**[P2.30]**

# A unified framework for incremental plasticity calculations under non-proportional variable amplitude histories

M.A. Meggiolaro*, J.T.P. Castro
*Pontifical Catholic University of Rio de Janeiro, Brazil*

In this work, an efficient incremental plasticity algorithm is proposed to obtain the multiaxial stress-strain history in the non-proportional (NP) case under complex variable-amplitude (VA) loadings, considering both isotropic and kinematic hardening. The algorithm framework is entirely developed in Papadopoulos' 5D deviatoric sub-space, which is more computationally efficient than Ilouchine's 9D or Voigt's generalized 6D representations, being able to deal with very long load histories. The flow rules and kinematic translation rules have to be adapted to this 5D notation (which becomes 3D in the plane stress case), which involves a few non-trivial steps presented here. The algorithm is able to reproduce the Mròz multi-surface model and all proposed non-linear kinematic (NLK) models using the same notation and variables, therefore providing a unified framework to directly compare such models and even to mix their surface translation rules. For instance, Jiang-Sehitoglu's efficient translation rules [1] could be used together with Mròz multi-surface model to deal with VA loadings without the drawbacks of some NLK models (which fail to reproduce histories with decreasing amplitude sections, which might be present in VA fatigue problems). The continuous Mròz model, which uses infinite surfaces, is also addressed in this framework, generating a new kinematic translation rule without adjustable parameters. Such rule is able to analitically show the dependence of the Mròz predictions on the number of hardening surfaces, one of the drawbacks of such model. A general class of translation rules is proposed, which can reproduce all hardening rules studied by Jiang and Sehitoglu [1], in addition to the Mròz and continuous Mròz rules, among others. The computational implementation of the algorithm is presented (Figure 1), efficiently dealing with large numbers of hardening surfaces to improve the loop predictions under VA. The use of Chaboche's discrete memory surfaces is also shown, to deal with the infinite surface case. It is found that the algorithm is able to reproduce the experimental hysteresis loops from NP VA loadings with a relatively low computational cost.

[1] Jiang Y, Sehitoglu H. Modeling of cyclic ratchetting plasticity. Part I - development of constitutive equations. ASME J Appl Mech 1996;63:720-725

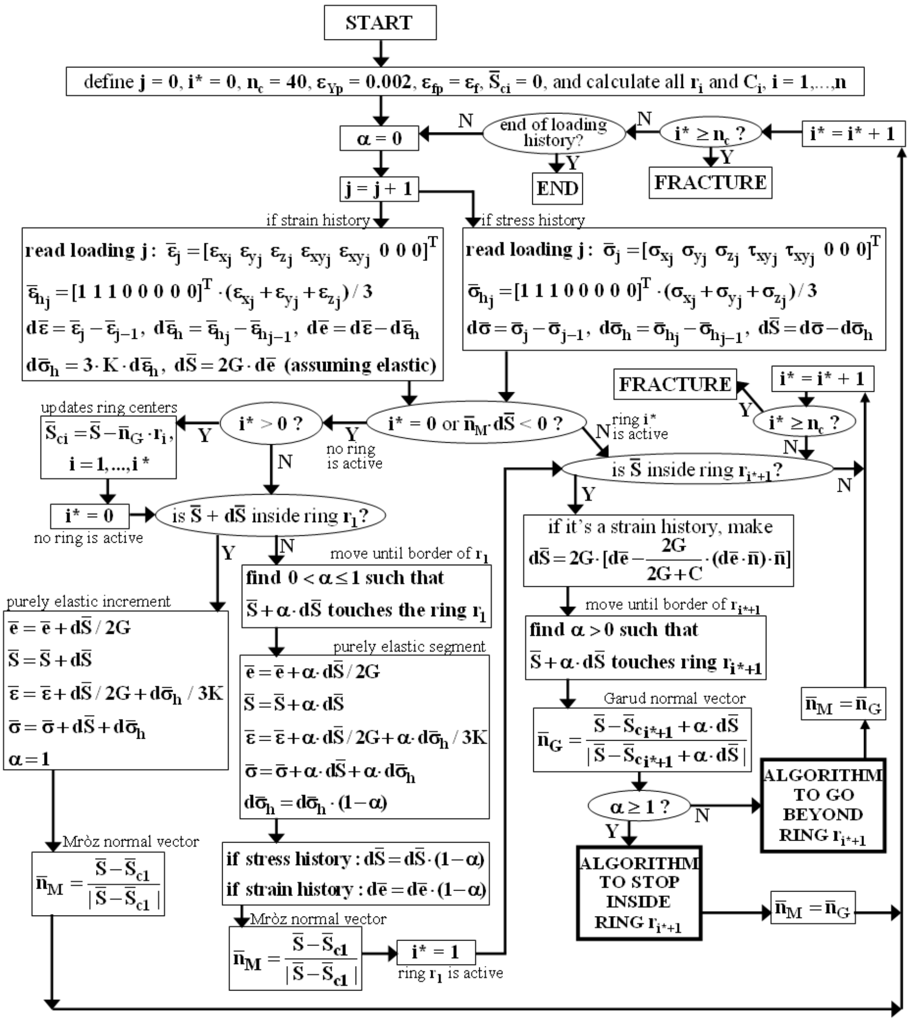


Figure 1 – Block diagram of an algorithm using the Mròz multi-surface model, using Ilouchine's 9D notation. The proposed algorithm is an improvement of the above, including several translation rule options in addition to Mròz and efficiently using Papadopoulos' 5D notation.

Keywords: non-proportional loading, variable amplitude, incremental plasticity, non-proportional hardening