Assessment of different non-linear kinematic hardening laws at variable temperature

Maël Perez*[1,2], Amélie Fau[1], Martin Poncelet[1], Florent Coudon[2], and Rodrigue Desmorat[1]

[1]Laboratoire de Mécanique Paris-Saclay – Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS - Laboratoire de Mécanique Paris-Saclay, 91190, Gif-sur-Yvette, France., Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS – Laboratoire de Mécanique Paris-Saclay, 91190, Gif-sur-Yvette, France – France

[2]Safran Tech – Safran Tech, Etablissement Paris Saclay, rue des Jeunes Bois-Châteaufort, 78772 Magny-les-Hameaux, France – France

Abstract

The progressive increase in temperatures and mechanical loads applied to aeroengine components leads to an enhanced need for the fatigue design to introduce non-linear phenomena linked to the inelastic behavior of materials. In order to model cyclic plasticity at variable temperature, a solution is to consider a non-linear kinematic hardening law, such as the Armstrong-Frederick one (1). The material parameters have then to be identified on a temperature range, most often from isothermal tests. Because of the parameters temperature dependency, some spurious model responses may arise (2). One of the "dangerous" effects is the cumbersome occurrence of plastic flow when varying temperatures after an isothermal preloading. Cailletaud and coworkers attribute such an issue to the saturation of the (dimensionless) kinematic hardening internal variable. A sound modeling considers instead a multi-kinematic hardening formulation with constant (or almost constant) backstress parameter.
The present work aims at understanding the subtleties concerning the history at variable temperature of the different thermodynamics variables: the stress and both kinematic hardening variables (the dimensionless internal variable as well as the associated thermodynamics force, homogeneous to stress). We propose an additional numerical uniaxial test under anisothermal conditions, which underlines the cumbersome plastic flow. Our numerical test shows that a temperature change translates the yield surface in the stress space, since the Prager hardening modulus changes with temperature. This plastic flow can change the value of the (dimensionless) kinematic hardening internal variable. Both the cumbersome plastic flow and the translation of the yield surface have an undesired effect on the cyclic plasticity model response.

An alternative to the multi-kinematic hardening is to consider a non-saturating, power-law type, kinematic hardening law (3), for which we provide two non-isothermal generalizations. These non-saturating kinematic hardening laws are then assessed on numerical tests. We use a set of material parameters cross-identified on the initial Armstrong-Frederick modeling. This type of non-saturating kinematic hardening law partially solves the cumbersome plastic

*Speaker

flow problem, but it has a little effect on the undesired yield surface translation. We investigate the behavior of such non-saturating kinematic hardening laws at variable temperature.

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