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RESEARCH ON THE BASE HEATING OF SUB-SCALE HYDROGEN/OXYGEN ROCKET

Abstract

Launch vehicles with multiple nozzle configuration in flight have an extremely complex flow field distribution at the rocket base, and changes significantly with the flight altitude. This is due mainly to plume interaction and plume-freestream interaction during the ascent of the rocket, resulting in a high-temperature backflow that produces significant heating at the baseplate of the rocket. The thermal environment of the rocket base is highly severe, so the accuracy of the prediction on the thermal environment will directly affect the safety design of the rocket base thermal protection structure. However, the cost of conducting this test for a full-size rocket engine is prohibitive, and base heating is highly correlated with the base nozzle configuration. Up to now, there have been many cases of failed rocket launches in recent years due to insufficient predictions of base heating. To evolve design solution to the above problems, clear understanding of the plume interaction and heating mechanism around the base is essential. In the present study, the relationship between the thermal environment and the flight environment, the scale of the vehicle, etc. was first theoretically derived. In addition, a sub-scale hydrogen/oxygen rocket was designed for testing in a high-altitude simulation facility to investigate the fundamental heating mechanism during rocket flight. The base heating at the sub-scale rocket was measured using heat flux sensors, temperature sensors, and radiometers mounted on the base plate at different simulated flight altitudes. Also, some optical measurement methods had been introduced to observe the base flow field. Before the plume reaches a choke state at the rocket base, the heat flux at the baseplate is mainly influenced by the ambient pressure, and it is almost linearly related to the pressure. This result was also clearly shown early in the theoretical formulation. In order to more widely adapt to the prediction of heat flux at different scales, the theoretical formula was modified accordingly based on the experimental results. Finally, a modified empirical formula can be effectively predicted for the rocket base thermal environment to guide the design of the launcher thermal protection system.