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# Multifield plasticity approach for scalable large strain simulations of Incremental Cold Flow Forming

**Karol Lewandowski[1*], Daniele Barbera[1], Andrew McBride[1], Paul Steinmann[1,2], Chris Pearce[1], Łukasz Kaczmarczyk[1]**

[1] Glasgow Computational Engineering Centre, James Watt School of Engineering, University of Glasgow, Glasgow, UK
[2]Chair of Applied Mechanics, University of Erlangen–Nuremberg, Erlangen, Germany
*karol.lewandowski@glasgow.ac.uk, mofem.eng.gla.ac.uk

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The Incremental Cold Flow Forming (ICFF) is a manufacturing process for forming axisymmetric components with remarkable geometrical accuracy and improved material properties in comparison with traditional methods [1]. Due to the nature of the process, including extreme plastic deformations, contact with series of rollers, and heat dissipation, it has been exceptionally difficult to simulate, thus, not allowing industry to take full advantage of this technique. To overcome these challenges and enable robust simulations, we have developed a massively parallel multifield plasticity approach. Unlike classical methods [2], the measures of plastic deformation are directly approximated using the finite element basis functions in $L^2$ space. The problem, initially involving displacements and plastic variables, is solved implicitly on a global system level with a monolithic Newton-Raphson scheme. However, this approach is also highly flexible, allowing for straightforward coupling with other physical phenomena.

The resulting block-structure of the tangent stiffness matrix is exploited by using efficient and scalable block preconditioners. Moreover, we utilise the additive kinematic approach proposed by Miehe, et. al. [3] for finite strain plasticity that enables the use of classic constitutive models developed in a small-strain framework by introducing a logarithmic strain measure. Performance of the proposed implementation is tested via classical benchmark studies and large scale simulations of ICFF.

## References

[1] D. Marini, D. Cunningham, P. Xirouchakis, and J. Corney, "Flow forming: A review of research methodologies, prediction models and their applications," *International Journal of Mechanical Engineering & Technology*, vol. 7, no. 5, pp. 285–315, 2016.

[2] J. C. Simo and T. J. Hughes, *Computational inelasticity*. Springer Science & Business Media, 2006, vol. 7.

[3] C. Miehe, N. Apel, and M. Lambrecht, "Anisotropic additive plasticity in the logarithmic strain space: Modular kinematic formulation and implementation based on incremental minimization principles for standard materials," *Computer Methods in Applied Mechanics and Engineering*, vol. 191, pp. 5383–5425, 2002.