An efficient Artificial Neural Network based non-linear flow law: towards the implementation into a radial return integration scheme

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Neural networks are becoming more and more important in scientific applications, and their field of application is expanding every day, especially in the field of numerical simulation by finite elements method. We present the development and the training of an artificial neural network (ANN) allowing computing of the flow stress, for a material enhancing a dependence on the plastic strain, the plastic strain rate and the temperature, in order to replace, when writing a VUMAT user behavior law in Abaqus/Explicit, the flow law usually modeled by an analytical formulation such as Johnson-Cook, Zerilli-Amstrong or Arrhenius. In this perspective, the integration of the ANN in the radial return integration scheme presented in [1-2] requires, in addition to the determination of the flow stress of the material, the determination of the 3 derivatives of this stress with respect to plastic strain, plastic strain rate and temperature. An ANN simulating a Johnson-Cook flow law [3] is presented in this communication and validated against the original analytical formulation of the flow law and its derivatives. One of the main difficulties encountered when using ANN concerns the dependence of the results quality on the architecture of the ANN. In this paper, several architectures (number of hidden layers, number of neurons per layer and activation functions used) are compared in order to identify those allowing the best compromise between simplicity of the architecture (and therefore training time and computing performance) and final precision for an implementation in the Abaqus/Explicit code.

References

[1] Ming, L., Pantalé, O., 2018. An efficient and robust VUMAT implementation of elastoplastic constitutive laws in Abaqus/Explicit finite element code. Mechanics & Industry 19, 308.

[2] J. C. Simo, T. J. R. Hughes, Computational inelasticity, Springer, 1998.

[3] Johnson, G., Cook, W., 1983. A constitutive model and data for metals subjected to large strains, high strain rates and high temperatures. In: Proc. 7th Int. Symp. on ballistics. The Hague, Netherlands.