DEVELOPMENT OF TRANSDUCER FOR HYDROGEN SERVICE UP TO 1500 BAR

Marco Palombo[1,2], Yusuke Kojima[3], Alberto Civati[4], Marco Borile[5]

[1] H2 IIS SIDER srl - Viale dell'Industria, 25, 29015 Castel San Giovanni (PC)

[2] IIS Ente morale – Lungobisagno Istria, 15 - 16141 Genova (GE)

[3] Kyowa Electronic Instruments Co., Ltd. - 3-5-1 Chofugaoka, Chofu Tokyo 182-8520 Japan

[4] Instrumentation Devices - Via Acquanera 29 – 22100 – Como (CO)

[5] Sider Test – Viale dell'Industria, 25, 29015 Castel San Giovanni (PC)

In the actual energy transition, the use of H2 as energy vector is growing very fast. The wide use of hydrogen in existing pipelines and vessel or in new components require specific monitoring and testing.

The study of the behavior of materials in gaseous hydrogen environment is now becoming even more necessary to better assess the properties of materials and to proper design new equipment. Therefore, mechanical testing (fracture mechanics and standard testing) is a fundamental tool to determine such properties.

Typically, mechanical testing requires the recording of the load and the displacement on a specimen to determine the stress and the strain applied on it and to determine further results (e.g. on cracked specimens using fracture mechanics). The use of strain gages for the manufacturing of transducers and for bonding on specimens, is widely diffused. However, the Cu-based alloys for the fabrication of strain gages suffer an initial drift due to the saturation caused by the H2 environment. In order to avoid this phenomenon and to obtain more reliable data, the development of new transducers is described in this work; in particular, a clip-on gauge for measuring crack opening displacement and a load cell were fabricated using specific strain gages for H2 environment: Fe-Cr-Al alloy strain gages, which does not suffer any drift and allow to perform tests measuring reliable data up to 1500 bar of gaseous H2.

Introduction

The determination of the mechanical properties of a material requires a lot of tools to be proper determined and to be sure of the reliability of the obtained results. Among these tools, the skills of the operator, the use of proper instruments (transducers) and machines can be listed. Furthermore, if such properties are determined in gaseous hydrogen environment, more effort have to be spent in order to get reliable results. Just to give an example, the use of a pressure vessel to carry out the test mechanical test in high pressure gaseous hydrogen environments is strictly linked to the use of seals and a pull-rod (see figure 1), therefore the presence of friction caused on the seals on the pull-rod can lead to difficult measurements of the load actually applied on the specimen inside the vessel. Therefore, the need to measure the load inside the vessel and directly on the specimen comes up.

For such a reason, this work was focused on the fabrication of a transducer to determine the load on the inside of a pressure vessel up to 1500 bar (150 MPa) of gaseous H2. Such transducer, otherwise known as load cell, was constructed using strain gages specific for hydrogen service (Fe-Cr-Al strain gages provided by Kyowa) and standard strain gages (Cu-Ni alloy strain gages). The load cell was assembled with an orthogonal active full-bridge system of strain gauges, SG (see Figure 2); in particular, a proving-ring like geometry was adopted both as load cell frame and counter reaction frame to sustain the load applied to the specimens during the mechanical tests (see figure 2).

Results and discussion

In order to verify the cell load, a calibration was performed in air (see figure 3) on both the circuits: standard Cu-based SG and Fe-Cr-Al SG (Kyowa). The results show a good elastic response of the SGs with a very similar linearity.

After the calibration, a load of 35 kN (35000 N) was applied and the vessel was pressurized up to 1500 bar with H2 gas. Therefore, the load was kept constant for around 60 hours (see figure 4, top graph). The data were recorded continuously for the whole test on the standard SG while the acquisition on the Fe-Cr-Al SG was cut just after few hours because no change in the recording appeared. Basically, the standard SG showed a wide drift of the recorded signal vs. time, this means the strain gauge were going to be saturated from the hydrogen environment. On the other hand, the Fe-Cr-Al SGs just suffered a small drift (around 0.1 hours, or 6 minutes as show in the bottom graph of figure 4).

The standard SG seems to reach the plateau of saturation around the end of the test (60 hours).

Conclusions

A transducer to the used in gaseous hydrogen environment up to 1500 bar was designed fabricated and the results showed a clearly different behavior of the Fe-Cr-Al SG vs. the standard Cu-based SG; indeed, the measured drift needed just a brief time 6 minutes to completed on the firsts with respect to the 60 hours of the standard SG. Such results help the users in the choice of the proper SG for the execution of mechanical tests or for the manufacturing of transducers suitable with H2 environment.

However, in this work, no long-term tests were performed, therefore no information about the duration of the cement used to bond the SGs to the metal surface of the load cell were recorded. Finally, the Fe-Cr-Al SGs can be considered as more suitable for hydrogen testing than standard Cu-based SG even if the knowledge about the long-term behavior will help to define a proper ratio of costs/benefits.

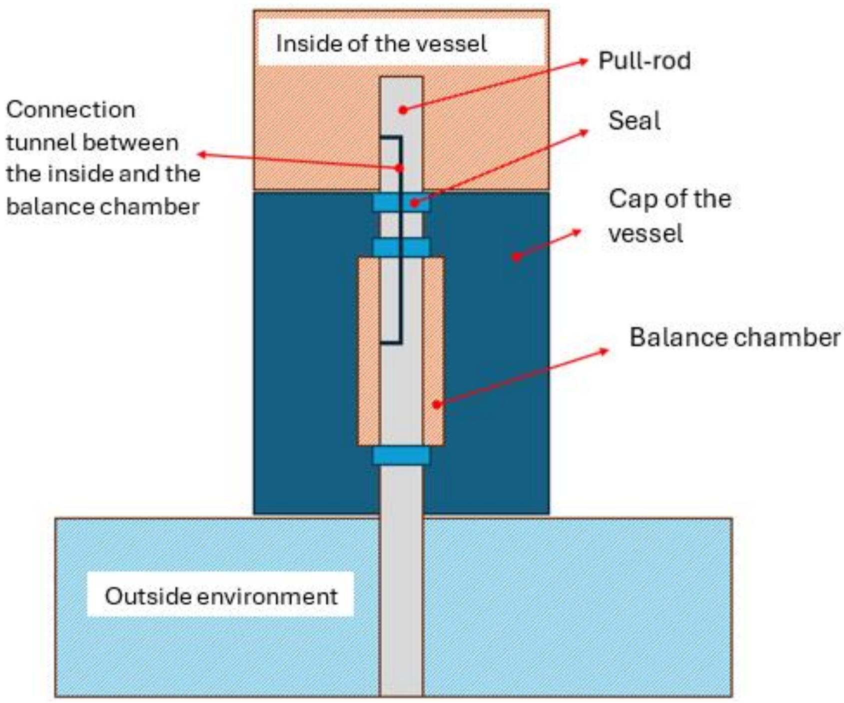

Fig. 1 - sketch of the vessel and its seals

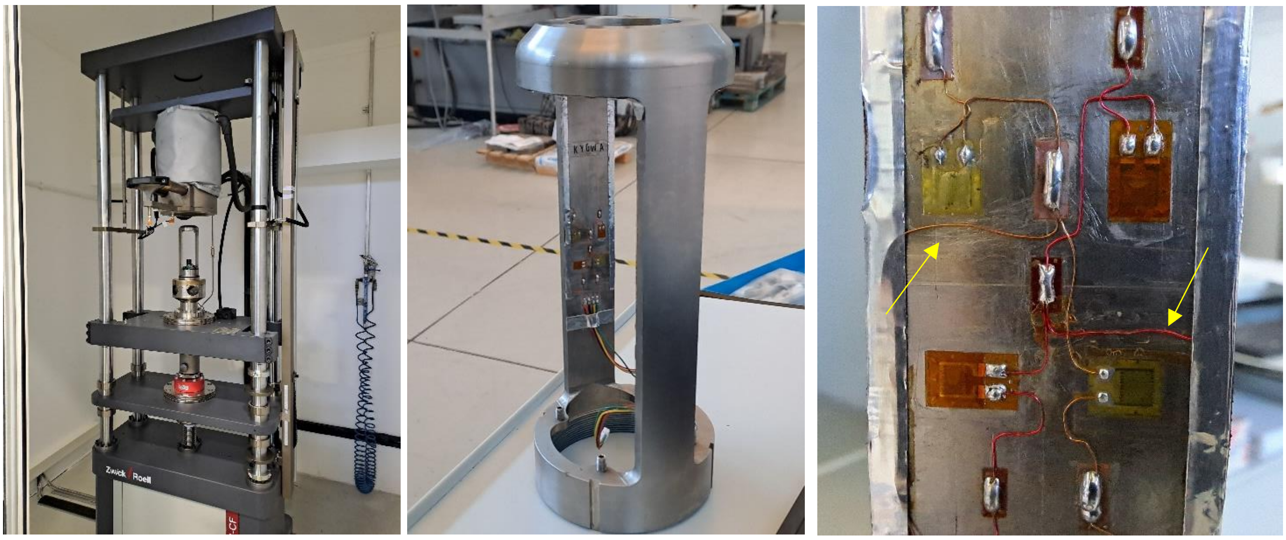

Fig. 2 – Overview of the machine coupled with the autoclave for mechanical tests up to 150 MPa (left panel), detail of the counter reaction frame used to attach the specimens ad as load cell frame also (center panel) and detail of the strain orthogonal active full-bridge strain gage system (right panel), note the full bridge was split into to two parts on each side and the strain gage were thus mixed using both standard (Cu-Ni alloy) and Kyowa (Fe-Cr-Al) strain gauges (the Kyowa strain gages are indicated by yellow arrows).

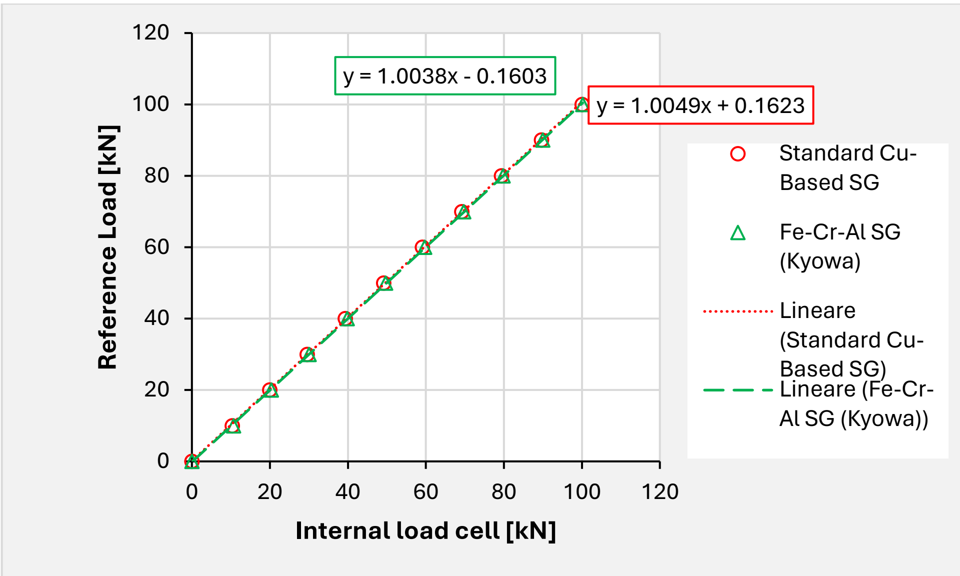

Fig. 3 – calibration of the internal load cell (with Standard SG and Fe-Cr-Al SG) in air.

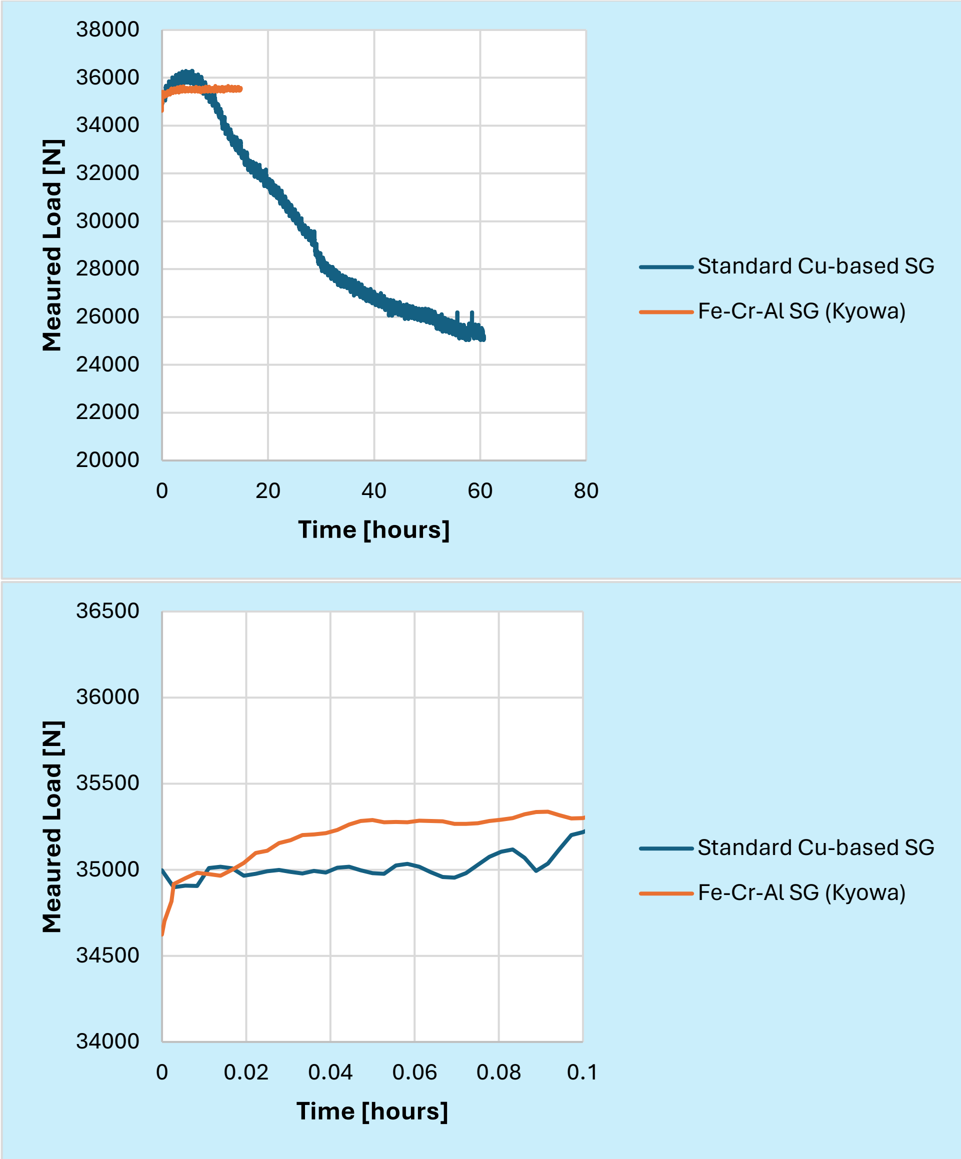

Fig. 4 – Drift of the initial applied load at 1500 bar of H2; top: overview graph, bottom: detail of the first 0.1 hour.

References

[1] RJ Billia, Strain gages subjected to a high-pressure hydrogen environment (report no. UCID-15908), Lawrence Livermore Laboratory, Livermore CA (1975).

[2] GF Chalmers, Materials, Construction, Performance and Characteristics,. AL Window, editor. Strain gauge Technology, 2nd Ed. Elsevier Science Publishers Ltd: Essex, England (1992).

Instrumentation Devices Srl
Via Acquanera 29 - 22100 COMO (Italy)
ph +39 031 525 391- fax +39 031 507 984
info@instrumentation.it - www.instrumentation.it