FUZZ AND OXIDIZER REACTION PRODUCT (FORP) EVALUATION

SUMMARY

Partially reacted Fuel and Oxidizer Reaction Products (FORP) has been shown to accumulate in hypergolic engines. The presence of FORP can lead to undesirable events. The NASA White Sands Test Facility (WSTF) maintains facilities capable of simulating conditions under which FORP is generated. WSTF can also analyze the by-products of incomplete hypergolic reactions and evaluate the consequences of FORP accumulation in thrusters.

BACKGROUND

FORP is generated during and after hypergolic engine firings. During firing, FORP can be generated due to incomplete combustion in fringe areas of the combustion chamber. Following engine firing, FORP is generated due to propellant valve leakage and residual uncombusted propellants in the injector. Depending on the engine’s design, FORP can accumulate within the thruster’s injector, combustion chamber, or more significantly, in acoustic cavities and in chamber pressure measurement tubes. Under certain conditions, an accumulation of FORP can be combustible or detonable, and can result in a violent reaction that can lead to thruster damage.

Two Shuttle Primary Reaction Control System (PRCS) thruster failures have been attributed to FORP igniting within the combustion chamber pressure (Pc) transducer’s sense tube. The first failure occurred in flight and resulted in de-selecting the damaged thruster for the remainder of the mission. The second failure occurred during a Fleet Leader mission duty cycle firing at Test Stand 301. In both cases, the Pc tube was breached. If the system had not been designed to detect and deselect the thruster in the event of a low chamber pressure, the results could have been catastrophic.

WSTF was heavily involved in both failure analyses and developed ground support equipment (GSE) necessary to remove the accumulation of FORP from Space Shuttle primary reaction control thrusters. Ground support equipment was also developed at WSTF and used at KSC to screen all the PRCS thrusters for potential Pc tube leaks (holes).

PROCEDURE

Following the in-flight failure of the PRCS thruster, a test program was initiated at WSTF to evaluate the cause and consequences of the breached Pc tube. It was initially thought that the Pc tube might have had a material defect that led to the rupture. A PRCS thruster was installed in WSTF Test Stand 405 and fired at altitude with a hole of a known size drilled into the Pc tube. The test established that hole growth (as seen in the in-flight failure) would not occur due to thruster firing, and that damage to the thruster and surrounding Orbiter structure caused by hot gases exiting the hole was minimal.

During this testing, it was discovered that FORP was accumulating in the Pc tube, and that the possibility of FORP ignition needed to be addressed. A test program was initiated to investigate under what conditions the FORP was generated, how the accumulated FORP could subsequently be ignited, and how much energy was released when FORP was ignited. Although the exact nature of the ignition was not identified, WSTF has characterized FORP formation and successfully developed processes that minimize the amount of FORP allowed to accumulate in the Pc tubes. There have been no FORP-related failures on RCS thrusters since these processes were implemented.

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