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FLOW SEPARATION IN ROCKET MOTORS DURING SEA LEVEL STATIC TEST

Abstract

Large rocket motors designed for higher altitude are tested at sea level as the ambient pressure simulation equivalent to higher altitude is difficult. In such cases flow inside nozzle will separate and thrust of the rocket will vary significantly from the actual performance. However, accurate prediction of performance of the motor during static test is mandatory. Clear knowledge on quantifying the parameters which affect the performance variation is necessary to evaluate at the designed altitude. Accurate prediction of motor performance is essential for understanding the possible vibration, heat transfer, and other flow separation related issues which can affect the normal performance of nozzle or even may lead to a failure. The Optimum thrust on rocket launchers are achieved when the nozzle exit pressure is equal to the ambient pressure i.e. an adapted or ideally expanded nozzle. But in most cases it is either over or under expanded. In overexpansion which arises when the exit pressure is less than the ambient pressure, the exit flow adapts to the higher ambient pressure through a shock-wave phenomena. As the exit pressure becomes too low, the boundary layer at wall can no longer withstand the adverse pressure gradient, the nozzle flow separates from the wall. When the ambient pressure is less than or only slightly greater than the nozzle exit pressure, the flow remains undisturbed. However, an ambient pressure considerably greater than exit pressure can induce boundary-layer separation and oblique shocks leading to flow separation.

Determination of the separation point in over-expanded nozzles and the resultant thrust is computed either by empirical models or computational fluid dynamic (CFD) techniques. As the CFD analysis is highly time consuming for carrying out for the full range of flow separation regimes, empirical models are adopted to have quick results with sufficient accuracy. In the current study, the methodology applied in predicting the separation point and performance of the motor is based on empirical models. Based on extensive review on flow separation in nozzles, models suggested by Kalt and Badal, Schilling, and Schmucker are chosen to study the accuracy of predicting the flow separation in different motors. Five solid rocket motors of ISRO having different sizes which were static tested in sea level are considered in the present study. Analysis indicated that all empirical models are equally good to predict the flow separation and associated thrust loss where as Kalt and Badal provides better results.