PAPER REF: 3960

EVALUATION OF DAMAGE ACCUMULATION IN HIGH PRESSURE COMPOSITE VESSELS USING FIBER OPTIC SENSORS

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ABSTRACT

The aim was to evolve a method for qualitative assessment of damage accumulation in composite structures and materials, especially for high-pressure hydrogen vessels for hydrogen storage (CH2) in the automotive and stationary applications. It was proposed to apply the strain measurements by a fiber optic FBG sensors, which were calibrated using measurements of acoustic emission (AE). Preliminary studies were realized on composite NOL ring samples and test pressure vessels (CH2). It was shown that the proposed solution allows the damage accumulation assessment of the composite elements during its operation using SHM system (so called: "on-line" Structural Health Monitoring).

Keywords: composite high pressure vessels, compressed hydrogen, optical fiber sensors, acoustic emission, damage accumulation.

INTRODUCTION

Evaluation of technical condition of composite structures during their lifetime is a complex task. Proper diagnosis requires consideration of both: the strain/stress state of composite structure as well as assess the level of the composite material degradation (cumulative damage). Strength state can be determined applying measurements of local strains (ie. using optical fiber sensors, like FBG), adoption of the material constitutive model, numerical model of the design and finally experimental verification.

Assessment of the composite material degradation (particularly during operation) is a complex problem. For this purpose the most commonly an acoustic emission (AE) method is used. Its suitability is well established in the literature. However, the advantages of AE method used in laboratory conditions do not occur in the case of real on-board monitoring systems (like high pressure vessels for CNG and CH2 storage in automotive applications). Level of interference (noise from a moving vehicle, engine running, etc.) does not allow proper interpretation of the result. Thus, it seems that a promising approach for estimating damage accumulation is measuring local deformations (in multiple points) and their calibration using acoustic emission AE.

RESULTS AND CONCLUSIONS

In studies NOL-ring specimens were used. They can simulate the behavior of the cylindrical part of the high-pressure vessel (CH2) and are described in detail in standards such as ASTM. Samples were made using the same materials and technology (winding) that was are used in the production of the high-pressure vessels (carbon fiber + epoxy resin).

NOL composite specimens were subjected to quasi-static test (till break), and creep test. During the experiment following parameters were recorded: strain (on a straight section of the NOL sample by two FBG sensors, glued on both sides of the sample), acoustic emission signals (via two AE transducers) and the testing machine parameters: applied force and displacement. The exemplary results from the tensile tests are shown in Fig. 1 (a,b), whereas similar setup for CH2 pressure vessel is presented in Fig. 1 (c), (Gasior, 2012).

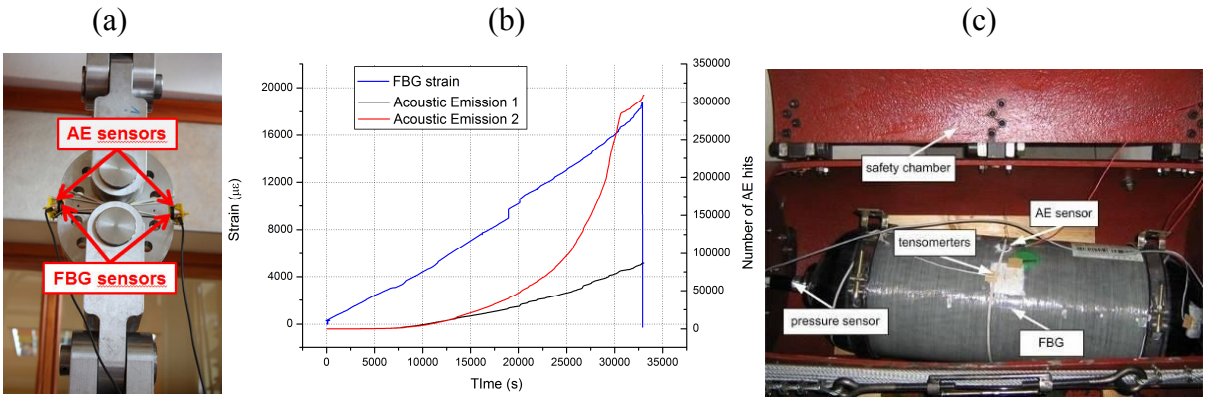

Fig. 1 - View of NOL rings testing setup (a), tensile test results: strain registered by FBG sensors and number of AE events (b) as well as CH2 pressure vessel with various sensors for evaluation of damage accumulation (c) .

AE sensors register acoustic events generated in the whole volume of the NOL specimen, while fiber-optic FBG sensors in the proposed configuration can measure only the strain in the straight section of the NOL. However, it can be concluded that there is a correlation between the changes in the distribution of a strain in composite material, detected by FBG optical sensors, and changes in acoustic emission signals.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the funding within the project “The Application of Nanotechnology in Advanced Materials” - NanoMat (POIG.01.01.02-02-002/08) financed by the European Regional Development Fund (Innovative Economy Operational Programme, 1.1.2).

REFERENCES

[1]-ASTM D2290 - 08 Standard Test Method for Apparent Hoop Tensile Strength of Plastic or Reinforced Plastic Pipe by Split Disk Method.

[2]-P. Gąsior, Optical fiber based strain monitoring method for high pres-sure composite vessels for gaseous fuel storage, PhD Thesis, Wrocław University of Technology, 2012.