PR 4200458036
Health Monitoring of Composite Overwrapped Pressure Vessels

Statement of Work

November 27, 2012

1.0 Background

Stress Rupture is a sudden and catastrophic failure of the overwrap of a pressure vessel while holding at a stress level below the ultimate strength for an extended time. Currently there is no simple method of determining the stress rupture life of either a composite overwrapped pressure vessel (COPV) or providing a screening technique to determine if a particular COPV is close to the time of a stress rupture failure.

A key factor for stress reliability modeling of COPVs is the Stress Ratio. Stress Ratio is defined as the stress in the overwrap at maximum operating pressures divided by the same stresses at burst. The stress at burst varies from vessel to vessel; therefore the stress rupture behavior varies from vessel to vessel. Recent Orbiter COPV testing has proven that analytic prediction of the stress ratio and subsequent reliability modeling are highly inaccurate. Therefore having the ability to directly measure the residual stress of the overwrap at the liner/overwrap interface would greatly enhance health monitoring and life prediction. Correlating this technology with acoustic emission (AE) would also enhance health monitoring capabilities.

This statement of work (SOW) provides the detailed tasks of year 2 of a 3 year program for developing a health monitoring capability for composite overwrapped pressure vessels (COPVs). The year 1 effort, which has been completed successfully, tested and evaluated new magnetic stress gauge (MSG) networks for both usage and damage evolution monitoring in COPVs. In the second and third years effort the project will include coordination and integration of acoustic emissions (AE) damage evolution data with the MSG data.

2.0 Scope

The scope of this project is to further demonstrate the ability of MSGs for the measurement of stresses and monitor damage to a COPV. MSG measurements results will be correlated with other NDE technologies such as acoustic emission (AE). AE work will be directed and performed by NASA as a third party.

3.0 Objectives

NASA KSC intends to investigate the ability of MSGs for the measurement of internal stresses of a COPV overwrap. Testing shall be performed on two (2) vessels at WSTF. WSTF will provide the testing facility and AE sensors and AE data.

4.0 Tasks

The Principal Investigator (PI) shall perform each of the following tasks:

Task 1. Adapt MSG sensors for COPV geometry – The contractor shall fabricate at least one MSG suitable for testing on a COPV. Previous tests have used standard MWM-Arrays and MWM-Arrays with geometries adapted for COPV applications are expected to improve the stress monitoring capabilities. The sensor itself will be designed under JENTEK internal research and development funding. This program will provide input into layup for the geometry to be used for the sensor footprint and the electrical connections. Factors to be considered include the size and aspect ratio (length to width) of the drive winding, the size of the sense elements, and the distance between the sense elements and the drive winding. At a minimum, the MSG will incorporate a different connector; an 80-pin connector has been used successfully on other sensors and should eliminate the need for intermediate adapter boards between the sensor and MUX units.

Task 2. Field Test A: Typical Operating Pressures – The goals of this field test are to develop a further understanding of the performance of MSGs at different orientations and positions on the COPV, to confirm repeatability of sensor results, and to test improvements in sensor designs and multiplexing units. If possible, AE sensors will be used during the test. The contractor shall demonstrate 2 or more MSGs instrumented using a MUX network on a COPV during pressurization testing. The MSGs shall be used to monitor fiber stress in different fiber wrap layers and/or at different positions on the vessel. The contractor shall select and adapt sensors and instrumentation for the test. The contractor shall develop a test plan including (i) identification of the locations of the MSG sensors, conventional strain gauges, and AE sensors; (ii) the load progression and range; (iii) MSG sensor type; (iv) sensor excitation frequencies; (v) calibration procedure; and (vi) other test procedure details. Testing shall be performed at White Sands Test Facility (WSTF) in Las Cruces, New Mexico. Bottle pressurization and AE sensor efforts will be performed by NASA or a third party in coordination with the contractor's efforts. NASA will provide a specification of the test COPV and a COPV of the same specification will be made to the contractor at least 2 month in advance of the test dates.

Task 3. Analysis of Test Results – The contractor shall provide an interim report analyzing the Field Test A results along with further analysis of the Year 1 test results. If AE data was collected, NASA will provide the AE data to the contractor. The analysis shall include a quantitative metric of performance (e.g., R^2 of MSG response with COPV pressure) for evaluation of the sensor technology. This task also includes analysis of the field tests performed under Task 4.

Task 4. Field Test B & C: Damaged COPVs – Under this task, four days of field testing shall be performed at WSTF on a COPV damaged by pressurization ("Field Test B") or impact damage ("Field Test C"). The scope and selection of field tests will be selected in consultation with NASA as constrained by the budget and time at WSTF. It is anticipated that only one field test of a damaged bottle will be completed during this

program year. In Field Test B the goal is to monitor MSG and AE responses of a nominally undamaged COPV as the burst pressure is approached, though, preferably without actually bursting the COPV. In this test, the contractor shall monitor a COPV using a MSG MUX network through progressively higher pressurizations. The expectation is to achieve significant AE events and to investigate how the MSG responses changes at these higher pressurizations. In Field Test C the goal is to monitor MSG and AE responses of an impact damaged COPV during pressurization. The pressurization cycles will be agreed upon with NASA and is likely to include several baseline cycles up to the maximum operating pressure. The contractor shall demonstrate the MSGs on a COPV damaged by impact in the cylindrical region. The contractor will work with NASA to define the nature of the impact damage (e.g., size, shape, force, orientation) and NASA will impact the vessel in accordance with the agreed to specification. The contractor shall perform scans of the cylindrical region of the COPV both before and after impact. For each field test performed the contractor shall select and adapt sensors and instrumentation for the test and provide an appropriate test plan.

Task 5. Final Report – The contractor shall submit a final report to NASA detailing the system setup and MSG selection, measurement and calibration procedures and detailed analysis of the test results.

5.0 Delivery

The Principal Investigator (PI) shall provide for following deliverables at the conclusion of each task:

1. The PI shall deliver a description of the sensors selected in Task 1 via email to Richard Russell, NASA, Kennedy Space Center.

2. The interim report described in Task 3shall be delivered via email to Richard Russell, NASA, Kennedy Space Center.

3. Final report shall be delivered via email to Richard Russell, NASA, Kennedy Space Center.

7.0 Security

- Contractor person must provide security information to the technical POC to meet access requirements for entrance to the WSTF at least 2 weeks prior to the start of Task 2 and 4 testing.

8.0 Place of Performance

- Vendor is authorized to perform the work at their facilities but shall be-onsite at WSTF for the performance of tests detailed in tasks 2 and 4.

9.0 Period of Performance

- From contract award until 9/30/13.

10.0 Milestone Payment Plan

Task	Payment	Estimated Completion Date
1		March 2013
2		June 2013
3		September 2013
4		August 2013
5		September 2013