Stress corrosion cracking of Ni-base alloys in pressurized water reactors: from the «Coriou effect» to the use of tracers

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Abstract

This overview of stress corrosion cracking (SCC) of nickel base alloys in pressurized water reactors (PWRs) includes an historical perspective and assesses the latest developments on the investigations regarding the SCC mechanisms.

The “Coriou effect” named the stress corrosion cracking of a nickel alloy (Alloy 600) in pure (or primary) water at high temperature. The SCC of Alloy 600 has been observed for the first time by Henry Coriou at the end the 1950s in pure water at 350°C. Even if these tests were more representative of water reactor conditions than those obtained in boiling magnesium chloride solutions where Alloy 600 is not susceptible to SCC, nevertheless, Alloy 600 has been used extensively in water reactors up to the 80s. Large researches and developments have been made and lead to the use of Alloy 800 or Alloy 690.

In the second part of the presentation, updated knowledge of SCC in PWRs is summarized and focuses on the use of tracers to determine SCC mechanisms: (i) formation of oxide layers and intergranular oxidation are studied with the help of oxygen 18, (ii) using deuterated species (D_2 versus D_2O), the main hydrogen uptake by the alloy comes from the cathodic reaction on water molecules, (iii) in the oxide layer of Ni-base alloys, the transport of hydrogen and of oxygen is concomitant, as observed by comparing diffusion of D and ^{18}O. These observations, together with some atomistic modelling, lead to a local intergranular approach where both oxidation and hydrogen may be involved in initiation and propagation of cracks in Ni-base alloys and under PWRs primary conditions (while impurities play a major role in secondary PWRs environments).

In conclusion, the good behavior of Alloy 800 and of Alloy 690 is underlined and linked to the higher chromium content. The remaining question is to know if these alloys are SCC immune, or if it is only the initiation time which is longer, over decades in PWRs conditions.

"CORROSION 2019"
INTERNATIONAL SCIENTIFIC CORROSION CONFERENCE, 27-29 MAY 2019
Warsaw, Poland