NUMERICAL ANALYSES OF THE INTERACTION CLASSICAL PLASTICITY - TRIP

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Summary The effect of classical plasticity on TRIP is analyzed considering martensitic transformation of ferritic steel. It is experimentally shown that TRIP is influenced by the previous strain hardening of the parent phase. As the obtained results are not easily explainable in the light of the existing models in the literature, the objective of this paper is to contribute to a better understanding of the mechanisms at the origin of the observed discrepancies.

TRansformation Induced Plasticity (TRIP) is one of the mechanical consequences of structural transformations at the solid state in steels. It can be defined as the anomalous plastic strain observed when metallurgical transformation occurs under 'moderate' external stress [1], [2], [3]. More generally a similar phenomenon may also result from some kind of internal stresses within the material and this has been advocated by Videau et al. [4] some years ago (studying martensitic transformation of a Fe-20Ni-0.5C) to explain the influence of an initial pre-deformation of the parent phase on the transformation and the resulting deformation. Two mechanisms are considered to explain the TRIP phenomenon: Magee and Greenwood-Johnson mechanisms. The relative importance of these two mechanisms depends on the steel and the transformation under consideration. It is generally admitted that Magee mechanism is present in martensitic transformation (diffusionless) whereas Greenwood-Johnson mechanism is dominant in diffusional transformations.
In this paper, TRIP is analyzed considering martensitic transformation of a 16MND5 steel (AFNOR norm). Different kinds of coupling may exist between the martensitic transformation and the classical plasticity in both phases. We shall focus here on the effect of classical plasticity on TRIP: the TRIP evolution generally depends on the mechanical characteristics and internal state of the parent and product phases. These may be influenced by the mechanical history of the parent phase and in particular by previous strain hardening. From an experimental point of view, this influence has been shown [5] through the comparison of the evolution of strain in free dilatometric test and in a test consisting in a significant strain hardening of the austenitic phase during cooling and before the metallurgical transformation occurs followed by the transformation without external applied load (Figure 1).

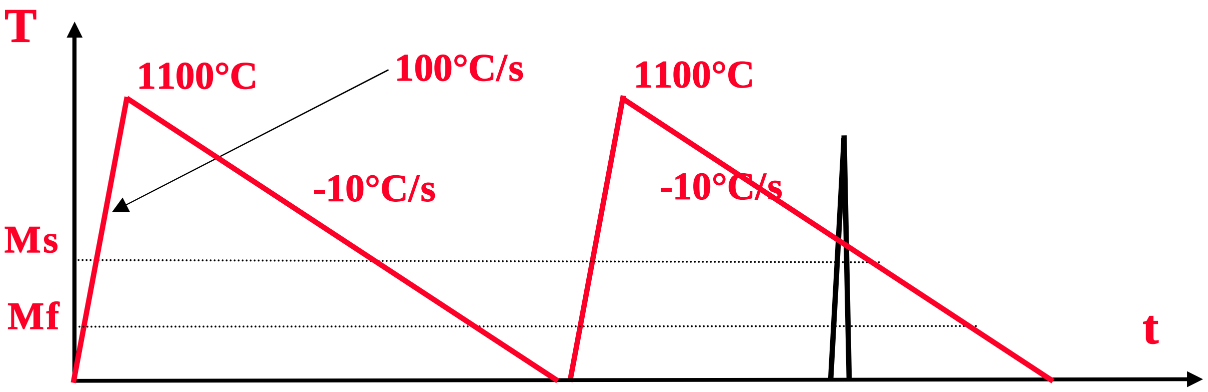
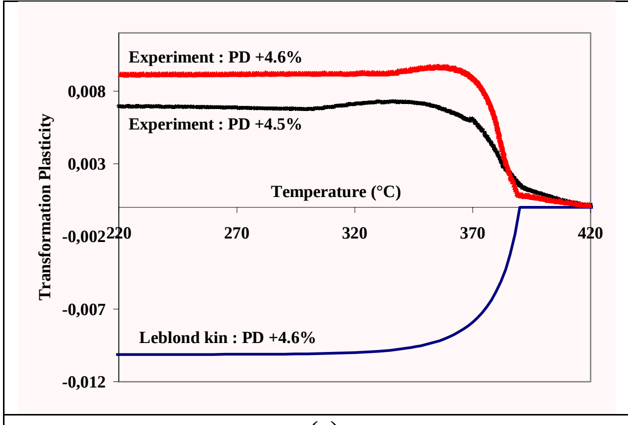
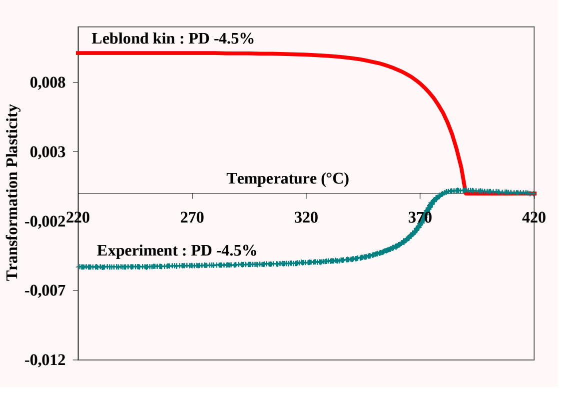


Figure 1: Free dilatometric test followed by predeformation test with a loading-unloading cycle applied before the starting of the martensitic transformation (M_s). The applied stress largely exceeds the yield limit of the austenitic phase.

These test results have been compared to the predictions of Leblond's model [6] that enables to take into account the interaction classical plasticity - TRIP. As it can be remarked in figure 2, the predictions are not at all in agreement with experiments: when experiment exhibits positive TRIP (after positive pre-deformation), the model predicts negative TRIP and vice-versa after negative pre-deformation. The objective of this paper is to contribute to a better understanding of the mechanisms at the origin of the observed discrepancies. For that, we consider in a first stage a classical finite element micromechanical approach already used (see for instance [7]). The mesh (2D) being loaded by a constant uniaxial stress, an arbitrary set of elements constituting a plate is first transformed (changing the material properties of the plate that is subjected to a strain corresponding to the transformation strain). Then the driving force is measured in each element of the mesh in order to select the following elements to be transformed. Figure 3 gives the results of two numerical FE simulations of TRIP following such procedure: it appears that the obtained TRIP depends on the first selected element to be transformed. Furthermore, it can be remarked that TRIP is negative under tensile applied stress which is not consistent regarding experiments. Before simulating the pre-deformation tests, other conditions enabling the selection of the transformed elements are now under consideration: the simulations are in progress and the results will be presented during the conference.



(a)



(b)

Figure 2: TRIP after pre-deformation (PD) test in which a loading-unloading cycle is applied before the starting of the martensitic transformation (M_s). The applied stress largely exceeds the yield limit of the austenitic phase. Comparison between experimental results and the predictions of Leblond's model: (a) Response after positive pre-deformation; (b) Response after negative pre-deformation.

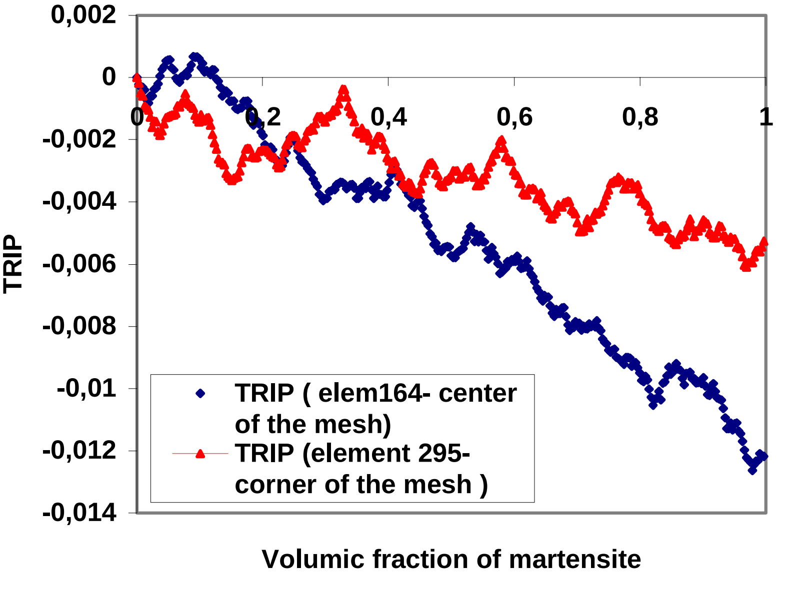


Figure 3: Numerical FE simulation of TRIP under constant applied stress. The result strongly depends on the choice of the first transformed element.

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