# On exploiting the weak invariance of multiplicative elasto-plasticity for efficient numerical integration

**Alexey V. Shutov*†**

* Novosibirsk State University
Pirogova 2, 630090 Novosibirsk, Russia
† Lavrentyev Institute of Hydrodynamics
Pr. Lavrentyeva 15, 630090 Novosibirsk, Russia
e-mail: alexey.v.shutov@gmail.com, web page: http://sites.google.com/site/materialmodeling

## ABSTRACT

The talk is devoted to the efficient and robust numerical integration of constitutive equations governing finite strain elasto-plasticity. We utilize in a consistent manner the approach based on numerous multiplicative decompositions of the deformation gradient. The nonlinear kinematic hardening is incorporated basing on the approach of Lion [1], the nonlinear distortional hardening is introduced through its generalization presented in [2].

The key notion of the talk is the property of so-called weak invariance of constitutive relations under isochoric change of the reference configuration [3]. We distinguish a group of constitutive equations of multiplicative metal plasticity which are weakly invariant. For these material models we discuss their numerical implementation which requires implicit time integration of underlying constitutive equations. The exploitation of the weak invariance allows us to construct new efficient numerical algorithms, which exactly preserve the weak invariance property. In particular, the application of the weak invariance restriction to elastic-perfectly plastic solid allows us to build an update formula which is similar to the explicit update formula previously reported for the Maxwell fluid [4]. Next, a straightforward implicit time stepping for the model with nonlinear kinematic hardening [5] would require a numerical solution of a system with 13 coupled scalar equations. For the newly developed algorithm, the problem is reduced to only one scalar equation. Finally, for the model with nonlinear distortional hardening [2], the application of the weak invariance restriction yields a new implicit time-stepping algorithm with only one scalar unknown, as well.

The resulting algorithms are first order accurate and unconditionally stable. Moreover, they exactly preserve the restriction of inelastic incompressibility which supresses the error accumulation. Numerical tests are used to compare the new algorithms with some known modifications of the classical Euler backward method.

## REFERENCES

[1] A. Lion, "Constitutive modelling in finite thermoviscoplasticity: a physical approach based on nonlinear rheological elements", *International Journal of Plasticity,* **16**, 469-494 (2000).

[2] A.V. Shutov, S. Panhans and R. Kreißig, "A phenomenological model of finite strain viscoplasticity with distortional hardening", *ZAMM,* **91**, 653-680 (2011).

[3] A.V. Shutov and J. Ihlemann, "Analysis of some basic approaches to finite strain elasto-plasticity in view of reference change", *International Journal of Plasticity,* **63**, 183-197 (2014).

[4] A.V. Shutov, R. Landgraf and J. Ihlemann, "An explicit solution for implicit time stepping in multiplicative finite strain viscoelasticity", *Computer Methods in Applied Mechanics and Engineering,* **256**, 213-225 (2013).

[5] A.V. Shutov, R. Kreißig, "Finite strain viscoplasticity with nonlinear kinematic hardening: Phenomenological modeling and time integration", *Computer Methods in Applied Mechanics and Engineering,* **197**, 2015-2029 (2008).