**ORIGINAL ARTICLE**

# A simplified finite strain plasticity model for metallic applications

Yiwei Chen[1] · Bassam A. Izzuddin[1]

## Abstract

In this work, a finite strain elastoplastic model is proposed within a total Lagrangian framework based on multiplicative decomposition of the deformation gradient, with several simplifications aimed at facilitating more concise code implementation and enhancing computational efficiency. Pre- and post-processors are utilised for conversion between different stress and strain measures, sandwiching the core plastic flow algorithm which preserves the small strain form. Simplifications focus on the pre- and post-processor components by substituting certain arithmetic operations associated with high computational demands with simpler ones without compromising accuracy. These modifications are based on assumptions, which are valid for most metals, that the elastic strains are small compared to plastic strains, and that the incremental plastic deformations are small for each step. In addition, the consistent tangent modulus matrix is derived in a reduced form, both for the general full model and the new simplified model, facilitating more straightforward computations in both cases. The models are verified against two classical numerical examples where favourable comparisons are achieved. Overall, the simplified model is shown to provide a significant reduction in computational demand for the two considered numerical problems, with negligible deviation in the results compared to the full model, subject to fulfilling the underlying assumptions with the adoption of a sufficiently small step size.

**Keywords** Multiplicative decomposition · Total Lagrangian framework · Finite strain plasticity · Consistent tangent stiffness

## 1 Introduction

Finite strain plasticity is present in many engineering procedures and physical phenomena, such as metal forming and ductile fracture, which requires accurate constitutive modelling to capture geometric and material nonlinearity at large deformations. Unlike hyperelasticity which is characterised by a single constitutive relation, elasto-plasticity entails combined features from the distinct elastic and plastic responses, which are associated with many debates concerning their proper kinematic decomposition in the range of finite strains [1]. Depending on the means of separating elastic and plastic deformation (rate), current prevalent large strain elastoplasticity models fall into one of three main categories: (i) hypoelasto–plastic models which additively decompose the total rate of deformation tensor [2–5];

(ii) hyperelasto–plastic models based on the multiplicative decomposition of the total deformation gradient [6–11]; and (iii) elastoplastic models based on direct additive decomposition of the Seth–Hill family strains [12–14]. Apart from these, a type of model employing the plastic metric tensor as internal variables was also proposed for the general anisotropic material [15, 16]. A detailed review and comparison of these models can be found in [1, 17–19].

The classical hypoelasto–plastic formulation is set in the Eulerian framework and adopts an incremental structure similar to the infinitesimal strain plasticity. To fulfil frame indifference, it links a particular objective stress rate with the rate of elastic deformation via a fourth-order elasticity tensor, where a variety of rate type were proposed and compared [20, 21]. Co-rotational rates such as the Zaremba–Jaumann rate was once considered as the optimal candidate as they fulfil the consistency condition initially established by Prager [22], which states that the yield surface must remain stationary with vanishing stress rate. Although simple in form, it was later discovered that the use of Jaumann rate causes an oscillatory stress response under simple shear

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# Plasticity Of Metals At Finite Strain Theory Computation And Experiment

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**Plasticity Of Metals At Finite Strain Theory Computation And Experiment:**

    **Plasticity of Metals at Finite Strain: Theory, Computation and Experiment** E. H. Lee,R. L. Mallett,STANFORD UNIV CA DIV OF APPLIED MECHANICS.,1982 Large strain deformation of materials at intermediate warm working temperatures has its useful aspects lower resistance to plastic flow reduces the amount of work required to deform the material increasing ductility at this temperature range allows for a large amount of deformation before fracture the oxidation rate is virtually zero and fine microstructures are developed leading to very desirable properties However in warm working problems arise as a result of the build up of residual stresses due to metal forming which can eventually cause failure Such fracture modes as central burst alligatoring edge cracking and unzipping are described and some methods of preventing their occurrence is discussed in the following paper **Plasticity of Metals at Finite Strain** ,1982 *IUTAM Symposium on Computational Mechanics of Solid Materials at Large Strains* Christian Miehe,2013-06-29 The steady increase in computational power induces an equally steady increase in the complexity of the engineering models and associated computer codes This particularly affects the modeling of the mechanical response of materials Material behavior is nowadays modeled in the strongly nonlinear range by tak ing into account finite strains complex hysteresis effects fracture phenomena and multiscale features Progress in this field is of fundamental importance for many engineering disciplines especially those concerned with material testing safety reliability and serviceability analyses of engineering structures In recent years many important achievements have been made in the field of the theoretical formulation the mathematical analysis and the numerical im plementation of deformation processes in solids Computational methods and simulation techniques today play a central role in advancing the understanding of complex material behavior Research in the field of ComputationalMechan ics of Materials is concerned with the development of mathematical models and numerical solution techniques for the simulation of material response It is a very broad interdisciplinary field of science with inputs from traditional fields such as Applied Mechanics Applied Mathematics Materials Science Solid State Physics and Information Technology The intention of the IUTAM Symposium Computational Mechanics of Solid Materials at Large Strains held at the University of Stuttgart Germany from August 20 24 200I was to give a state of the art and a survey about recent developments in this field and to create perspectives for future research trends **Transactions of the ... Army Conference on Applied Mathematics and Computing** ,1991 From Creep Damage Mechanics to Homogenization Methods Holm Altenbach,Tetsuya Matsuda,Dai Okumura,2015-06-03 This volume presents a collection of contributions on materials modeling which were written to celebrate the 65th birthday of Prof Nobutada Ohno The book follows Prof Ohno s scientific topics starting with creep damage problems and ending with homogenization methods Applied Mechanics Reviews ,1984 **Advances and Trends in Structures and Dynamics** Ahmed K. Noor,Robert J. Hayduk,2013-10-22 Advances and Trends in Structures and Dynamics contains papers presented at the symposium on Advances and Trends in Structures and Dynamics held in Washington D C on

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Formability and Workability of Metals S. L. Semiatin,John J. Jonas,1984 Computational Methods for Predicting Material Processing Defects M. Predeleanu,1987-08 The papers in this book deal with computational methods for predicting material processing defects Using recent advances in finite strain plasticity and viscoplasticity damage modelling bifurcation and instability theory fracture mechanics and computer numerical techniques new approaches to mechanical defect analysis are proposed Appropriate methods for explaining and avoiding the defects leading to fracture high porosity strain localization or undesirable geometrical imperfections are presented In addition some papers are devoted to new formulations and new calculation algorithms to be used for solving the forming problems Finally two papers deal with physical description of defects occurring in forming and cutting operations focusing on the academic and practical interest of these topics This is

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