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CONCERNING TRANSFORMATION PLASTICITY MECHANISMS FOR DIFFERENT PHASE TRANSFORMATIONS IN STEELS

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When a specimen transforms in a stress field, a plastic deformation is observed, even for stresses lower than the yield stress of the different phases present, which is know as deformation due to transformation plasticity. It has been observed for different alloys and different types of transformation in a same alloy.

We have studied transformation plasticity in steels and Fe-Ni-C alloys for phase transformation controlled by diffusion (pearlitic transformation) and transformation controlled by shear (martensitic transformation of steel and Fe-Ni-C alloys). The relationships : deformation due to transformation plasticity - content of phase formed - applied stress have been obtained for these types of transformation when transformation occurs during isothermal creep tests (pearlitic transformation - 0.8 C steel ; Figure 1) and non-isothermal creep tests (martensitic transformation - Fe-Ni-C alloy ; Figure 2). For pearlitic transformation, the obtained results show a linear relationship between deformation due to transformation plasticity ε^{pt} , content of phase formed X and applied stress σ ($\varepsilon^{pt}(x) = K\ \sigma\ X$). For martensitic transformation, at a given stress, the variations of deformation due to transformation plasticity during progressive transformation are more complex. The slope $d\,\varepsilon^{pt}/dX$ is highest at the beginning of the transformation, decreases when X increases and is constant at about $X > 0.25$.

Moreover, we have obtained the variations of transformation plasticity versus the content of phase formed, during a tensile test of martensitic transformation. The results show that the value of deformation due to transformation plasticity is very large compared to the creep tests and is extremely dependent on the thermomechanical testing conditions.

From the analysis of these results, given in [1] and [2], we discuss the different mechanisms which contribute to transformation plasticity regarding the two basic mechanisms which have been put forward to explain transformation plasticity :

A - Selection of variants of martensite by the applied stress (available for transformations with shear)

B - Orientation of plastic yielding around the transforming particles due to applied stress when transformation occurs with volumic variations and/or shear strain.

For pearlitic transformation (and thus transformation controlled only by diffusion) only mechanism B is acting. For martensitic transformations of steels the two mechanisms are acting. An example of the preponderance of mechanism A can be found in thermoelastic alloys.

The comparison with the models established by different authors leads us to propose that :

* For mechanism A, the selection of martensite variants by the applied stress is related to :

i) the mechanical energy needed for transformation (function of the mechanical properties of the parent phase and of the transformation strain),

ii) the accommodation processes of the transformation strains,

iii) the ratio applied stress versus local internal stress state due to transformation (the internal stress level increases when transformation progresses and is highly dependant on the accommodation process of the transformation strains).

* For mechanism B, different authors have published experimental results considering variations of transformation plasticity with applied stress for a complete transformation and have modelized the variations of transformation plasticity with applied stress. The correlation between transformation plasticity, volumic variation due to transformation and yield stress of the softer phase has been well reported in the litterature. In order to explain our results, another factor must be taken into consideration, that of the velocity of the growing interface compared to the velocity of the accommodation dislocations. Indeed, if the velocity of the growing interface is higher than the mean velocity of the dislocations due to accommodation strains, "recovery" of these dislocations will be held rapidly by the growing interface. Transformation plasticity will be low in amplitude.

However, if growth rate is lower than the velocity of the accommodation dislocations the amplitude of deformation due to transformation plasticity will be greater.

Also, for phase transformations where both mechanisms are acting (martensitic transformation of most ferrous alloys, bainitic transformation) the transformation plasticity will depend on numerous factors. Each mechanism must be taken into account but its contribution must be analysed in relation to the nature of the alloys, the nature of the transformation and the conditions of mechanical testing.

Références :

[1] E. GAUTIER, A. SIMON, G. BECK - Acta Met., in press

[2] E. GAUTIER, A. SIMON, G. BECK - Proceedings of 7th International Conference on Strength of Metals and Alloys (Edited by Mc Queen et al., Pergamon Press) 1985, p. 569.

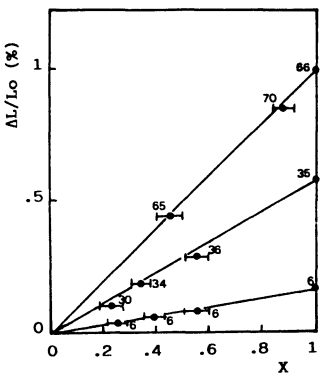

Figure 1 : Variations of deformation during isothermal transformation versus content of pearlite for different applied stresses.

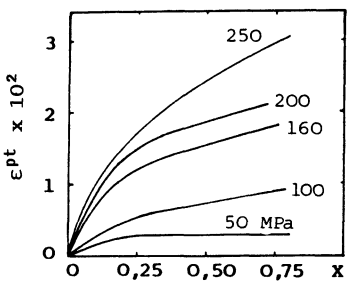

Figure 2 : Variations of deformation due to transformation plasticity versus content of martensite for different applied stresses.

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