Material Testing and Recommendations for H_2 Components under Fatigue

(GA 303422)

Laurent Briottet
CEA / LITEN (French Atomic and Alternative Energy Commission)
www.mathryce.eu

PROJECT OVERVIEW

- SP1-JTI-FCH.2011.2.8 Pre-normative research on design and testing requirements for metallic components exposed to H_2 enhanced fatigue
- October 1, 2012 to September 30, 2015
- Budget: Total budget 2,492,937€
  FCH JU contribution 1,296,279€

To provide **recommendations** and a **methodology** based on **lab-scale experimental tests** to design and assess the **life of a pressure vessel** taking into account **fatigue loading under H_2 gas**

- Stage of implementation 100%

PROJECT TARGETS AND ACHIEVEMENTS

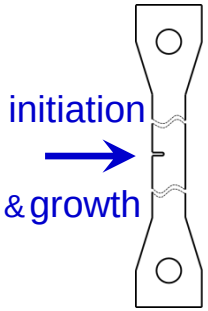
Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
MAIP			
"…Removal of non-technical market barriers particularly through the development of RCS"	To propose a design methodology Recommendations for implementation in international standards.	100 % A methodology and recommendations have been presented to ISO/CD 19884 and to EN 13445-3	

PROJECT TARGETS AND ACHIEVEMENTS

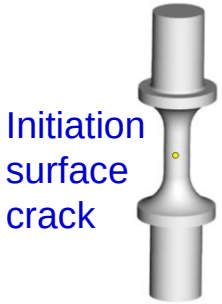
Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
AIP			
Design code for pressure equipment in hydrogen service	To provide recommendations to improve design standards or codes	100% Recommendations on ISO/CD 19884 and on ASME KD10 article	
Metallic material characterization for hydrogen service	Lab-scale tests developments	100% • Three type of tests have been used • Data for only one material AISI 4130 • Results on FCI as well as on FCG	
Experimental implementation of design approach and design testing approach	Development of methodology based on **lab-scale tests**	100% • A methodology have been proposed based on H_2 sensitivity factor (HSF) • 2 test methods are proposed to evaluate this HSF	

PROJECT TARGETS AND ACHIEVEMENTS

Lab-scale tests



Notched tension

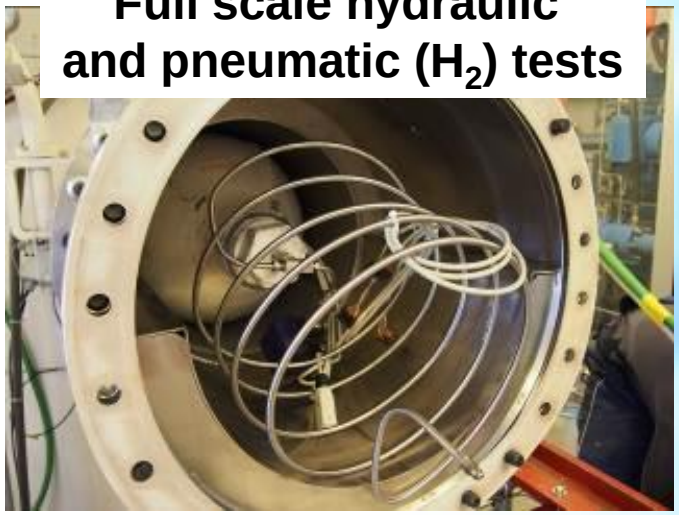


Drilled LCF bar

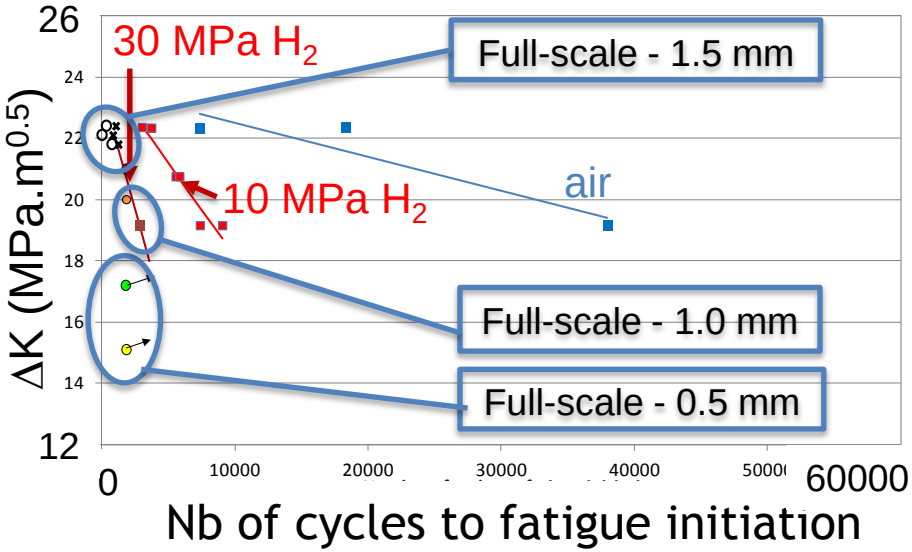
Relevant pressure cycle

Disk test by pressure

Full scale hydraulic and pneumatic (H_2) tests



Fatigue Crack initiation



- N_i ↘ when P_{H2} ↗
- N_i ↘ when ΔK ↗

Hydrogen sensitivity factor

Deep notches / loading
P ~30 MPa
} α_{H2} ~ 12

$\alpha_{H2} \leq 12$ for less severe conditions

PROJECT TARGETS AND ACHIEVEMENTS

Use of Fracture Mechanics

Based on a H_2 sensitivity factor (HSF)

How to define HSF?
From lab scale tests
- Disc tests
- SENT (SENB)

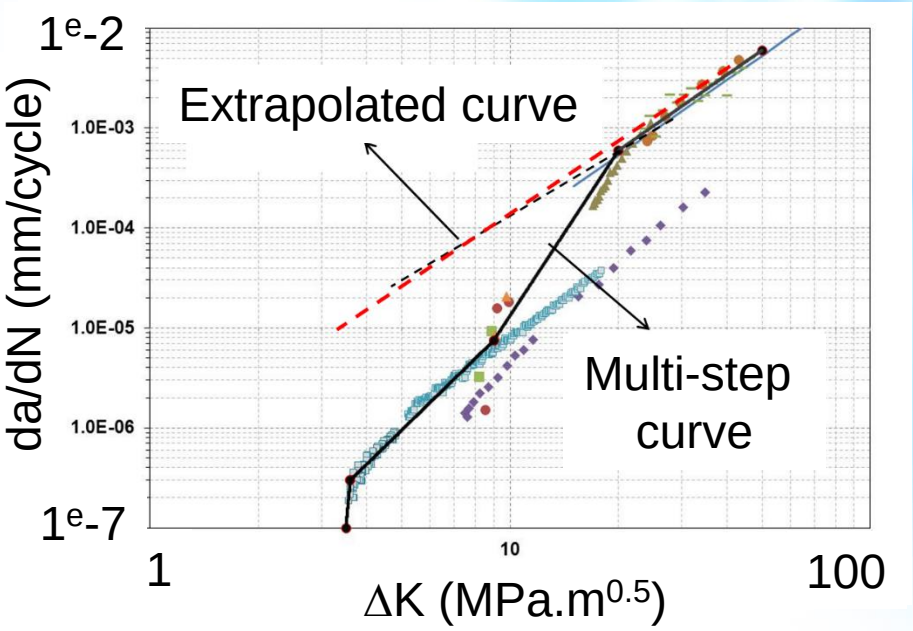
↓

How to use HSF ?

↓

Full scale hydraulic tests

ISO TC197 / WG15



Extrapolation of FCG (ASME KD10) at low ΔK, replaced by a multistep FCG law

RISKS AND MITIGATION

The obtained results should still be checked and updated for the following cases:

- High H_2 pressure
- Low ΔK
- R effect
- Data base for other materials

SYNERGIES WITH OTHER PROJECTS AND INITIATIVES

- Several partners imvolved in the following projects : *HyComp*, *HyIndoor*, *HyTransfer* dedicated to Hydrogen structural integrities or Prenormative research

- Two letters of interest from Sandia National Laboratory (USA) and Hydrogenius (Japan)
- Prof Murakami (Hydrogenius) and Somerday (SNL) attended technical meeting
- Mathryce invited in forums and workshops organised by SNL and Hydrogenius
- SNL and Hydrogenius experts invited to Mathryce workshop

- SNL is performing Crack Initiation tests at 1000 bar H_2

HORIZONTAL ACTIVITIES

- Several partners are involved in RCS working groups. In particular, ISO/TC 58/ WG 7 dedicated to *Gas cylinders – Compatibility between gases and materials*
- 2 Workshops organised by the project
- Recommendations and methodology presented to CEN and ISO experts
- Recommendations and methodology presented during an ISO/TC197 WG15 meeting

DISSEMINATION ACTIVITIES

H_2 testing workshop	USA	04/13	Testing device under H_2
H_2 design code workshop	USA	07/14	Mathryce approach for RTD
Materials Qualification for H_2	USA	07/15	Testing and fatigue assessment
1st Mathryce Workshop	Paris	Sept 18, 2015	H_2 enhanced Fatigue
2nd Mathryce workshop	Paris	Sept 21, 2015	Recommendations (ISO, CEN)

Int. H_2 forum	Japan	2013-2015	Mathryce project
ICHS 2013	Belgium	2013	Mathryce project
Steel & Hydrogen 2014	Belgium	2014	Fatigue experimental dvpts
ASME PVP 2014	USA	2014	H_2 enhanced fatigue
HY-Storage, Embrittlement, Applications	Brazil	2014	- H_2 enhanced fatigue - Comparison of existing standards
ASME PVP 2015	USA	2015	Fatigue and full scale tests under H_2

Briottet L. et al., *Fatigue crack initiation and growth in a CrMo steel under hydrogen pressure*, Int. J. of Hydrogen Energy, 2015, in Press.

EXPLOITATION PLAN/EXPECTED IMPACT

- Increase of knowledge on metal/hydrogen/fatigue interactions, including **fatigue crack initiation.**
- **Experimental developments** to address hydrogen enhanced fatigue.
- A **design code** dedicated to pressure vessel design including rules **for hydrogen enhanced fatigue** is necessary to **ensure safety** and **facilitate competitive development** of dedicated infrastructures. Particular concern: H_2 buffer vessels ($p \geq 850$ bar, public access)

- Cross-cutting:
  - After presentation to ISO TC197 WG15 → some recommendations may be included in the current standard draft
  - Need for additional data at low ΔK, at high P
  - Need for additional work to improve FCI characterization under H_2

  → Common interest with USA and Japan