HYDROGEN EFFECT ON THE ACTIVATION ENTHALPY OF PLASTIC DEFORMATION

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The strain rate sensitivity of a material arises from a thermally activated contribution to the rate-determining deformation process, e.g. to dislocation slip or dislocation grain boundary interaction. For instance, nanocrystalline f.c.c. metals exhibit an increased strain rate sensitivity compared to a coarse-grained equivalent due to the constraints on dislocation plasticity caused by the multitude of grain boundaries. In this study, the extent to which hydrogen affects thermally activated dislocation mobility and thus the strain rate sensitivity was investigated. For this purpose, specimens were charged in situ, both cathodically and by low-pressure hydrogen plasma, and subjected to nanoindentation, micropillar compression, and strain-rate jump macro-tensile tests, and the results were contrasted. Hydrogen is shown to increase the strain rate sensitivity of f.c.c. nickel but not in a b.c.c structural steel.

The temperature was then varied to the cryogenic level. For this purpose, the macro strain rate jump tests were carried out in a bath cryostat combined with ex situ charging. The low temperature prevents from outgassing. The activation volume for plastic deformation in a head-to-head comparison between nanocrystalline and coarsely grained f.c.c. nickel as well as the b.c.c. structural steel shows that the rate-determining deformation mechanism seems to change for f.c.c. but not for the b.c.c. material. This, together with an increase in hardness and strength in all materials tested, can be interpreted as a pinning effect of hydrogen on dislocation movement originating from the comparatively high hydrogen concentration due to electrochemical charging. This shows how important a direct control of the hydrogen content in the material is to enable reliable conclusions about the influence of hydrogen on the material performance, especially regarding the standardization of material testing methods in the context of decarbonization and hydrogen economy.