Develop and Demonstrate Safety Inspection Methods for NGV Tanks

Contractor: Gas Technology Institute and Battelle

Cosponsors: Gas Technology Institute, U.S. Department of Energy, Office of Transportation Technology, Lincoln Composites, Dynetek Industries

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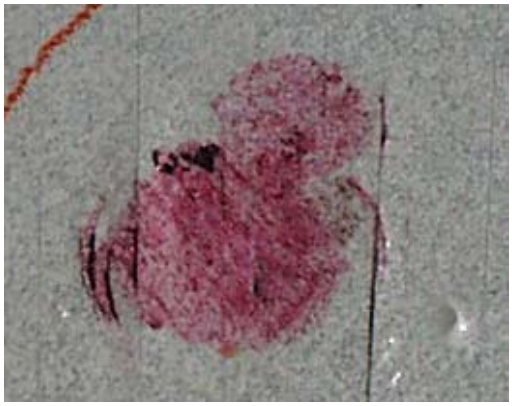
Background

Composite materials provide a strong, durable and lightweight material for construction of compressed natural gas (CNG) fuel cylinders for natural gas vehicles (NGVs). While these cylinders are rugged, impacts such as dropping the cylinders from an excessive height or high velocity impact by moderate sized rocks and debris may induce delamination and other structural damage to the composite materials. Such impacts are unique compared to other forms of cylinder damage, because they can cause damage within the composite wall that is not visible on the outer surface. Damage caused by impact is not always easily detected. In the worst case scenario, significant damage that is undetected may grow during service until it becomes large enough to cause rupture of the fuel cylinder. Hence, cost-effective methods for detecting damage before failure could enhance the safety and service of composite NGV fuel cylinders. Two such systems are in development: damage indicator coatings and acousto-ultrasonic inspection.

Damage indicator coatings provide a brightly colored indicator that is easy to see and easy to identify when potentially threatening impacts have occurred. Such an indicator can permit simple and reliable visual checks of the cylinder condition prior to refueling without removal of the vehicle from service and or affecting normal operations.

Acousto-ultrasonic inspection is an electronic means of actively monitoring the physical condition of NGV fuel containers. In practice this type of system could activate a warning light to alert drivers and maintenance personnel of the possibility of a damaged cylinder onboard and allow remedial action to be taken before serious failure occurs.



Example of Damage Indicator Coating With Red (Damaged) And White (Undamaged) Coating On Cylinder.

Project Objective

In this investigation the damage indicator coating developed for Type 4 (all composite) NGV fuel cylinders in previous work was implemented on Type 3 (metal lined) NGV cylinders to demonstrate its technical and economic feasibility. Following this laboratory evaluation, the coating was field demonstrated on Type 4 cylinders.

In addition to the development work on damage indicator coatings, the team was demonstrated and evaluated acousto-ultrasonic technology in the laboratory on full-scale Type 4 NGV cylinders to evaluate cylinder integrity and performance.

Technology Description

A damage indicator coating is a simple concept of a durable and cost-effective coating for the

exterior of an NGV fuel cylinder that changes color when impacted to help locate areas where damage may have occurred. While simple in concept, significant efforts have been necessary to develop a coating system that can withstand the rigors of NGV service.

Based upon experience and a review of the literature, the team adopted a development approach based upon microencapsulated beads. Microencapsulated beads are a two-component system in which a solid, liquid, or gas core material is coated with an encapsulant. These microcapsules rupture when impacted, releasing their contents, which react and change to a contrasting color. Microcapsules typically range in size from microns to millimeters. Common examples where microencapsulation is used include carbonless copy paper and "scratch-n-sniff" perfume samples.

In acousto-ultrasonic testing (AUT), thin piezo-electric transducers, similar to those used for acoustic emission evaluation, are used to actively transmit signals from one transducer to another, evaluating the structural condition of the cylinder through measuring changes in signal amplitude and frequency content. The AUT method is a rich technique which can potentially capture more information on cylinder integrity than conventional acoustic emission methods. It is also an active system which can continuously scan cylinder integrity, rather than a passive system which can only evaluate integrity during refueling.

Status

This program was completed on May 2, 2005 with the completion of the Field Demonstration and Evaluation of the Damage Indicator Coating Technology. The report on this work, as well as the reports on the laboratory demonstration of the Damage Indicator Coating System and the laboratory evaluation of Acousto-Ultrasonic Inspection Methods, is on file, with complete technical detail.

Results

The results of full-scale demonstration experiments on Type 4 NGV cylinders clearly show that the damage-indicator coating increases the visibility of impacted areas on the cylinder and can provide additional information that may be useful to the cylinder inspector and to the cylinder manufacturer in determining the condition of the cylinder. The results show that the force and energy of impact of blunt objects on the sidewall or dome can be can be estimated from the contact blush area. The field demonstration the coating system maintained its integrity, showed no visible signs of degradation, and performed its intended purpose without interfering with normal vehicle operation and maintenance.

The acousto-ultrasonic inspection work provided empirical demonstration of the potential capabilities of the method. The method shows promise for detection and discrimination of damage, although further work is needed in refining the analyses and validation on a series of containers with well characterized damage.

Benefits

Damage indicators coatings and acousto-ultrasonic inspection methods are expected to significantly enhance the safety of NGV cylinders by:

Simplifying the inspection process

Encouraging more frequent inspections

Making it easy for untrained personnel to identify a potential problem

Increasing the likelihood that a damaged cylinder will be identified and removed from service before failure can occur.

Project Costs

The total estimated cost of conducting the effort for SCAQMD is approximately $300,000. GTI, Lincoln Composites and the U.S. Department of Energy have invested approximately $1,130,000 in the related advanced composite cylinder technology development program.

Commercialization and Applications

Because of the significant safety benefits and potential low cost of these systems, it is anticipated that they will be implemented broadly on Type 3 and Type 4 composite reinforced NGV fuel cylinders. Further development is required prior to the commercial introduction of these technologies.

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