A thermo-mechanical model for TSTs based on TRIP, and numerical treatment

Frédéric Lebon, Grégory Antoni and Thierry Desoyer
Aix Marseille Université/Laboratoire de Mécanique et d'Acoustique
31 Chemin Joseph Aiguier 13402 Marseille Cedex 20, France

Some of the French railroad network's rails have been affected for the last about twenty years by an undesirable physical phenomenon known as Tribological Surface Transformations (TSTs), which are irreversible, quasi-surface solid–solid phase transformations. Although the physical causes of TSTs have not yet been clearly established, it seems likely that the mechanical loads combined with the thermal effects of the wheel/rail contacts may be largely responsible. The present study is based on the assumption that the combined thermo-mechanical constraints may generate solid–solid phase transformations.

Two thermo-mechanical models developed on these lines were based on previous studies on TRansformation Induced Plasticity (TRIP), which are extended here to account for TSTs. Based on non-standard generalized materials framework, the two models are presented with a "associative" plastic flow linked to classical plasticity and a "non-associative" flow rule for the TRIP-like plasticity. The ability of these models to describe TSTs initiation and development is also assessed by performing a 2-D finite element analysis. The complete algorithmic treatment of the constitutive models is presented with the consistent tangent operator associated. The efficiency and robustness of the present algorithmic framework for modeling the two plasticity processes – which can exist in the irreversible solid-solid phase transformations – is assessed for some numerical examples.