Application 2016

Hydrogen embrittlement of quenched and tempered steels

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INTRODUCTION

Hydrogen offers effective solutions to energy supply with a low environmental impact. However, such development is based on a convenient and safe hydrogen infrastructure including transport, distribution to end users and hydrogen storage. However, problems linked to hydrogen embrittlement (HE) of metallic materials such as steels have been highlighted.

HE results from a synergy of three parameters: materials (e.g. chemical composition, microstructure, mechanical properties), environment , and design (applied stresses).

OBJECTIVE

Main aim is to carry out slow strain rate tests (SSRT) under different hydrogen charging conditions, using some facilities offered by Tecnalia within the H2FC European Project, on high strength quenched and tempered low-alloy steels manufactured by Dalmine S.p.A., in order to appraisal its sensitivity to HE.

MATERIALS

Two low alloy steels in quenched & tempered (Q&T) conditions having similar strength level, but different microstructures.

EQUIPMENT

A SSRT (Slow Strain Rate Test) device from Cortest will be used for this evaluation. It is composed by a 2.2 l capacity reactor, 2 LVDT, a pressure and temperature controller, and a load cell with a maximum capacity of 10 000 lbs.

TESTING CONDITIONS

SSRT under four different conditions will be carried out. At least three specimens will be tested for each material and environmental condition.

- Inert atmosphere (nitrogen) at a pressure of 1 bar (reference measurement);
- 5%NaCl, 0.5%CH3COOH at pH 2.7 saturated with H2S at 1 bar;

- 5%NaCl, 0.5%CH3COOH at pH 2.7 or/and synthetic seawater (standard ASTM D1141) under cathodic polarization at -1.5V vs. Ag/AgCl (low H electrochemical charging);
- 5%NaCl, 0.5%CH3COOH at pH 2.7 or/and synthetic seawater (standard ASTM D1141) under cathodic polarization at -1V vs. Ag/AgCl (high H electrochemical charging).

The tensile rate during the test will be 4x10-6 s-1.

After the tensile test the rupture time, the presence of secondary cracks, and the decrease of sample diameter will be evaluated.

Hydrogen embrittlement will be assessed through the measurements of reduction of area and total elongation at the end of the test under hydrogen charging compared to the values obtained in the inert environment.

TEST MATRIX

Hereafter, the proposed test matrix for a short term H2FC project to be completed in three months, is reported:

- Two low-alloy steels in quenched & tempered (Q&T);
- Four environments: 1) inert (N2 gas), 2) low H charging, 3) high H charging, 4) NACE solution A with 100% H2S at 1 bar;
- Two specimens for inert environment and three specimens for each H-charging environment (3 conditions) are foreseen.

The minimum total number of tests will be 22: 2x2 (inert) + 3x3x2 (with H).

Materials will be supplied by Dalmine S.p.A. in the form of pipe samples. Specimens will be machined by Tecnalia which will perform all SSRTs. After testing and HE evaluation, all broken specimens and remaining material shall be returned to Dalmine S.p.A.