

Shell-NASA Vibration-Based Damage Characterization

John Michael Rollins

Introduction

This article describes collaborative research between Shell International Exploration and Production (IE&P) scientists and ISAG personnel to investigate the feasibility of ultrasonic-based characterization of spacecraft tile damage for in-space inspection applications. The approach was proposed by Shell personnel in a Shell-NASA “speed-matching” session in early 2011 after ISAG personnel described challenges inherent in the inspection of MMOD damage deep within spacecraft thermal protection system (TPS) tiles. The approach leveraged Shell’s relevant sensor and analytical expertise. The research addressed the difficulties associated with producing 3D models of MMOD damage cavities under the surface of a TPS tile, given that simple image-based sensing is constrained by line of sight through entry holes that have diameters considerably smaller than the underlying damage cavities. Damage cavity characterization is needed as part of a vehicle inspection and risk reduction capability for long-duration, human-flown space missions. It was hoped that cavity characterization could be accomplished through the use of ultrasonic techniques that allow for signal penetration through solid material.

Basic Approach

The project was originally planned to require up to three tests – the acquisition test, in which the basic ability to transmit an ultrasonic signal through the TPS material of interest (and acquire a response) was examined, and one or two imaging tests to convert signal response into a 3D model of the TPS cavity being studied. The imaging tests would be conducted only if the acquisition test showed that an adequate ultrasonic signal could be detected after traveling through the tile material. As it turned out, the acquisition test and following analysis showed that the acoustic transmissivity through TPS material was too poor to pursue the method into the imaging tests. The process of test planning through final report generation took place between January and December 2012, and the project is considered complete with respect to ISAG participation.

Acquisition Test

The acquisition test was performed at JSC. Shell designed the tests; provided test articles of interest, transducers, and a submersion pool for one of its test articles; and sponsored the sensing (*i.e.*, vibrometer) resources. NASA and its contractors provided the tiles, the test work area, signal-generation equipment, the lifting apparatus, drainage, and safety and technician support.

Test Implementation

Each trial consisted of attaching an ultrasonic transducer near or onto one surface of a test article and reading the response with the laser vibrometer. The test data was collected by Polytec vibrometer analysts (using their equipment) and analyzed by the project lead scientist from Shell, who had designed the test procedure.

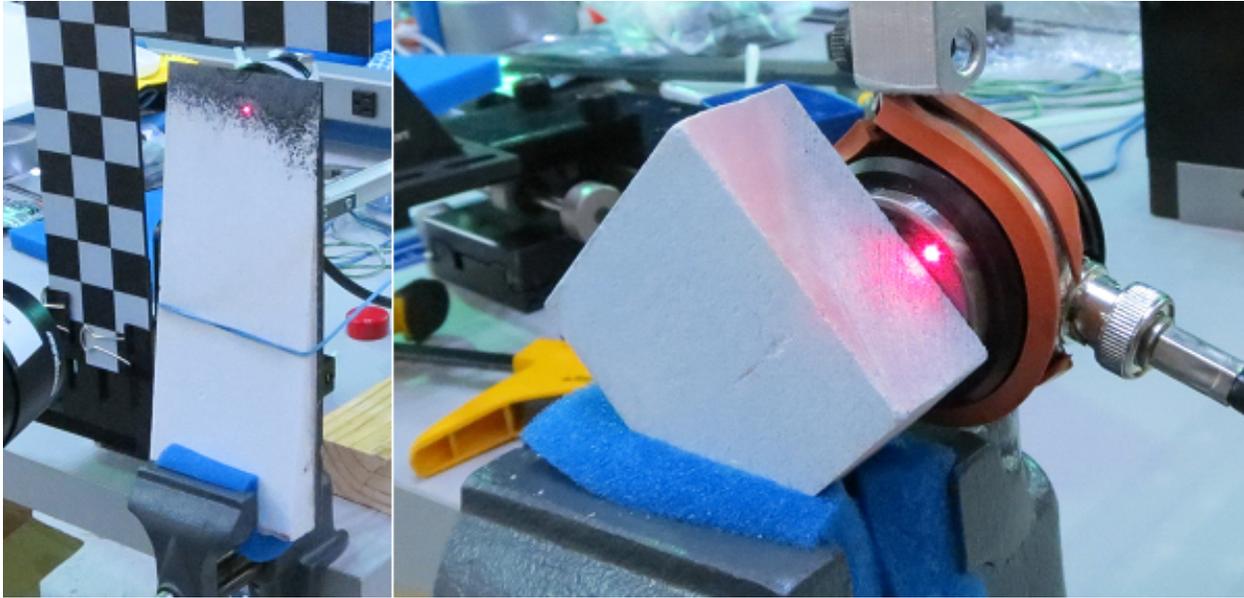


Figure 1.– (Left to right) Tile wedge and low-density tile slab with a vibrometer laser spot hitting the transducer.

Test Results

For through-transmission testing with the tile wedge, extremely large attenuation (1000x amplitude damping per inch of thickness) was observed in comparing ultrasonic excitation with response amplitudes (after propagation through tile material). Given these results, ISAG has no further plans to pursue such a method for spacecraft damage characterization. Results were more promising for at least one test article from Shell, and Shell may pursue such analysis further.

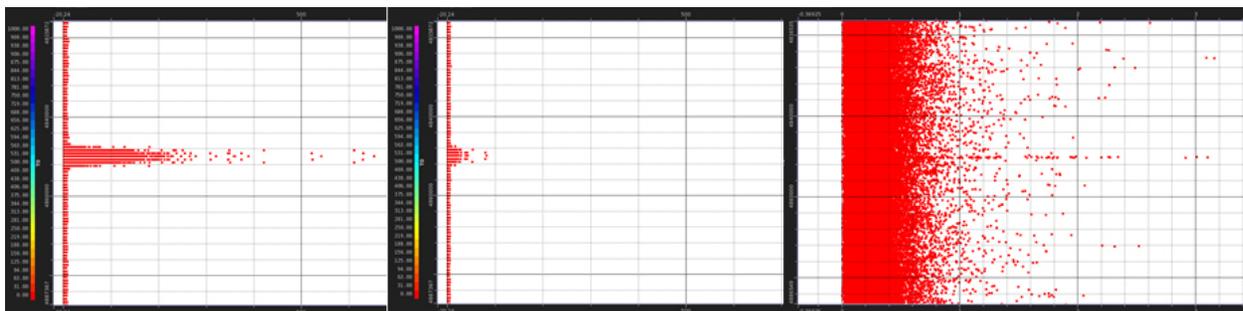


Figure 2.– Plots showing the relative amplitude of an ultrasonic signal propagating through the tile wedge, after transmission through (left to right) 0.16-in., 0.40-in., and 0.87-in. of thickness, respectively. Note that the amplitude is practically in the noise for a signal traveling through less than an inch of tile. Courtesy of Shell IE&P.