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Title

Vibration test of upper stage engine for KSLV-II

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Abstract

A launch vehicle consists of two or more stages for launch efficiency. During the combustion of first stage engines, upper stage engines are considered as a payload and are exposed to severe dynamic loads until the first stage separation. The upper stage engines must operate perfectly even after being exposed to the dynamic loads for success of entire launch missions. The 7-ton class liquid engine is newly developed for the upper stage engine of Korea Space Launch Vehicle-II(KSLV-II), and the vibration test was taken into account during the engine development process to verify the structural integrity of the upper stage engine against the dynamic loads during the flight.

First, the test engine was assembled to have same configuration with the actual flight model. During the assembly process, the modal test was conducted to correlate the modal test result of the test engine with the analysis result of the finite element(FE) engine model. From the modal test and correlation process, the high accuracy FE model was obtained and was used to set the vibration test specification.

Next, the coupled load analysis(CLA) was conducted using the full-scale launch vehicle model to estimate the equivalent sine input(ESI) for the vibration test. The ESI from the CLA result cannot be directly used to the vibration test because the boundary condition of the engine interface is different between the test engine and CLA model. Therefore, to obtain the adequate vibration specification, the frequency response function(FRF) analysis was conducted using the correlated FE model. The force and moment on the engine interface at the test frequency range were calculated from the FRF result. Based on the analysis results of the maximum force and moment at the interface, the notched input was generated and was set as the test specification.

The vibration test was conducted with the notched input specification. To control the input level of the shaker and monitor the condition of the test engine during the vibration test, various types of sensors, such as accelerometers, strain gauges, and force sensors, were installed at the pre-selected location. The change in dynamic characteristics of the engine, safety of margin at primary load carrying structures, and load on the engine interface were analyzed from the test data to check the condition of the engine during and after the vibration test. The leak test and disassembly inspection were conducted on the test engine, and the test engine and its sub-components had no problem with its function and performance after the vibration test. The test data and post inspection results showed that the developed engine met all the requirements for the vibration test.

Finally, the disassembled components were reassembled, and the combustion tests were conducted using the reassembled engine as the final verification. As a result, the structural integrity of the engine was verified through a series of several verification processes. After that, second flight of KSLV-II was successfully done in the middle of 2022.