Motor Vehicle Fire Research Institute
Awarded Contracts

Title: Evaluation of Fuel Tank Drop Tests and ASTM Tensile Tests to Investigate Pinch-off Seam Failure

Duration: July 1, 2004 – September 30, 2004

Purpose:

A series of fuel tank drop tests were conducted by Southwest Research Institute (SwRI) in 2003 in accordance with the US Department of Transportation 49 CFR 393.67, Section E, as well as a series of tensile tests in accordance with ASTM D 638-00 [1]. The tests included new and conditioned tanks for each of the Saturn Twin Cam four door sedan, Jeep Grand Cherokee SUV, and Plymouth Grand Voyager mini van. Results of the drop tests, based on the minimum acceptable flow rate of the leaking fluid after the test, indicated that the conditioned tanks from the Grand Cherokee and Plymouth Voyager failed under the subjected drop tests. Leaks were observed to occur due to pinch off separation. The tensile tests were then carried out to compare the pinch off strength of the new versus conditioned tanks. The results were not conclusive in that the failures of all the tensile specimens occurred due to the plastic elongation and not the pinch-off separation.

The following questions still remain unanswered:

1. Is there an aging effect on the structural integrity of the plastic fuel tanks?

2. If so, do the geometry of the tank, type of plastic, and pinch off strength have an influence on the structural integrity?

3. Are the tensile tests that were conducted by SwRI adequate to replicate the loads seen in the drop tests to assess the strength of the pinch off?

4. What additional tests, if any, should be carried out to complete the evaluation and make final conclusions?

Proposed Approach

An initial review of the SwRI final report indicates that the tensile tests clearly did not replicate the types of loads generated at the pinch off regions during the drop tests. During a drop test, the pinch off edge is loaded directly in the upward direction with a point load, while the surrounding region is loaded downward with the inertia of the fluid inside the tank. This type of loading could be more accurately replicated with a three point bending test, rather than a tensile test. A detailed analysis of the tank configuration and pinch off geometry would confirm this observation.

Furthermore, a failure is likely to occur if the material looses its ductility, a property common in plastics during aging. While aging alone may not cause a severe enough loss of ductility, extended temperature cycling, in service loads, and exposure to gasoline may accelerate the process. This can be further evaluated with tests aimed at measuring the ductility (or brittleness) of the plastic material at different ages.

Finally, other factors, such as strain rate effects, need to be addressed to evaluate their influence on the results. The behavior of plastics under dynamic loading is strain rate dependent, and what would need to be understood is the effect of aging on the strain rate properties of the plastics in question. The following is a brief description of the tasks that will be executed under this project:

Task 1: Detailed review of SwRI test results and tanks - The tanks that were tested by SwRI in 2003 will be studied carefully and the test results published in the final report correlated to their respective tanks. The objective here is to achieve a better understanding of the tank configurations, the loading conditions, and the observed failures. Any tested tensile specimens that are still available will also be evaluated.

Task 2: Analysis of tank drop tests - In this task, simple finite element models of the tank geometries will be developed and loaded similar to the SwRI drop tests. The objective of this analysis is to understand the loading conditions and the stress distribution on the failed sections of the tanks. This analysis will provide valuable insight into what loading caused the pinch off areas to fail, and would enable the replication of this loading with a simple laboratory test.

Task 3: Literature review of plastic material behavior - To enhance the understanding of the aging effect of plastics, a review of published literature in areas including temperature effects, strain rate changes, exposure to gasoline, etc. will be carried out.

Task 4: Design and execution of laboratory sample tests - A simple laboratory test (similar to the tensile or three point tests) will be designed and set up to test several coupons extracted from the fuel tanks. It is assumed that there is sufficient material remaining in the SwRI tested tanks to extract these specimens. If successful, these tests should clearly demonstrate failure in the pinch off areas. The tests should also give some indication of the effect of aging on the pinch off strength. Coupled with the findings of task 3 these results should provide the necessary conclusions to assess the tank integrity and any effects of aging.

Task 5: Conclusions and final report - A final report will be prepared summarizing the findings of tasks 1 through 4 and including conclusions that address the four questions raised above. The final report will also recommend a series of additional drop tests and coupon tests to be carried out to bring this project to completion.