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# A LOCKING-FREE SMOOTHED FINITE ELEMENT FORMULATION (MODIFIED SELECTIVE FS/NS-FEM-T4) WITH TETRAHEDRAL MESH REZONING FOR LARGE DEFORMATION PROBLEMS

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In the computational analysis of solids with finite deformation, finite element (FE) method is usually adopted as the de-facto standard method. The accuracy of the conventional FE formulation, however, is not yet sufficient in cases of severely large deformation. The insufficiency of accuracy mainly comes from shear locking associated with severe element distortion. The mesh rezoning method is a suitable solution for the shear locking issue; however, the conventional mesh generators can remesh arbitrary deformed shapes only with tetrahedral elements, which lead to volumetric locking with the conventional FE formulation. Accordingly, development of locking-free FE formulations with tetrahedral mesh rezoning still remains to be solved.

There have been several approaches on the development of locking-free FE formulations: higher-order elements, enhanced assumed strain (EAS) method, B-bar method, F-bar method, F-bar patch method, hybrid elements, selective reduced integration elements, selective smoothed finite element methods (S-FEM) [1], and so on. However, these formulations with the use of tetrahedral meshes don't have sufficient accuracy, stability, or practicality so far.

In this study, a modified formulation of the selective smoothed finite element method (modified selective FS/NS-FEM-T4) is proposed. Our formulation modifies the way of selective calculation of the conventional selective FS/NS-FEM-T4 [2]: FS-FEM-T4 is assigned to the deviatoric part instead of the $\mu$ part, whereas NS-FEM-T4 is assigned to the hydrostatic part instead of the $\lambda$ part. Owing to this modification, our method can handle any kind of material constitutive models other than elastic models with keeping the volumetric locking-free nature. We also present a mesh rezoning method specialized for our method to avoid shear locking associated with severe element distortion. As a demonstration, the outline and result of the shear necking analysis are presented in Fig. 1 and 2.

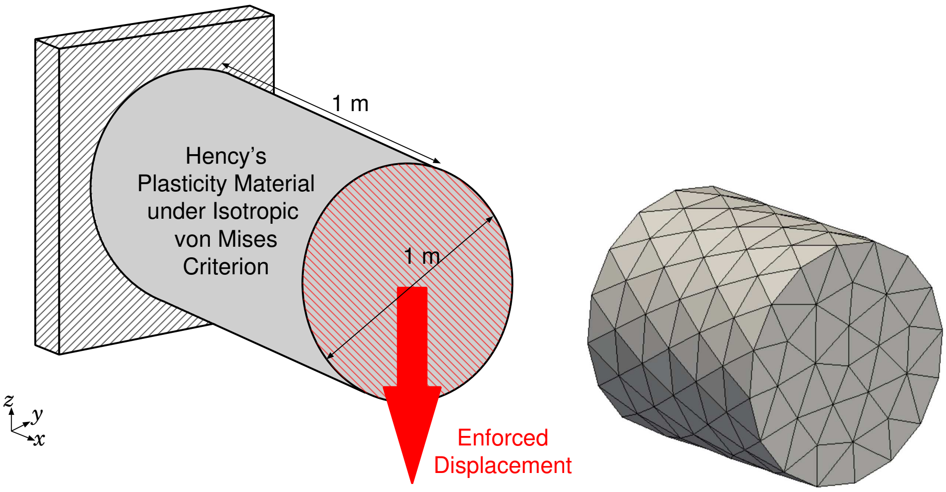
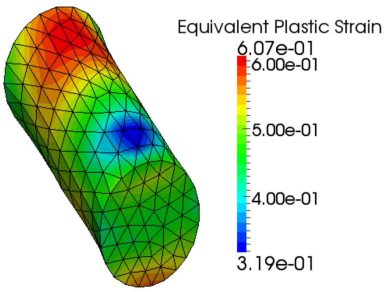
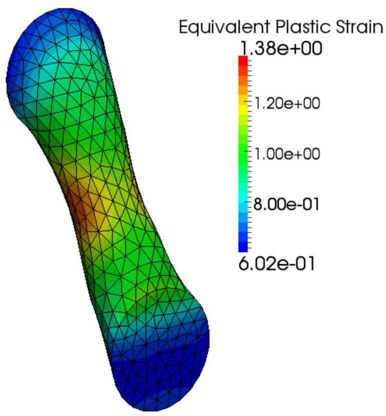


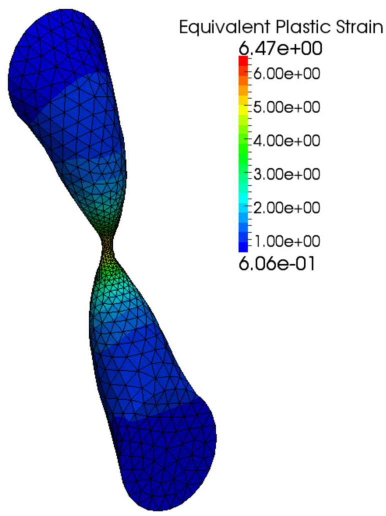

Figure 1: Outline of the shear necking analysis and the initial mesh. The material properties are 70 GPa Young's modulus, 0.3 Poisson's ratio, 100 MPa yield stress and 0.7 GPa constant plasticity coefficient.




(a) 1.0 m displacement state with 3-times Mesh Rezonings




(b) 2.0 m displacement state with 7-times Mesh Rezonings




(c) 2.8 m displacement state with 12-times Mesh Rezonings

Figure 2: Time histories of deformation and equivalent plastic strain distribution of the shear necking analysis with our modified selective FS/NS-FEM-T4. Shear deformation dominates at the earlier stage; tensile deformation rises gradually, resulting in necking at the later stage.

## REFERENCES

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