ABSTRACT

Rocket Motor Static Test is the most essential one that is required to validate its design and evaluate its ballistic performance. It is important to validate the design of the rocket motor case owing to high pressure, thrust, strain and vibration coupled with high temperature. In order to qualify the motor, it is essential that minimum two consecutive static tests are carried out successfully with same configuration without design modifications from one test to another.

Two such static tests of Solid Rocket Motor (SRM-3 & SRM-4) have been conducted. The thrust data is acquired by load cell mounted to the head end of the motor through thrust frame and butting against thrust wall, Pressure of chamber is measured through the pressure transducers and strain data are acquired by bonding strain gauges, temperature data are acquired by mounting thermocouples and vibration data are acquired by mounting accelerometers. Both linear and radial deformation/dilation of casing is measured by suitably mounted LVDTs.

The test data of both static tests revealed small amplitude unwanted oscillations for short duration in the pressure and the thrust performance of the motor. In the light of these observations, the present research work focuses on the study of the unwanted oscillations and determining the root cause of the same through analysis.

Frequency analysis of pressure and thrust data using “Sigview” FFT software revealed that the dominating oscillation frequency in both pressure and thrust is 54.29 Hz for SRM-3 and 55.176 Hz for SRM-4.

Frequency response of static test system consisting of test bed and test stand is then analysed using NISA and IDEAS software. From these analyses, it is found that the axial mode of the test bed is 2.674 Hz; the fundamental mode of test stand is 1.16 Hz in axial direction and the axial mode of thrust transmitting elements is 29 Hz. From these results it is evident that these frequencies do not interact with each other and hence do not affect the thrust measurement accuracy.

Vortex flow analyses are then carried out on the pressure data of SRM-3 using FLUENT CFD software at the time of maximum amplitude of oscillations that occurred at t_0+32 s. At this time, the dimensions of inhibition obstacles from the surface of burning propellant at the segment joints and the chamber pressure apart from geometrical dimensions of the motor are simulated for the analysis. Quadrilateral mesh has been implemented for analysis with mesh interval size of 5mm. This analysis revealed vortex shedding at the frequency of 55.43 Hz. This closely matches with the pressure oscillation frequency of SRM-3 and SRM-4. The oscillation seen in the thrust is consequence of pressure oscillations.

Having found out the cause of the pressure oscillations in SRM-3 and SRM-4 is due to the vortex shedding caused by the inhibition obstacles in the gas flow path, three alternate proposals are recommended to avoid vortex shedding in SRMs.

Proposal one is for optimizing the thickness of inhibition so that its erosion rate is matching with the propellant burn rate. This will prevent inhibition projection above the burning surface of propellant.

Proposal two is for developing a new inhibition resin that meets the functional requirements and at the same time having an erosion rate equal or slightly less than the burn rate of propellant. This also would avoid inhibition obstacles.

Third proposal which is more practical is to avoid nozzle end and middle segment inhibition joint by having this joint only at the hardware level. As the head end segment burns out faster due its less propellant grain web thickness compared to the grain web thickness in the remaining portion of the SRM, vortex shedding is will not happen with one inhibition projection at the head end joint. CFD analysis of this two segmented version of SRM is suggested as future scope of work.