Hydrogen absorption evaluation in PHS 2000 hot stamping process with online non-destructive method

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Speaker: Serena Corsinovi, Letomec srl

AGENDA

- Hydrogen Embrittlement
- Hydrogen Embrittlement Control and Prevention
- The TDA Analysis
- HELIOS 4 Hot Probe
- Slow Strain Rate Test
- Four Point Bending Test
- Measures on finished coils and assembled car bodies
- Industrial case study in Cassino FCA plant
- Conclusions
- Future Works

Hydrogen Embrittlement

REDUCTION OF FUEL CONSUMPTION, CO_2 EMISSIONS, ELECTRICAL CAR GENERATION

COSTS REDUCTION

CRASH RESISTANCE INCREASE

VEHICLE WEIGHT REDUCTION

AHSS ARE MUCH SENSITIVE TO HYDROGEN EMBRITTLEMENT

IT IS ESSENTIAL TO CONTROL THE HYDROGEN PICK-UP AND CONTENT IN STEELS DURING STEELMAKING, CARMAKING AND IN THE VEHICLE IN-SERVICE CONDITIONS

Hydrogen Embrittlement Control and Prevention

What is the better solution for an efficient and reliable quality control?

A VERY PRECISE MEASURING EQUIPMENT WITH A TIME CONSUMING SAMPLE PREPARATION PROCEDURE, ASSUMING THE RISK OF HYDROGEN DESORPTION DURING SAMPLE CUTTING AND TRANSPORT → **TDA ANALYSIS**

OR

HELIOS 4 HOTPROBE ← **A FEW MINUTES NON DESTRUCTIVE MEASUREMENT?**

CAN PERFORM MEASUREMENT DIRECTLY ON ASSEMBLED CAR BODIES OR COILS. LESS SIGNIFICANT DIGITS BUT USEFUL FOR PROCESS MONITORING!

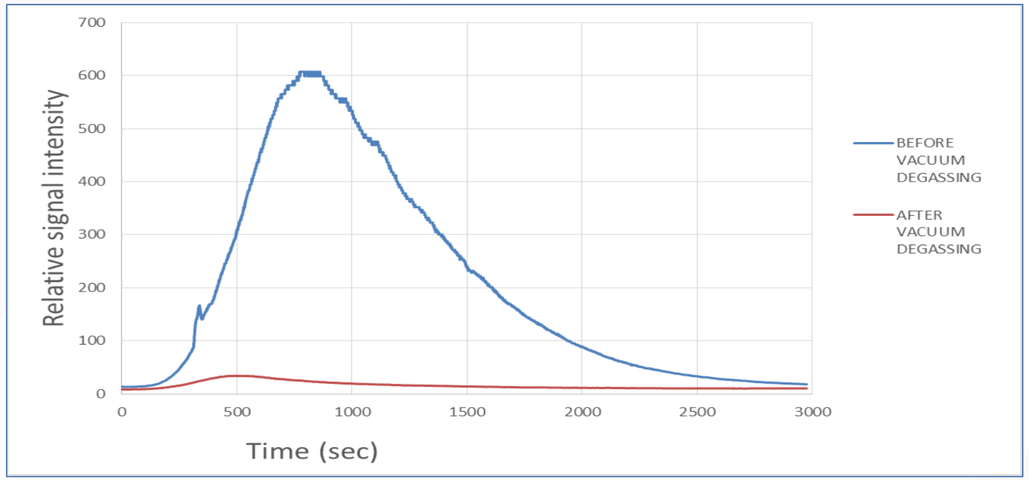
The TDA ANALYSIS

HELIOS 3

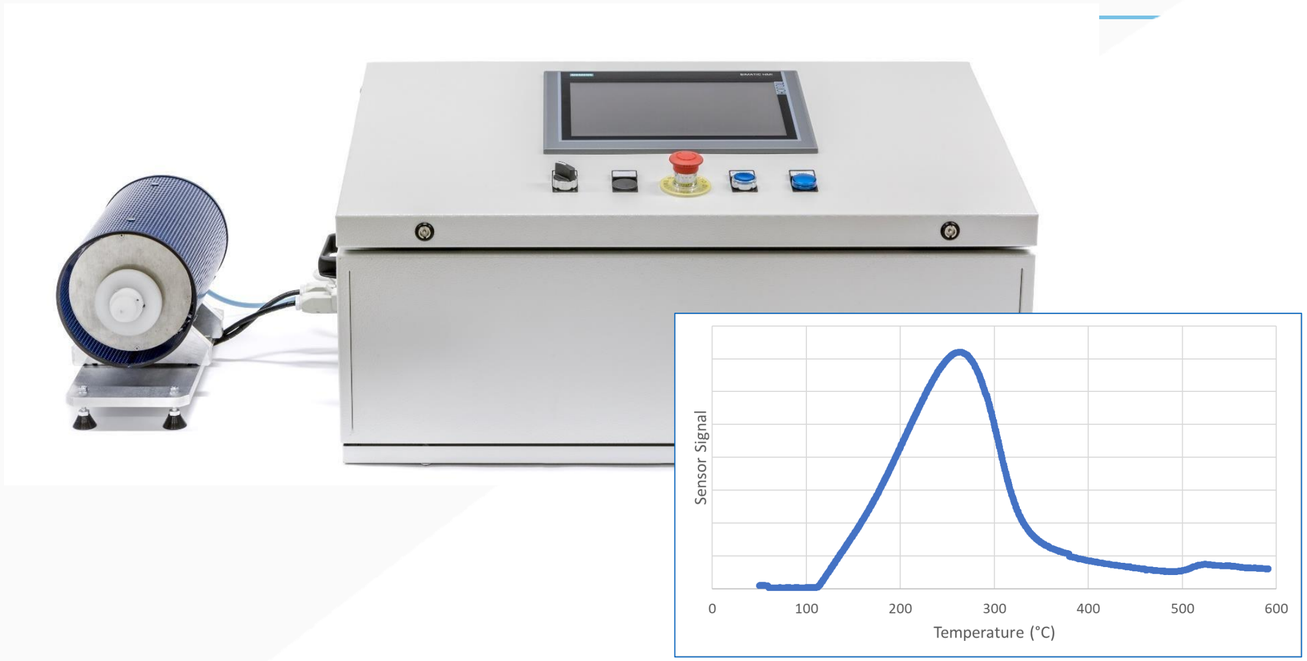
HYDROGEN SOLUBILITY AND TRAPPING

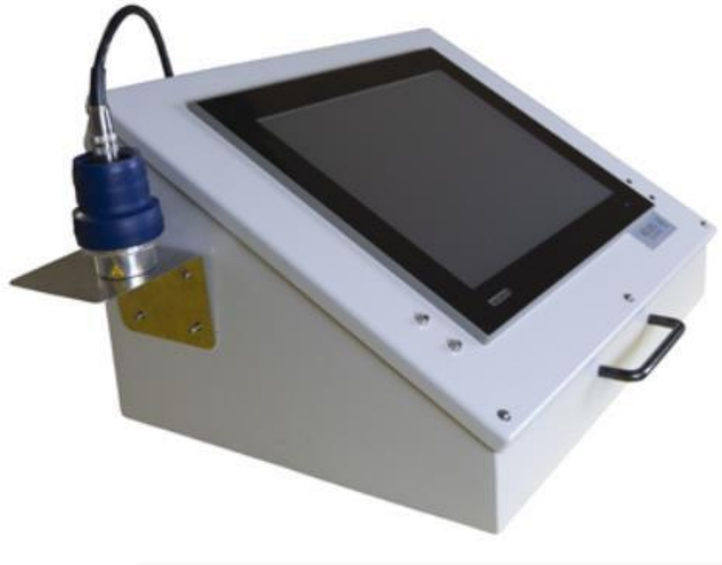
The HELIOS 3 instrument detects the reversible hydrogen (TDA) and is can perform TPD analysis.

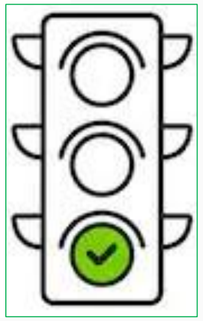
HELIOS 3 can become the basis for developing methods able to evaluate the hydrogen content in components to quantify, for instance with proper indices, the risk of hydrogen induced delayed fracture in service.



- NO SAMPLE CUTTING – CUSTOMIZED FURNACE DIMENSIONS
- TEST ON COATED PARTS (NO COATING REMOVAL!)
- NO CARRIER GAS NEEDED: INSTRUMENT CAN BE LOCATED ON PRODUCTION LINE!
- INDUSTRIAL AND ROBUST EQUIPMENT
- USER FRIENDLY INTERFACE







HELIOS 4 HOT PROBE ANALYSIS

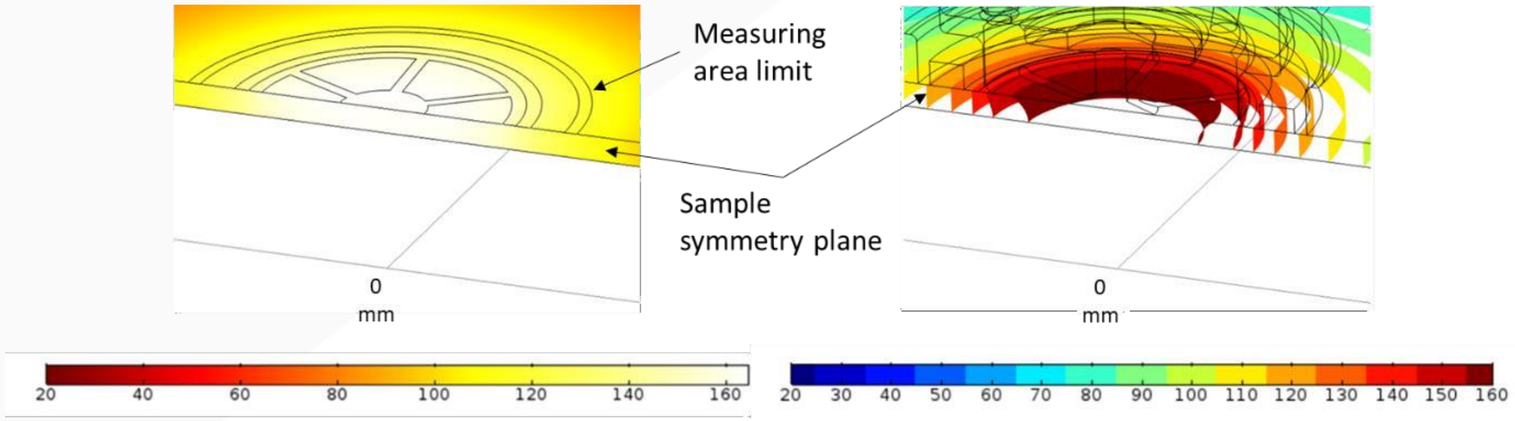
The evolution of TDA applied to finished components

HELIOS 4 HOT PROBE

HELIOS 4 HOTPROBE

DIFFUSIBLE HYDROGEN ONLINE MEASUREMENTS

HELIOS 4 HOT PROBE is an innovative instrument useful to perform diffusible hydrogen measurements on metallic samples or directly on finished parts.



- QUICK MEASURES
- NO USE OF ELECTROCHEMICAL CELLS
- NO CARRIER GAS
- NO SAMPLE PREPARATION
- MEASURES ON FINISHED PARTS
- ALUMINIZED AND ZINC COATED STEELS

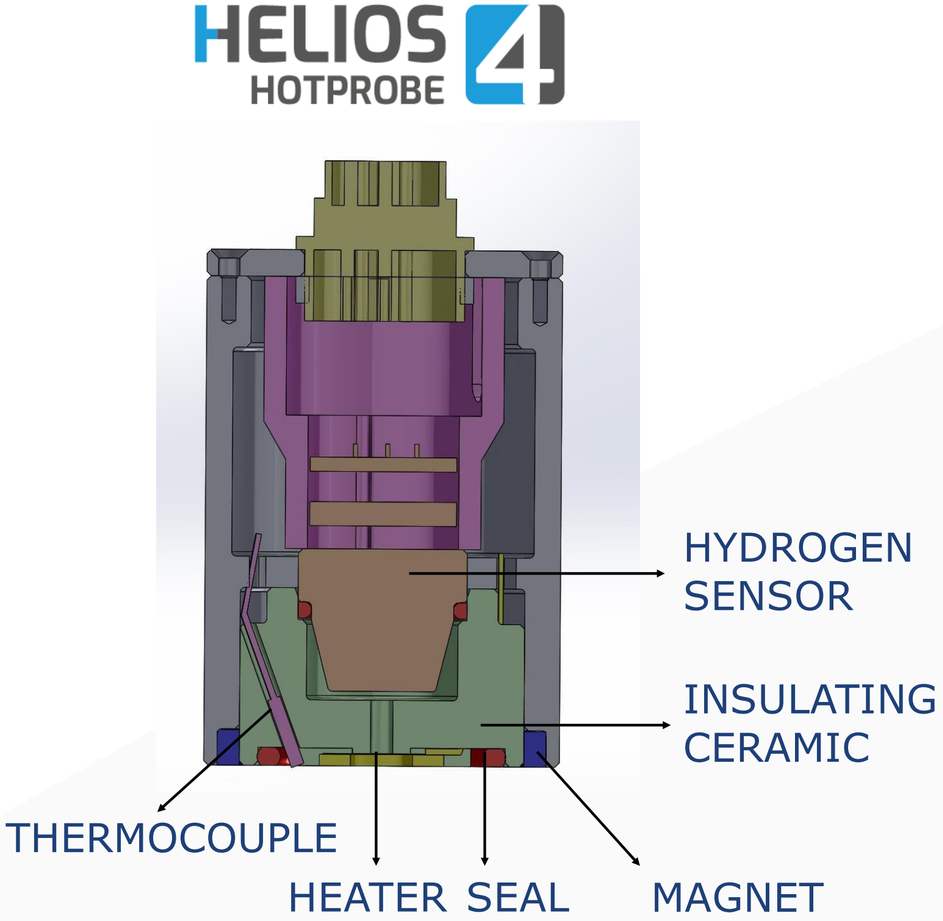
HELIOS 4 HOT PROBE

The ceramic heater locally heats the component enhancing hydrogen diffusion out of the metal. The heating doesn't reach a temperature higher than about 180°C, avoiding any damage or modification to the part.

Moreover, the test temperature was chosen and optimised in function of material coating.

The hydrogen flux coming out of a metal surface flows through a chamber inducing an electrical signal to the sensor, that depends on the diffusible hydrogen flux in the examined sample.

Once acquired the signal is processed by complex mathematical codes to determine the parameters related to hydrogen diffusion, flux and concentration.

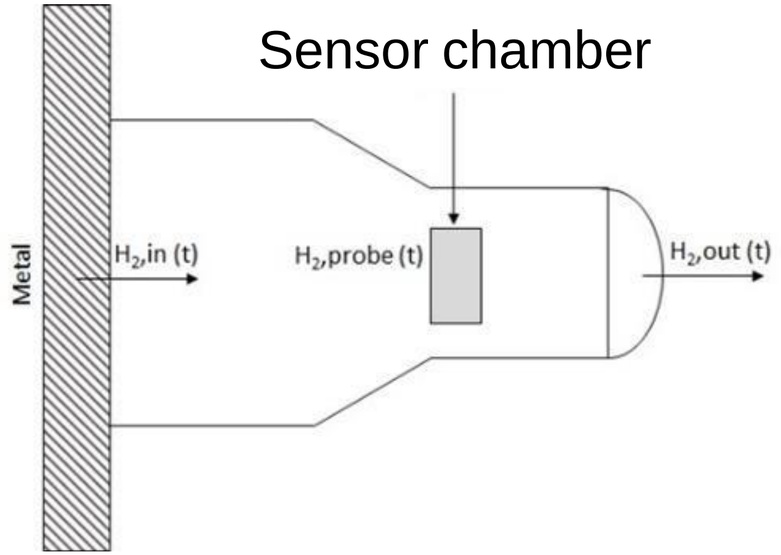


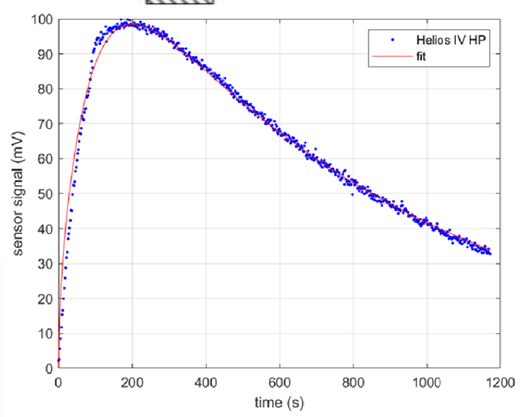
HELIOS 4 HOT PROBE

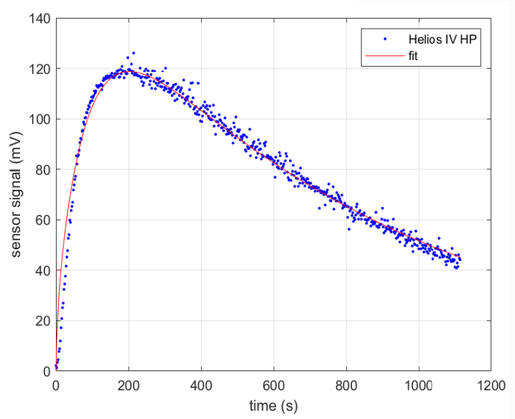
$$\frac{dC(t)}{dt} = K J_{in}(t) - aC(t)$$

$$C(t) = Ke^{-at} \int_0^t J_{in}(r) e^{ar}\, dr$$

Where Jin is the hydrogen flux from metal to the probe:
- K is a constant function of material and probe geometry;
- a is a constant function of probe geometry.



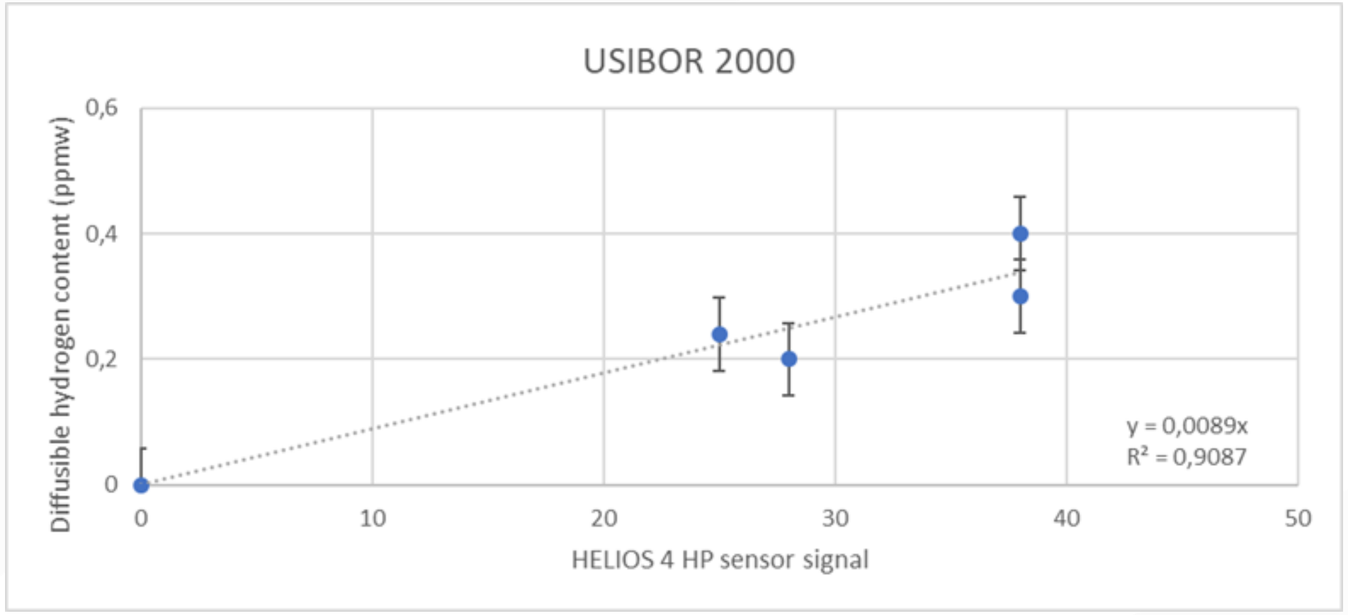




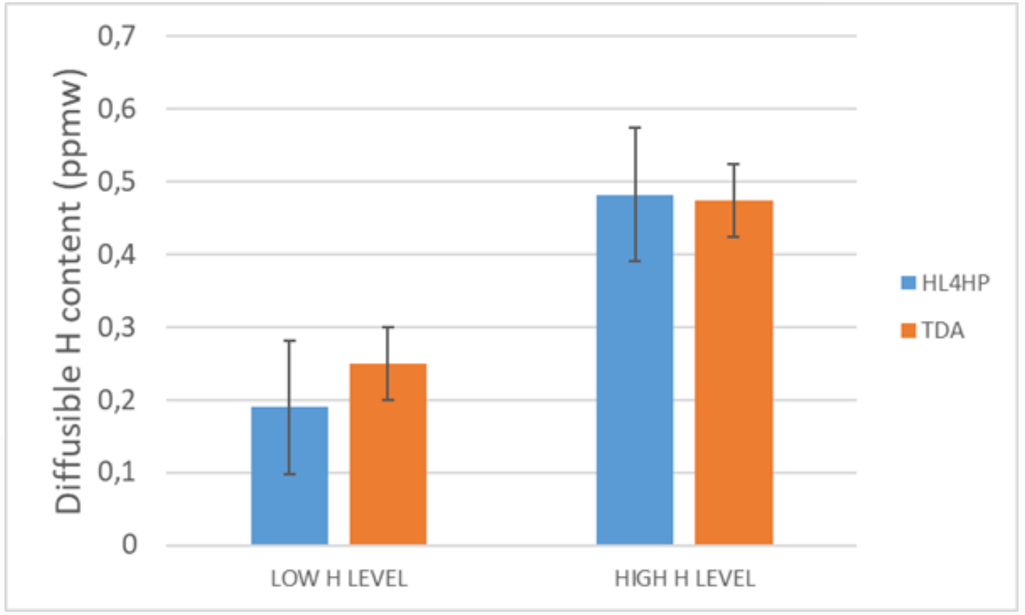
HELIOS 4 HOT PROBE

Sensor calibration curve: USIBOR 2000

Sensor response, for very low concentrations, can be assumed linear.



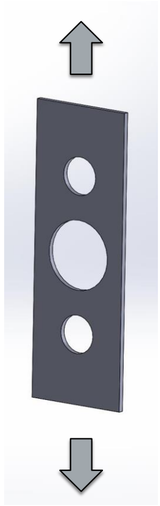
Average values of diffusible H content measurements.

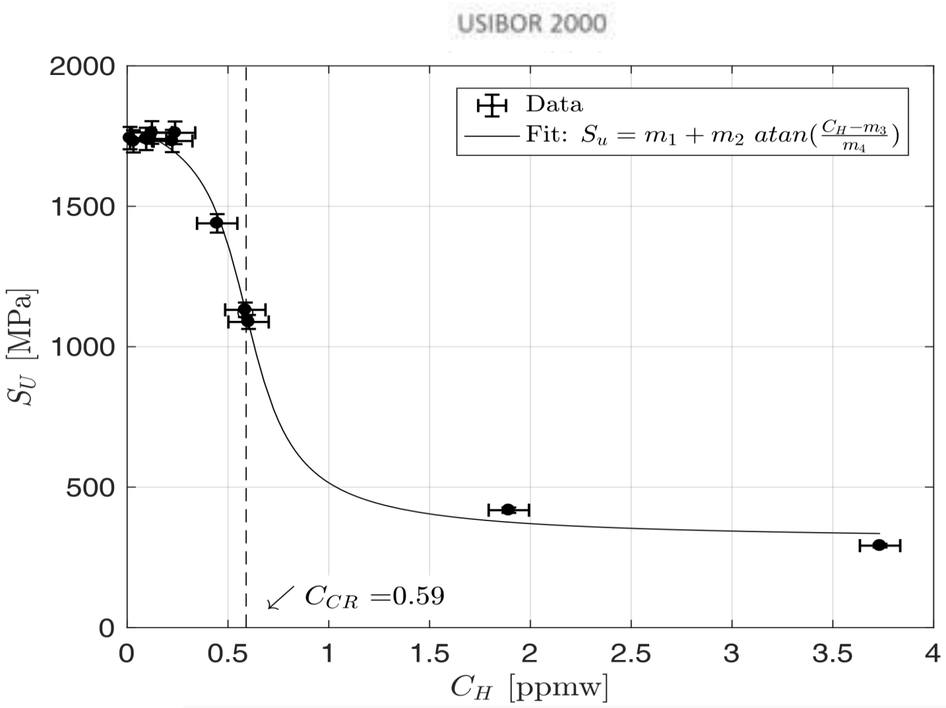


Slow Strain Rate Test

STANDARD ASTM G-129

- Sample geometry in accordance with SEP 1970:2011
- Regression of experimental data (UTS vs diffusible hydrogen content) m1, m2, m3, m4 are best fitting parameters
- Threshold value according to ASTM STP 962



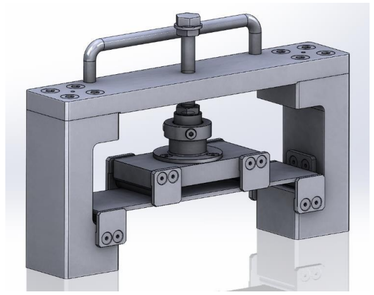


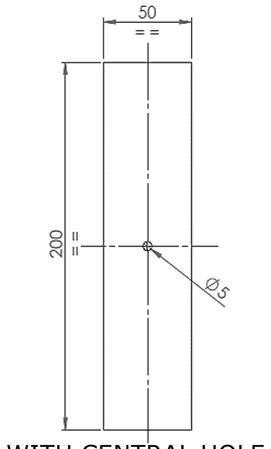
$$UTS = m_1 - m_2 \arctan(\frac{C_H - m_3}{m_4})$$

4 Point Bending Test

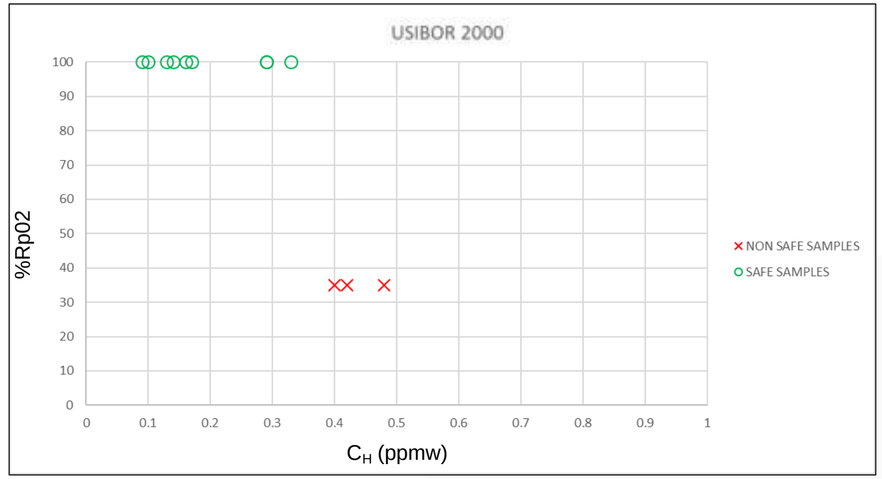
STANDARD ASTM F-1624

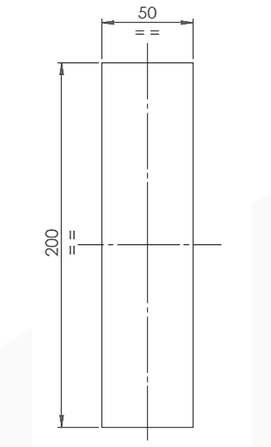
- Step loading from 50% to 90% of the Yield strength
- Specimen is a thin plate 50x200 mm with/without 5 mm central hole
- If no breakage has occurred after 54 hours the sample is classified as safe



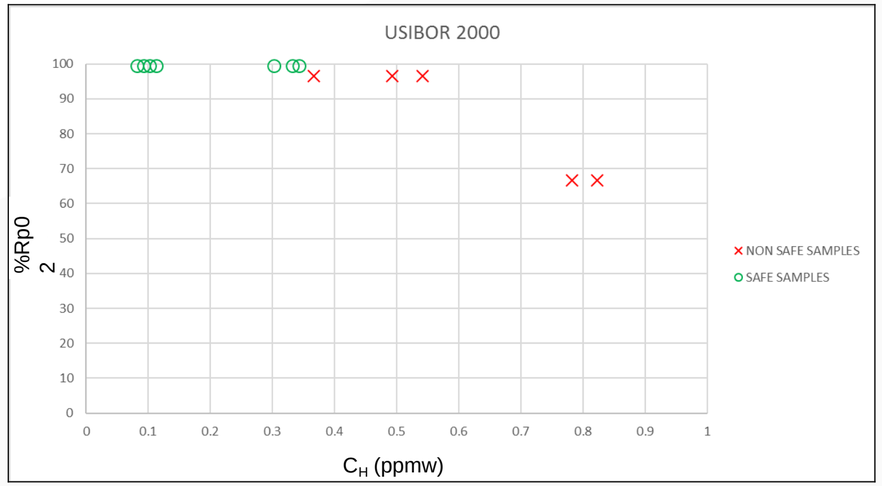


WITH CENTRAL HOLE





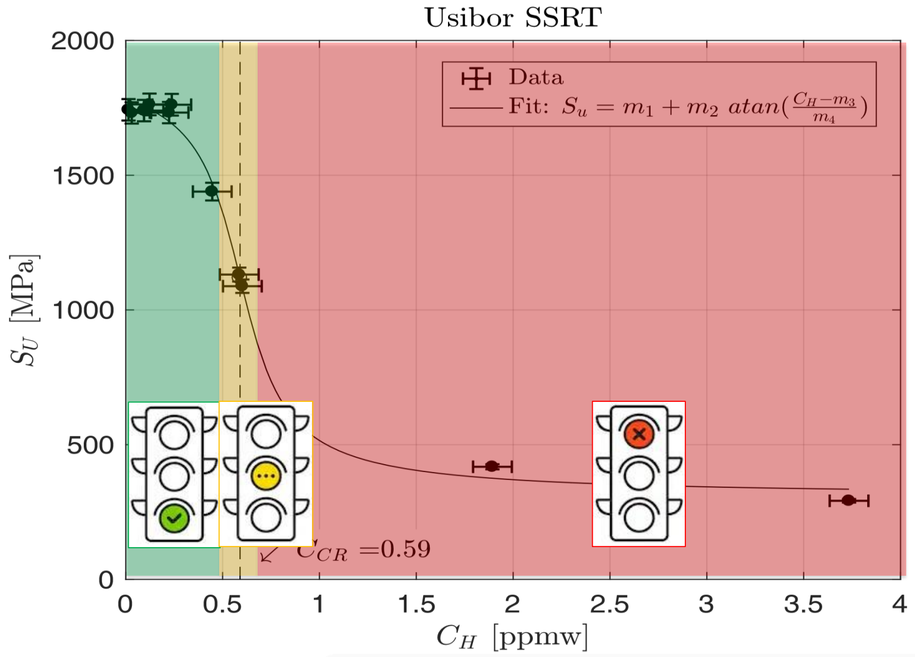
WITHOUT HOLE



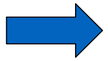
Measures on finished coils and assembled car bodies

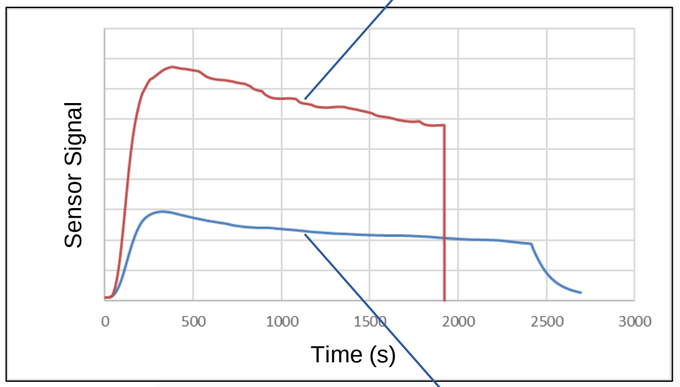
HELIOS 4 is designed to evaluate the goodness of the process with non destructive diffusible hydrogen measurement on sheet steels without any surface preparation nor geometry limits. The result will assure the process parameters to be under control preventing the risk of hydrogen embrittlement due to the process itself.

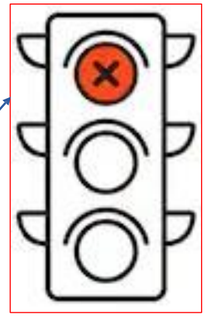
HELIOS 4 operation concept is the same of the **TRAFFIC LIGHT**.

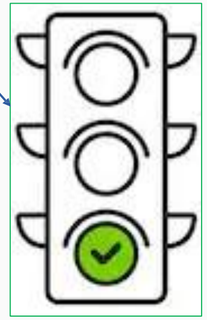


Measures on finished coils and assembled car bodies









Industrial case study in CASSINO FCA plant

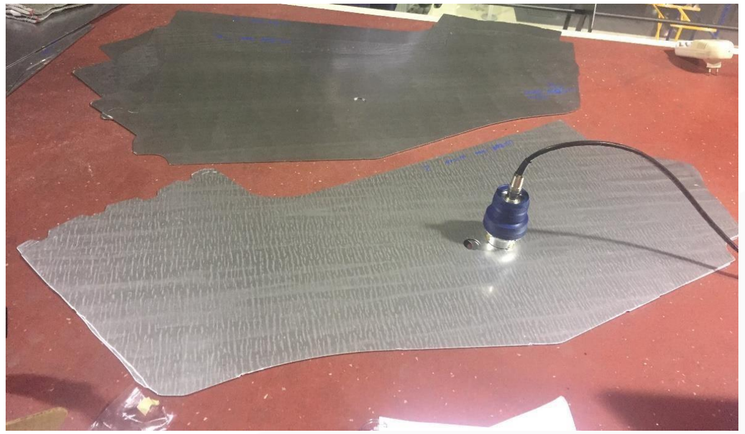
Evaluation of the hot stamping process parameters influence on the delayed fracture behaviour of USIBOR 2000 Al-Si:

1. Study of the effect of **Furnace Dew Point** and **Dwell Time** on the hydrogen absorption
2. Study of the effect of raw materials exposition in the **salt spray chamber** or **to the water vaporization**

The blank semi-products were subjected to the hot stamping process under different conditions (dew point under control or not).

Industrial case study in CASSINO FCA plant

Condition	Blank preparation	Hot stamping conditions	Diffusible Hydrogen Content (ppmw)
N°1	USIBOR before Hot Stamping	N.A.	0,0 ppmw
N°2	USIBOR before Hot Stamping Presence of white rust depositions	N.A.	0.1 ppmw
N°3	USIBOR before Hot Stamping At the end of salt spray test	N.A.	0.0 – 0.3 ppmw
N°4	USIBOR after salt spray test and Hot Stamping	Time Dwell: 300sec Dew Point: 1°C	0.0 ppmw
N°5	USIBOR after salt spray test and Hot Stamping	Time Dwell: 700sec Dew Point: 1°C	0.2 ppmw
N° 6	USIBOR after water vaporization and Hot Stamping	Time Dwell: 700sec Dew Point: 1°C	0,2 ppmw
N° 7	USIBOR after water vaporization and Hot Stamping	Time Dwell: 600sec Dew Point: 1°C	0.2 – 0.3 ppmw
N°8	USIBOR after Hot Stamping	Time Dwell: 500sec Dry air control: Active	0.0 -0.1 ppmw



CONCLUSIONS

1. The use of AHSS is necessary to achieve weight reduction.

2. Different mechanical tests are available to assess HE risk. They all present advantages and disadvantages so the optimal method should be chosen depending on the material and the objectives. In any case is fundamental to measure the diffusible hydrogen content in order to estimate the critical level of diffusible hydrogen that is capable to induce HE.

3. The critical level of diffusible hydrogen capable to reduce the UTS of USIBOR 2000, established by SSRT, was 0.59ppmw, while for 4 Point Bending Test the regression curves shown a critical concentration of 0.37ppmw (sample with hole) and 0.54ppmw (sample without hole).

4. The dew point and dwell time can influence the final diffusible hydrogen concentration. According to our test the dew point control reduces drastically the hydrogen adsorption during the hot stamping process.

CONCLUSIONS

5.The hydrogen adsorbed during corrosion phenomena was about 0.3ppmw. At the end of the hot stamping process, the hydrogen content was lower.

6.SSRT have been performed from samples obtained by the hot stamped parts. The UTS was the nominal one, confirming, once again, the HELIOS 4 Hot Probe results and its potential.

7. Hydrogen pick-up can be monitored with **non-destructive technique** at industrial scale.

Hydrogen Embrittlement of AHSS in the Automotive Industry

FormPlanet project's main goal is to tackle the upcoming challenges in formability and part quality assessment by developing knowledge-based testing methodologies to address formability and quality part problems in the sheet metal manufacturing sector, covering a wide range of materials (steel, Al, Ti and Ni alloys, and multi-layer sheet metals). FormPlanet project will develop novel testing methodologies to address formability and crack-related problems in high strength materials.

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FORMPLANET

Sheet metal forming testing hub

High performance parts with new high strength materials

Start: January 2019 **- End:** December 2021

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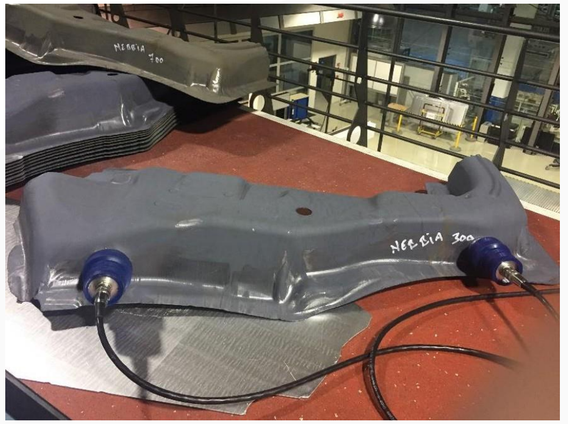
8 European countries



The potential of the novel approach will be proven in several **INDUSTRIAL DEMONSTRATORS**.

This project has received funding from the EU Horizon 2020 programme under grant agreement No. 814517

FUTURE WORKS

Available for future collaborations and open to any standardization proposal.

We recently asked for consent on a CEN Workshop Agreement (CWA) proposal based on Horizon 2020 project results

Reference technical committee

CEN/TC 262

Title: *Measurement of diffusible hydrogen in metallic materials – HELIOS 4 HOT PROBE method*

Scope: This document defines a test procedure for the measurement of diffusible hydrogen content in metallic materials by means of the HELIOS 4 HOT PROBE equipment.

CRYSTAL

Control of Risk for Hydrogen embrittlement in Steels for Automotive applications

Start: September 2020

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