

Spring 2014 Internship Diffuser Data Analysis

Robert T. Laigaie¹ and Harry M. Ryan²

Engineering and Test Directorate, NASA John C. Stennis Space Center, MS, 39529

Abstract

J-2X engine testing on the A-2 test stand at the NASA John C. Stennis Space Center (SSC) has recently concluded. As part of that test campaign, the engine was operated at lower power levels in support of expanding the use of J-2X to other missions. However, the A-2 diffuser was not designed for engine testing at the proposed low power levels. To evaluate the risk of damage to the diffuser, computer simulations were created of the rocket engine exhaust plume inside the 50ft long, water-cooled, altitude-simulating diffuser. The simulations predicted that low power level testing would cause the plume to oscillate in the lower sections of the diffuser. This can possibly cause excessive vibrations, stress, and heat transfer from the plume to the diffuser walls. To understand and assess the performance of the diffuser during low power level engine testing, nine accelerometers and four strain gages were installed around the outer surface of the diffuser. The added instrumentation also allowed for the verification of the rocket exhaust plume computational model.

Prior to engine hot-fire testing, a diffuser water-flow test was conducted to verify the proper operation of the newly installed instrumentation. Subsequently, two J-2X engine hot-fire tests were completed. Hot-Fire Test 1 was 11.5 seconds in duration, and accelerometer and strain data verified that the rocket engine plume oscillated in the lower sections of the diffuser. The accelerometers showed very different results dependent upon location. The diffuser consists of four sections, with Section 1 being closest to the engine nozzle and Section 4 being farthest from the engine nozzle. Section 1 accelerometers showed increased amplitudes at startup and shutdown, but low amplitudes while the diffuser was started. Section 3 accelerometers showed the opposite results with near zero G amplitudes prior to and after diffuser start and peak amplitudes to +/- 100G while the diffuser was started. Hot-Fire Test 1 strain gages showed different data dependent on section. Section 1 strains were small, and were in the range of 50 to 150 microstrain, which would result in stresses from 1.45 to 4.35 ksi. The yield stress of the material, A-285 Grade C Steel, is 29.7 ksi. Section 4 strain gages showed much higher values with strains peaking at 1600 microstrain. This strain corresponds to a stress of 46.41 ksi, which is in excess of the yield stress, but below the ultimate stress of 55 to 75 ksi. The decreased accelerations and strain in Section 1, and the increased accelerations and strain in Sections 3 and 4 verified the computer simulation prediction of increased plume oscillations in the lower sections of the diffuser. Hot-Fire Test 2 ran for a duration of 125 seconds. The engine operated at a slightly higher power level than Hot-Fire Test 1 for the initial 35 seconds of the test. After 35 seconds the power level was lowered to Hot-Fire Test 1 levels. The acceleration and strain data for Hot-Fire Test 2 was similar during the initial part of the test. However, just prior to the engine being lowered to the Hot-Fire Test 1 power level, the strain gage data in Section 4 showed a large decrease to strains near zero microstrain from their peak at 1500 microstrain. Future work includes further strain and acceleration data analysis and evaluation.

¹ Intern, Systems Analysis and Modeling; Engineering & Test Directorate; NASA John C. Stennis Space Center; University of Texas at El Paso

² Lead, Systems Analysis and Modeling; Engineering and Test Directorate; EA33, Building 3225, Room B29; NASA John C. Stennis Space Center