Abstract

This thesis concerns the development of numerical models for the prediction of fractures in steel under the influence of hydrogen. Hydrogen is present many places in nature, not least around metals exposed to aggressive environments such as seawater or acid. Furthermore, hydrogen is poised to become a significant feature of a sustainable energy infrastructure. Therefore, it is an unfortunate effect that hydrogen is capable of diffusing into steel and, by its presence, make the steel brittle. This hydrogen embrittlement can cause sudden failure in high-strength components at loads far below what would otherwise be expected. For this reason, it is important to develop efficient numeric models for the prediction of such brittle fractures.

As a base element in the models developed in this thesis, the so-called *phase field* fracture model is used, which has been immensely popular in recent years. The advantage of the phase field model is that it is especially flexible and can be used for both complex fracture scenarios and, as here, multiphysics with hydrogen interaction.

The suitability of the phase field model is assessed in this Thesis through a succession of numerical experiments which reveal that the model yields reliable results in accordance with classic fracture mechanics. Afterwards, the capability of the model to capture the expected physics of hydrogen-assisted fatigue is demonstrated. A set of relevant engineering problems are studied to demonstrate the suitability of the proposed model in an applied context, where both virtual experiments and in-service strength assessments based on inspection data are shown to be possible.

Finally, an advanced version of the model is applied, which is enhanced with strain gradient plasticity, to show that the hydrogen embrittlement model utilized together with the increased crack tip stresses predicted by strain gradient plasticity are able to rationalize brittle fracture in an otherwise ductile material.

In addition, this thesis contains detailed discussion of relevant aspects of the phase field model and yet unpublished work on the acceleration of fatigue computations.