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A block-coupled vertex-centred finite volume method for nonlinear solid mechanics using PETSc

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Since its inception in the late 1980s, the finite volume method for solid mechanics has slowly gained momentum as a viable alternative [1] to related approaches, like the finite element method. Solid mechanics solvers, such as `solidDisplacementFoam`, have been included in the main forks of OpenFOAM/FOAM from its early days. However, they have been limited to small deformations and linear elasticity. Over the past decade, various extensions have been made available in the community, primarily based on the cell-centred grid arrangement. The current talk presents a new *vertex-centred* formulation for solid mechanics in OpenFOAM, built on a block-coupled solution algorithm where the three components of the momentum equation are simultaneously solved. The resulting linear systems are solved using the PETSc linear solver library [2], allowing efficient parallel scaling. Nonlinearities from the material, large strains, and boundary conditions are resolved using a Newton-Raphson algorithm with a simple line search method. Temporal discretisation is performed using three implicit schemes: (i) 1st order backward Euler, (ii) 2nd order backward, and (iii) 2nd order Newmark-beta.

In contrast to existing cell-centred formulations for solid mechanics, vertex-centred formulations exhibit several interesting (and potentially favourable) characteristics, including (i) a more convenient approach to traction boundary conditions in a block-coupled formulation and (ii) no special procedures required for multi-material interfaces. In addition, improved displacement and stress accuracy may be possible, particularly for low-quality meshes. Several static and dynamic cases are examined to explore the method's accuracy, efficiency and robustness, including the classic hole in a plate case (Figure 1) and a bicycle pedal (Figure 2).

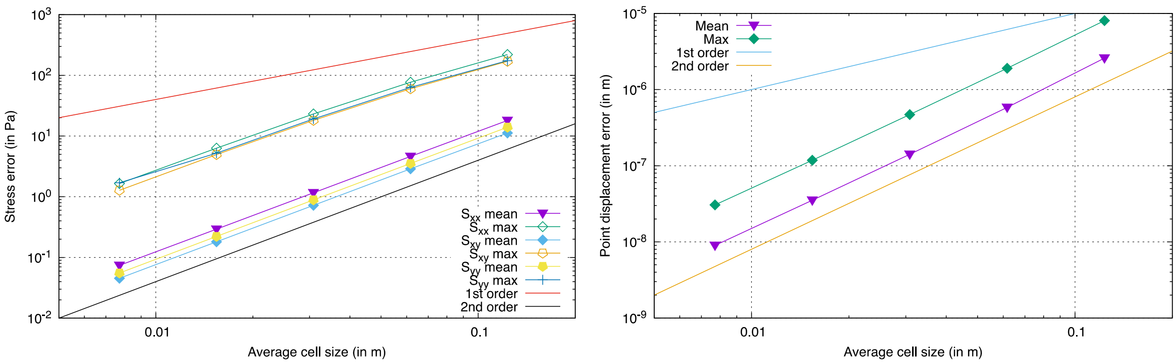

Figure 1: Order of accuracy for the classic 2-D *hole in a plate* case for displacement and stress

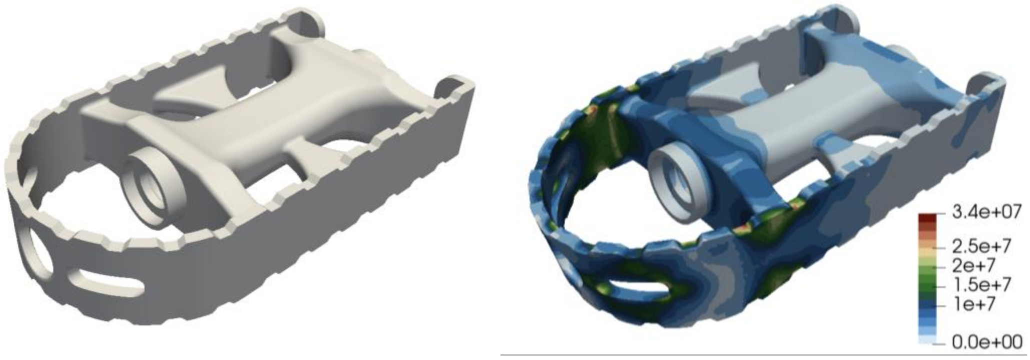

Figure 2: Stress analysis of an aluminium bicycle pedal, showing the von Mises stress (right)

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