Development of a Composite Overwrapped Pressure Vessel Profilometry and Eddy Current Scanning System to Meet Manufacturing and Analytical Needs

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Composite overwrapped pressure vessels (COPVs) are used extensively in spacecraft and other applications because they offer significant weight savings over metal vessels. However, even though a great deal of effort has been expended to ensure consistency of manufacturing processes and materials, variability has been higher with COPVs than with metal vessels. Samples from a recent batch of COPVs built for stress rupture testing resulted in T1000 vessel burst pressures that varied by 5%, and IM7 vessel burst pressures that varied by 8.5%, even though they were wound on computer-controlled equipment and were made from the same lots of fiber. This type of inconsistency necessitates an increase in safety factor to cover the scatter unless the lower-performance vessels can be identified and removed from the population. Additionally, issues have occurred due to liner flaws that were not detected prior to wrapping. Most COPV manufacturers apply fluorescent dye penetrant for external liner flaw detection while video scope inspections evaluate interior surfaces for defects; however, these inspections sometimes miss the presence of defects and mild ripples or buckles that result from liner anomalies.

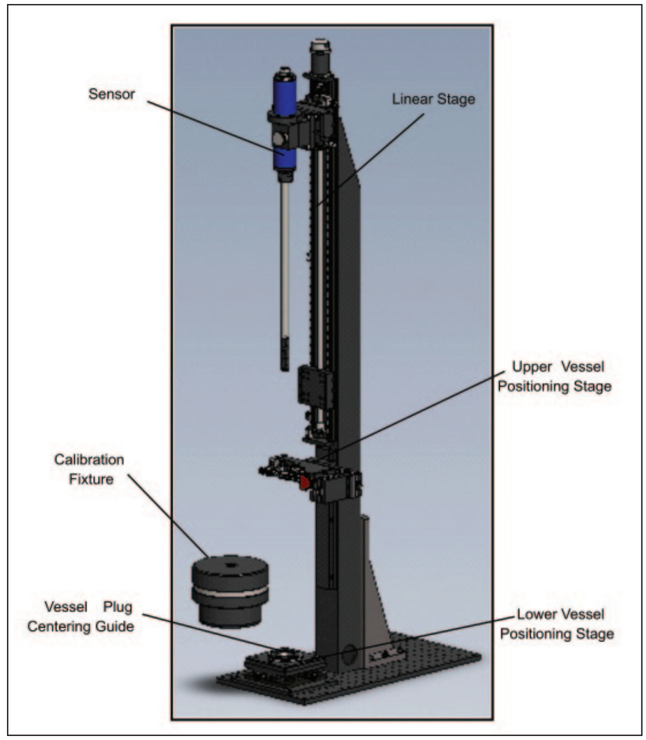

Fig. 1. *White Sands Test Facility cylindrical composite overwrapped pressure vessel mapping system.*

Johnson Space Center's White Sands Test Facility (WSTF) and the NASA Nondestructive Evaluation (NDE) Working Group (NNWG) recently developed an NDE system to inspect COPVs and provide an analytical tool to understand mechanical responses of the vessels. The system consists of an internal and external laser profilometer and eddy current (EC) scanner, and can be used both during the manufacturing process and as a part of test programs. The basic COPV scanning station was originally built as shown in figure 1. The station consisted of several positioning stages, a vessel centering guide, and a calibration fixture traceable to the National Institute of Standards and Technology.

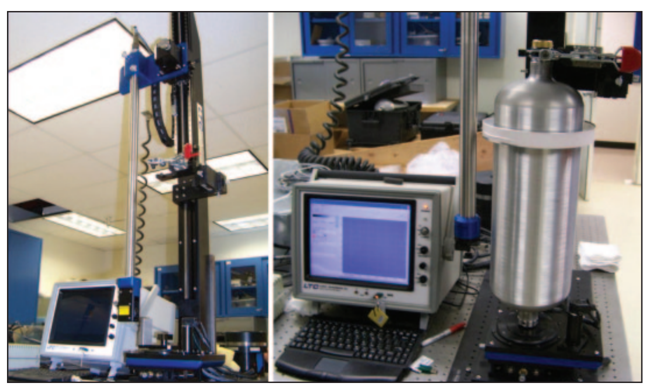

Fig. 2. *External scanner calibration using NIST-traceable standard (left) and scan of liner defect standard (right).*

The NDE system was recently modified to retain the internal profilometry capability, but also to allow it to be reconfigured for either external profilometry or EC scanning. The rotating interior sensor probe is easily removed and replaced with offset external probes (figure 2). A rotational stage is used to spin the bottles or liners for EC and external profilometry. The system is operated by a modern LP4000 data acquisition, control, and display system, and a motor controller. This makes the system uniquely applicable to in-process manufacturing support since it has the ability to scan vessel liners and ensure that

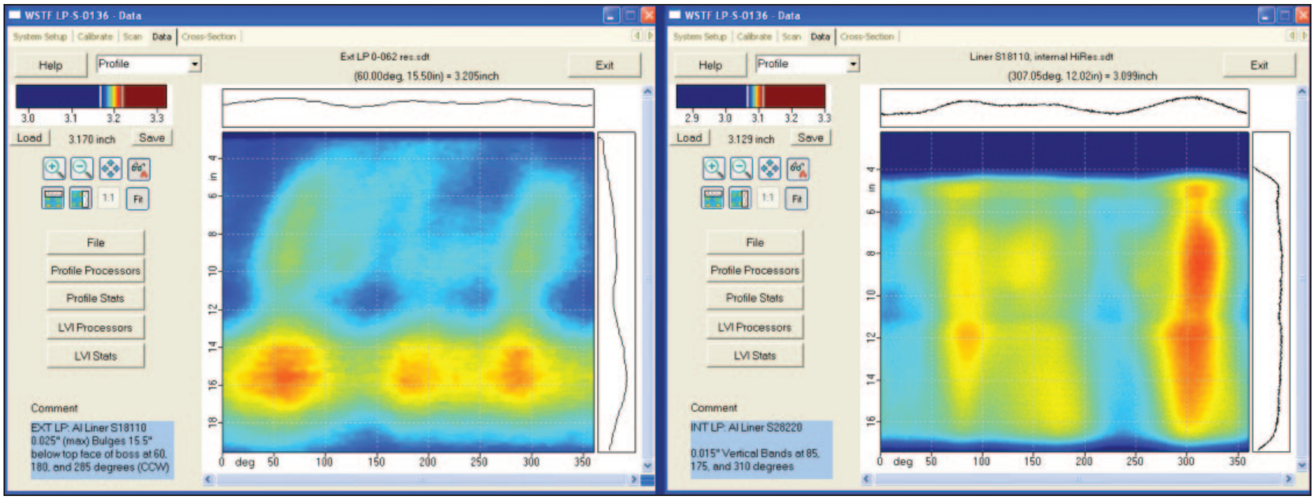

Fig. 3. Internal cylindrical scan (left) and external scan of the same vessel (right).

critical cracks and other EC-detectable defects do not exist, and then provide an accurate profile map of the interior and exterior (figure 3) after wrapping and testing.

The internal and external scanning system is designed to provide data accurate to +/- 0.001 of an inch (in.), which allows an accurate evaluation of any pits, bulges, and distortion, and evaluation of the amplitude and periodicity of any liner buckles or anomalies. These data provide engineering information used to see if specifications are met, and for calculation of resulting allowable cycles. These data can also support rationale to continue using COPVs with minor defects rather than replacing them. The EC system has detected surface defects approximately 0.001 in. deep in aluminum liners. A current project is under way to add sensors to evaluate for internal cracks as well as for liner crack though the composite after wrapping. The flaw detection sensitivity will be less in the new modes and will be quantified using physical standards.

The system has been used for many COPV applications at White Sands Test Facility and vendor facilities. It was shipped and used at General Dynamics (Falls Church, Virginia) to evaluate changes that occurred as the liners were wrapped and then autofrettaged to help produce optimum vessels to use for stress rupture testing. This helped identify vessels that indicated “out-of-family” deformations after autofrettage. The system was also used in a NASA Engineering and Safety Center study that characterized the response of T1000 and IM7 vessels to autofrettage. Additionally, it was used by the NNWG to evaluate bulging and other distortions that occurred as 60 vessels were incrementally strained to stress rupture failure (visit *http://nnwg.org/current/WSTF/composite.html* for more information).

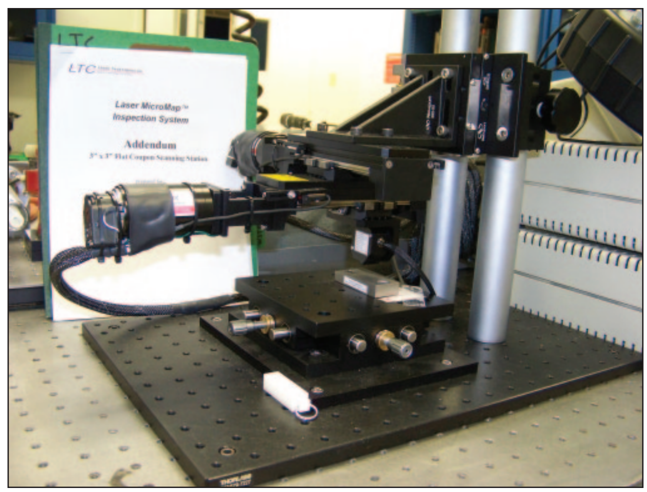

Fig. 4. *X-Y scanner, shown with NIST-traceable calibrations standard.*

An add-on to the system is an X-Y scanner for measurement of small features and defects. This can be configured as a coupon scanner (figure 4) or with legs to sit on a surface being evaluated to accurately measure and map defects, such as those resulting from impacts. This system is engineered for a shorter range and greater accuracy of 0.0002 in.

More information is available on the NNWG website (*http://nnwg.org/current/WSTF/copv.html*) or by contacting the authors.