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► To cite this version:

Apou Martial Kpemou, M C Baietto, Jean Desquines, Tatiana Taurines, A Ambard, et al.. An experimental approach for the analytical study of secondary hydriding of *m5 framatome clad fuel rods during a loca. NuMat2022: The Nuclear Materials Conference, Oct 2022, Ghent, Belgium. irsn-04594542

HAL Id: irsn-04594542

<https://irsn.hal.science/irsn-04594542>

Submitted on 30 May 2024

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AN EXPERIMENTAL APPROACH FOR THE ANALYTICAL STUDY OF SECONDARY HYDRIDING OF *M5_{Framatome} CLADDED FUEL RODS DURING A LOCA

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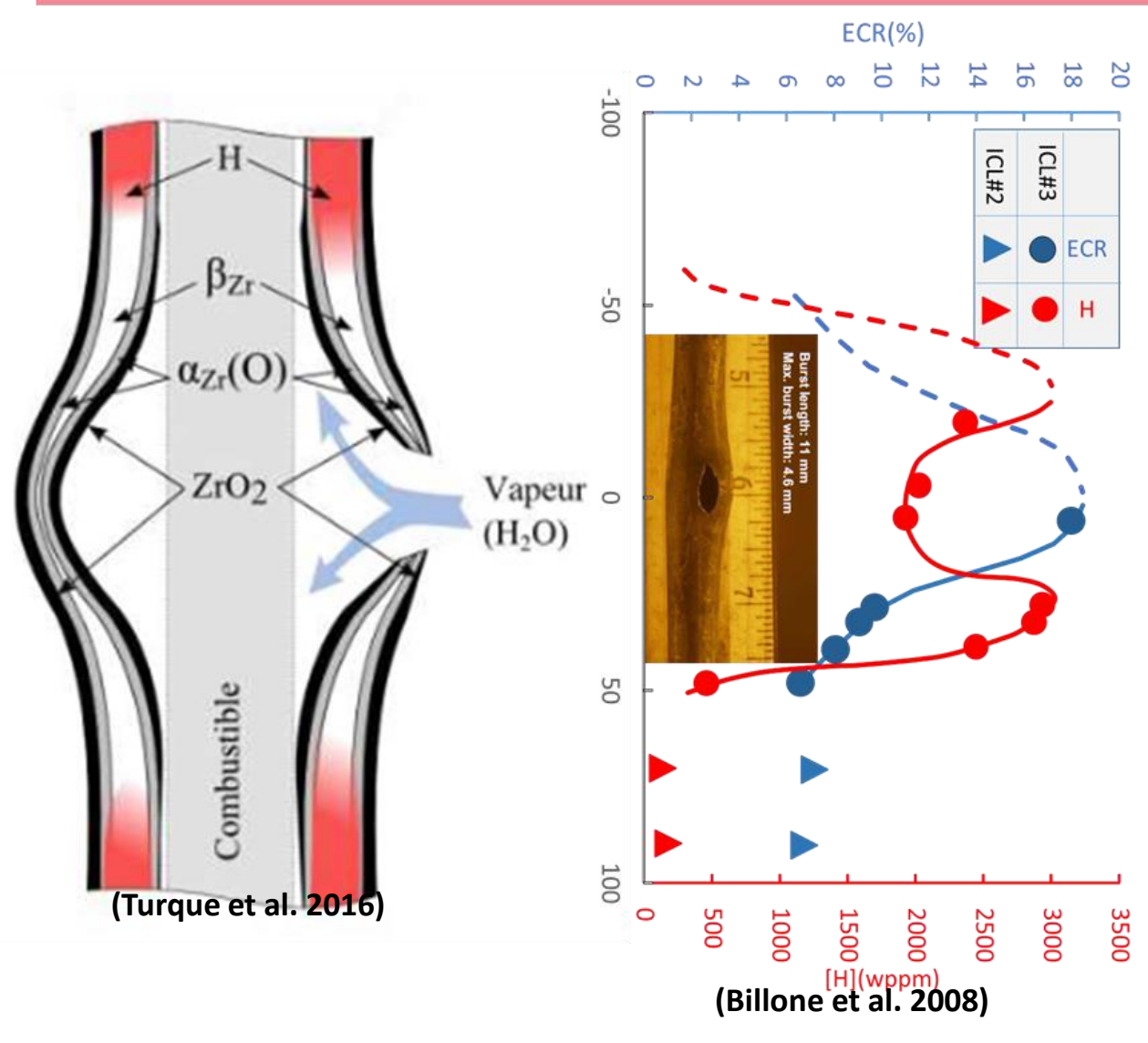
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ABSTRACT

Secondary hydriding may occur in nuclear fuel cladding exposed to steam at high temperature in Loss of Coolant Accident (LOCA) conditions. During a LOCA transient, the cladding may burst, and the steam ingress into the cladding results in inner surface oxidation in the vicinity of the burst region. A high hydrogen uptake can then occur near the burst position, leading to localized hydrogen peak concentration in the cladding: this is known as secondary hydriding (Hsec). The aim of this project is to improve the understanding of this phenomenon. Burst opening and gap size, oxidation duration and other parameters influences are characterized using an axisymmetric testing procedure reproducing LOCA conditions including oxidation and final quench on *M5_{Framatome} cladding.

Hydrogen axial profiles from semi-integral LOCA tests



ANALYTICAL LOCA TESTS - METHODS

LOCA semi-integral tests transient

Analytical LOCA tests for secondary hydriding

Two types of pellets:
Porcelain pellet (~ 8.0 mm)
Alumina pellet (8.1 mm, 8.2 mm)

Sample: As-received M5_{Framatome} cladding

LOCA analytical tests transient

Study parameters:
Oxidation duration
Gap size
Opening size
Pre-oxide layer
Oxidation temperature

ANALYSIS METHODS

Cladding inner surface

Pellet visual examination

Hsec position

Axial hydrogen profile

Metallographic image

Test with pellet centering

Temperature profiles

Internal oxide decreasing distance

μ-Libs (O & H)

EPMA (O, Nb, Fe)

SIMS (O & H)

Post-tests analysis

- Dark deposit on pellet surface indicating position of the boundary between inner oxidation & secondary hydriding. Similar marking at the cladding inner surface
- Hydrogen axial profiles obtained by Hot Vacuum Extraction
- Metallography: Identification of the different phases of the cladding. Outer and inner oxide layer thickness axial profile
- EPMA and μ-LIBS analysis for local chemical species content

O 2D Map using EPMA & μ-LIBS analysis

PRELIMINARY RESULTS

1200 °C oxidation duration influence

Influence of oxidation duration: [H] average (ppm) vs Distance from opening (mm) for various durations (100s to 1400s).

Integrated [H] picked-up (ppm*mm) vs oxidation duration (s).

Hydrogen axial profiles for different oxidation duration: HP = 14 ± 1.5 mm.

- Hydrogen profile broadening
- Hydrogen peak position evolves with oxidation duration
- Hydrogen uptake process rate seems to be fast at the first minutes and the slow down in time

CONCLUSIONS - PERSPECTIVES

- Analytical tests allow secondary hydriding parametric studies during HT oxidation under steam environment.
- The longer the oxidation duration is, the higher the hydrogen uptake is with a decreasing rate.
- The study of gap size, pre-oxide layer, opening size and oxidation temperature influence is under progress.
- Semi-integral segmented tests (creep ballooning then HT oxidation) are planned.