DEFECTOSCOPY AND SOLUTIONS PERSPECTIVES RELATED TO METALLIC MATERIALS ADOPTABLE IN HYDROGEN STORAGE TANKS PRODUCTION

Cesari F. G. [(1)], **Pelonzi I.** [(2)], **Rogante M.** [(1,3)]*

[(1)] Nucl. Eng. Lab., DIENCA, Univ. of Bologna, via dei Colli, 16, 40136 Bologna, Italy
[(2)] Nuova MA.NA.RO. S.p.A., Via S. Pertini, 6, 60035 Jesi, Italy
[(3)] Rogante Engineering Office, NDT, Contrada San Michele n. 61/P.O. Box 189, 62012 Civitanova Marche, Italy

* *Fax: 39 (0733) 774664 E-mail: engineering@interfree.it*

Introduction

Hydrogen is frequently related with mechanical properties degradation and failure, in particular corrosion defects. The diffusion of the atomic hydrogen (H^+) from the H molecule toward the constitutive plate of storage tanks can produce cracks similarly to Hydrogen Induced Cracking (HIC), especially to the presence of residual stresses. Dissolved H can also cause cracking, blistering and embrittlement [1, 2].

Defectoscopy and characterization of metallic materials which can be considered for Hydrogen storage tanks production should play a decisive role in the debugging of new storage tanks, giving an essential support to advance safety and durability. A development of welding processes is also essential in order to obtain quality assurance improvement and safety enhancement of the welded joints involved in the same tank production. Recent investigations of welds have shown the benefits related to the employment of neutron techniques, to obtain substantial information that cannot be found by using other means [3].

Main text

Hydrogen represents, currently, the most potent fuel going - packing almost three times gasoline's energy -, and its employment is able to reduce carbon dioxide emissions till ~60% compared with diesel based systems.

A pre-condition for Hydrogen use is to solve the problem of its storage and circulation under acceptable conditions, taking into account also the costs of such operations. Hydrogen can be stored in the form of gas, cryogenic liquid or adsorbed gas in solid materials. The most ordinary type of storage involves confining the compressed gas in secure tanks, with a pressures range of ~200-700 bars and an estimated averages size of fixed tanks (distribution stations) of $\sim1\cdot10^4$ m^3. Conventional storage, such as compressed gas cylinders and liquid gas tanks, should be made stronger, lighter and more economical.

The present work addresses significant technical items related to defectoscopy of metallic materials – including welded joints - which can be considered as constitutive for H-storage tanks. The same work takes into account that the adoptable containers must be corrosion and pressure-resistant, especially in order to avoid any infiltration by light H-atoms and, in general, H-embrittlement or Stress Corrosion Cracking (SCC) phenomena.

Various investigations have been carried out on aluminium alloys and steels, in particular concerning the following materials:

- AISI 316;
- AISI 316 L;
- AISI 304;
- Fe 410;
- Al 7020;
- P-Al Mg 4,4 UNI 545.

The following methods have been adopted:

- radiographic in-situ inspection techniques, including radiation sources, film types and computed radiography systems, especially concerning circumferential and longitudinal joints;
- magnetic particle test (MT);
- ultrasonic test (UT);
- tensile and cold-bend test;
- macroscopic sections;
- hardness test;
- metallographic examinations;
- microanalysis (EDS).

The following defects have been mainly revealed:

- cavity inclusions, due to the welding process or to the quality of the adopted gas;
- discontinuity of the weld bead;
- weld sticking;
- segregation lines of inter-metallic and not-metallic (silicates, oxides, etc.) compounds, in the thickness centre of welded plates, imputable to the materials quality.

Concerning cracks, their starting and development are nearly unpredictable, since they depend in wide measure from the residual stresses extent and distribution inside the material (especially in the weld bead and in its surrounding zones). Stress corrosion involves Hydrogen diffusion towards the tank constitutive material producing the cracks. On the other side, high H motilities have been revealed at ambient temperatures in metallic and nano-structured materials [4]. Recent experiments have shown the eligibility of neutrons for the investigation of structural peculiarities of welded joints. Neutrons techniques, in fact, are more and more becoming acknowledged as a valuable tool for structural-integrity assessment of industrial components and advanced materials development [5]. Mechanical properties, such as creep resistance and joints ageing, are strongly dependent on nanostructure (precipitates, pores and dislocations groups) formed in the metal. A welded joint Small Angle Neutron Scattering (SANS) scan enables obtaining the data on nanoscopic characteristics inside the joints, assuming possible local deviations in technology, composition, etc. [3]. Despite numerical modelling is a powerful instrument for residual stresses calculation, validation with reference to experimental results is essential. Neutron diffraction, in this case, represents a valuable solution in order to perform internal residual stresses measurements, offering significant improvements in welding joints assessment and their behaviour in practice, in order to better characterise metallic materials adoptable in Hydrogen storage tanks production.

Conclusions

The performed work contributes in showing that development and testing of prototype Hydrogen storage tanks should be connected with a study in depth of defectoscopy and microstructural characteristics of the involved constitutive materials - e.g., aluminium alloys and steels -, in order to understand more deeply their behaviour and assess their suitability.

References

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