

EVALUATION OF THE DIFFUSIBLE HYDROGEN CONCENTRATION IN STEELS WITH THE ELECTROCHEMICAL PERMEATION TECHNIQUE

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A good knowledge of the hydrogen diffusion, distribution and uptake in materials with respect to the hydrogen activity (or pressure), material microstructure, time and temperature, is necessary for the assessment of the performance of equipments used in hydrogen environments if hydrogen damage is a concern.

The data derived from electrochemical permeation measurements can be used for this purpose, as this technique is one of the main tool used for the measurement of hydrogen diffusion in metals [1] in the near room temperature range. Hydrogen atoms are usually generated on one side of a thin metal membrane by potentiostatic or galvanostatic cathodic polarization in acid or alkaline media. The hydrogen atoms which diffuse through the sample and reach the exit side are detected with a high sensitivity as an oxidation current by anodic polarization in alkaline solutions. Beside the well known Arrhenius behaviour of the hydrogen diffusivity and solubility in metals [2], the hydrogen discharge mechanism, the permeation yield and the hydrogen diffusion coefficient are observed to depend more particularly on the metal structure and the hydrogen activity. Accordingly, the comparison of the permeation characteristics of different materials measured from electrochemical permeation experiments is not straightforward and requires the calibration in terms of equivalent hydrogen pressure. Owing to the large versatility associated with electrochemical charging methods, equivalent hydrogen pressures similar to those involved in gas phase charging experiments can be generated and the transport and uptake of hydrogen investigated for given hydrogen activity or concentration. Furthermore, electrochemical permeation measurements are particularly well suited for the investigation of the influence of microstructure on the hydrogen transport and uptake which are strongly affected by hydrogen trapping [3,4] on microstructural defects which may act as sinks or sources for hydrogen. In complex microstructures such as those encountered in ferritic steels, reversible and irreversible traps play a large role on hydrogen diffusion and absorption. Both types of traps affect the build up permeation transients [5,6]. The measurement of hydrogen concentrations in metals is difficult due to the small solubility of hydrogen in structural materials [7] and more particularly in bcc materials where the hydrogen diffusivity is very large at room temperature. The discrimination of the diffusible (total lattice and reversibly trapped) and irreversibly trapped hydrogen concentration is an even more difficult problem, whereas the quantification of local hydrogen concentrations needs further important developments of innovative experimental techniques [8,9]. An advantage of the electrochemical permeation technique is the possibility to evaluate the amount of diffusible hydrogen, which is of paramount importance in the occurrence of hydrogen-induced damage in ferritic steels, by monitoring the degassing of hydrogen, from the onset of the suppression

of the hydrogen source, in materials previously charged at steady state. This is achieved by recording the decay of the permeation current with time, after interruption of cathodic polarization which involves a change of the boundary conditions on the former charging side of the sample.

This paper reports experimental results on the influence of electrochemical charging conditions and microstructure of Cr-Mo steels on the permeation of hydrogen investigated with the electrochemical permeation technique. A special attention is paid to the quantification of the hydrogen activity and its influence on the effective hydrogen diffusion coefficient derived from build up and decay transients. The values of the hydrogen concentration, the hydrogen diffusion coefficient and the boundary conditions which can be used in order to evaluate the diffusible hydrogen content from decay transients are discussed. The results are compared to those obtained with the fusion thermal conductivity method applied to samples cathodically charged, prior to outgassing in air at room temperature for different times.

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