A Fractional-Order Uniaxial Visco-Elasto-Plastic Model for Structural Analysis

J.L. Suzuki*, M. Zayernouri†, M.L. Bittencourt*, and G.E. Karniadakis†

* Department of Integrated System, Faculty of Mechanical Engineering, University of Campinas,
Campinas SP, 13083-970, Brazil
e-mails: jlsuzuki@fem.unicamp.br, mlb@fem.unicamp.br, web page: http://www.fem.unicamp.br

† Division of Applied Mathematics, Brown University
182 George St. Providence, RI 02912, USA
emails: mohsen_zayernouri@brown.edu, george_karniadakis@brown.edu - Web page:
http://www.cfm.brown.edu/people/gk/

ABSTRACT

A non-local fractional-order model for uniaxial large deformation and rate-dependent plastic behavior of materials in structural analysis is proposed. This approach is amenable to modeling nonlinear and more sophisticated effects namely "*visco-elasto-plastic*" response of materials. This approach seamlessly interpolates between the standard *elasto-plastic* and *visco-plastic* models in plasticity, taking into account the history-dependency of the accumulated plastic strain to specify the state of stress. To this end, we propose a fractional-order constitutive law that relates the Kirchhoff stress to the linear combination of the total strain and its Caputo time-fractional derivative of order $\alpha \in [0,1)$. When $\alpha = 0$ the standard elasto-plastic (rate-independent) model is obtained; when $\alpha \rightarrow 1$ the corresponding visco-plastic model is recovered. Since the material behavior is path-dependent the evolution of the plastic strain is achieved by integrating the plastic strain rate with respect to time. The strain rate is then obtained by means of the corresponding plastic multiplier and deriving proper consistency conditions. Finally, the nonlinear system of the equilibrium equations is solved employing the so-called *return-mapping algorithm*.

REFERENCES

[1] J. Bonet and R. D.Wood, Nonlinear Continuum Mechanics for Finite Element Analysis, 2nd Edition, Cambridge University Press, 2008
[2] Podlubny, Igor. Fractional Differential Equations: An Introduction to Fractional Derivatives. Vol. 198. Academic press, 1998