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GRP TANK LOADING INVESTIGATION USING CFS AND DFOS SENSORS

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1. Introduction

Surface water management is one of the main topics nowadays. The Glass Reinforced Plastic (GRP) surface water treatment tank is one of the important parts of the system chain solution. GRP tanks are placed below the surface, and during the placement process, high loads can occur on the tank structure. The possibility of monitoring loading using sensors is being investigated. Resistive and optical sensors were installed on the surface of the vessel, and verification measurements were performed during the vacuum test of the vessel. The obtained results were compared with the FEM calculation.

2. Method

The body of the investigated vessel is manufactured using the winding technology, where the bottoms and other technological inputs and outputs are subsequently manually connected to the body. Locations suitable for monitoring the load of the structure were selected based on the initial FEM calculation. The vicinity of the service input was selected for the installation of sensors. Strain Gauges (SG), Carbon Fiber Sensors (CFS), and Distributed Fiber Optic Sensing (DFOS) sensors were used for measurement.

3. Measurement

Two specimens were loaded under vacuum at four load levels. Three types of sensors were used to determine the tank loading.

3.1 Strain Gauges

HBM LY-11-6/350 strain gauges were used and were glued with cyanoacrylate adhesive and connected to the HBM QuantumX 1615B measuring unit, as well as CFS sensors. The strain gauges were installed in the tangential and radial directions on specimen 1, see Fig. 1, and in the tangential direction following the CFS sensor direction on specimen 2, see Fig. 2. Specimen 1 with installed sensors is shown in Fig. 3.

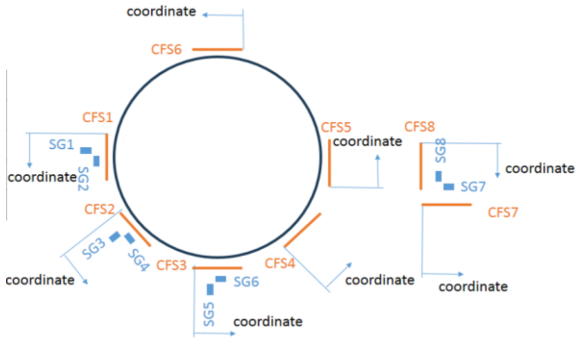

Fig. 1. Schema of sensors placement around service input -- Specimen 1.

3.2 Carbon Fiber Sensors

Carbon Fiber Sensors (CFSs) were prepared in ta length of 200 mm from carbon fiber roving T300 1000-50A. The methodology for the manufacturing of the CF sensor was described in [1], and the identical approach was implemented in this investigation. A nickel electrolyte coating was applied to the ends of each roving. Subsequently, thin copper wire was used to establish electrical connections. Prepared CFSs were installed on the polished, clean, degreased surface of the tank. In the area near the inlet were installed 6 sensors for specimen 1 were installed according to Fig. 1. 6 CSF sensors were placed on specimen 2 as shown in Fig. 2.

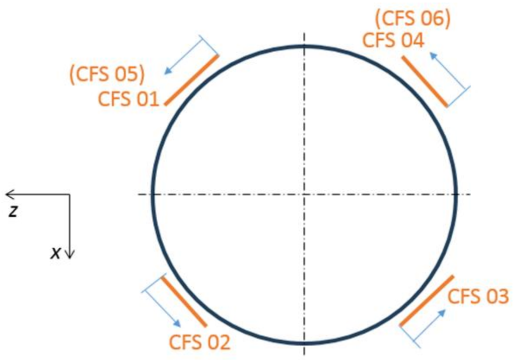

Fig. 2. Schema of sensors placement around service inputs -- Specimen 2.

3.3 Distributed fiber optic sensing sensors

A Distributed Fiber Optic Sensing (DFOS) system is used in this measurement for its unique properties – dense measurements of the strain points along the length of the fiber optic sensor. This is especially valuable in the development of new products or systems with complicated material layouts, such as composite structures. With this method, it is possible to evaluate material properties in a wider context of the larger structures. In this case, the sensor is placed along the critical spot – the neck of the water tank.

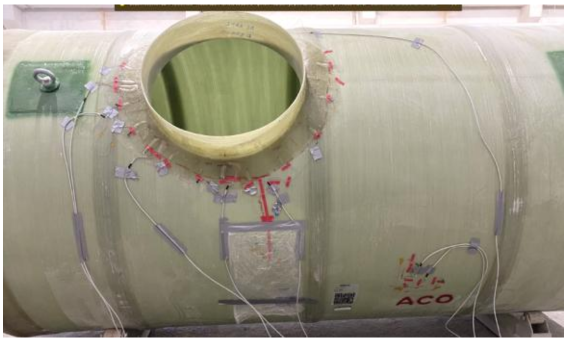

Fig. 3. Specimen 1 with installed sensors.

For the installation, the main DFOS sensor was prepared and welded for ad-hoc use at a length of 4.8 m. The DFOS sensor was installed with cyanoacrylate adhesive. CFS sensors and DFOS sensors were placed together in the prepared sections in a tangential direction along the neck of the tank. The strain from DFOS sensors was measured with the optical interrogator Luna ODISI 6100 system based on the Rayleigh backscattering principle.

4. Numerical analysis

Numerical analysis was performed in ABAQUS CAE. Continuum shell elements were used to model the vessel body. The sensors are modeled by beam elements that are connected to the tank by a Tie connection. The model allows for obtaining the strain course in the direction of the longitudinal axis of the sensor. The tank model is loaded with negative pressure, just like in the experiment. FE mesh of specimen 2 is shown in Fig. 4.

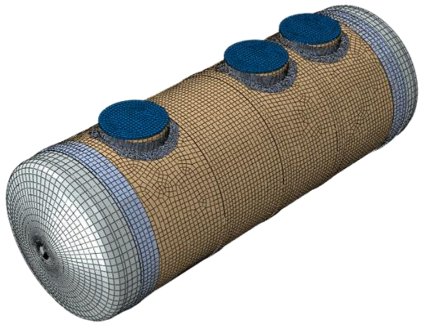

Fig. 4. FE mesh of specimen 2.

5. Conclusions

Data obtained from measurements on sample 1 showed differences with the numerical solution in some places, caused by certain differences between the numerical model and the actual design of the tank. About the level of the measured signals, measurement locations corresponding to CFS2 and CFS4 locations on sample 1 were selected for sample 2, see Fig. 2. The results obtained from the experiment on specimen 2 and the numerical solution were in good agreement in some places, while larger differences were found in others. Because signals from different sensors in given places showed similar levels of detected strains, the differences between the experiment and the numerical solution are caused by imperfections in the ideal shape of the tank. Further research should enable the potential of the mentioned sensors to be exploited for a given application, i.e., a low-cost solution for monitoring vessel stress during installation.

Acknowledgments

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