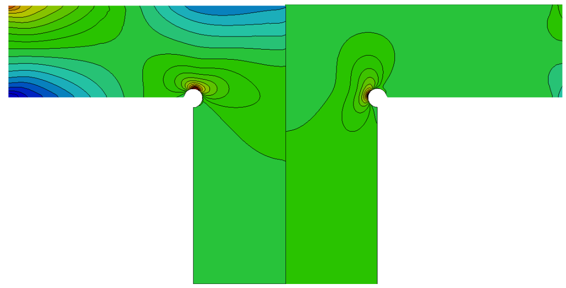
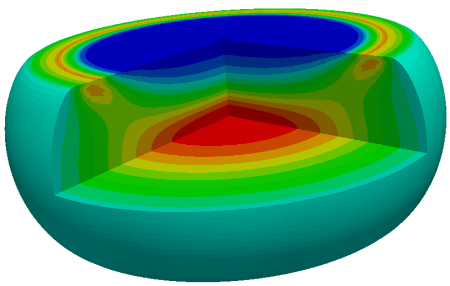


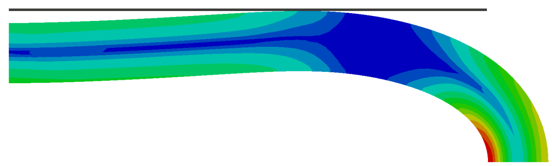
(a) Stress distribution within an elliptic plate subjected to out-of-plane bending



(b) Stress distribution within the narrow T-member under tension



(c) Upsetting of a cylindrical billet showing the plastic equivalent strain distribution



(d) Crushing of a pipe showing the von Mises stress distribution

Figure 1: Linear and nonlinear benchmark test cases

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