Paper ID: 27521
poster

SPACE PROPULSION SYMPOSIUM (C4)
Interactive Presentations (IP)

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NUMERICAL STUDY FOR SIMULATING LIQUID ROCKET ENGINE EXHAUST PLUME USING MULTI-SPECIES UN-REACTED FLOW MODEL

Abstract

The exhaust gas of liquid rocket engine was considered as a state-variant multi-species turbulent flow by experience. The molecular weight of the gas varies continuously as the gas travels from the combustor to the nozzle. However, the plume maintains a relatively constant molecular weight if the control volume is limited to the flow outside the nozzle. In former studies, the flow field analyses conducted as the constant molecular weight which is determined via the CEA analysis, the single-species un-reacted model. It can yield a meaningful at simulating temperature field for a better computational efficiency. As a compromise, this study presents several 2D multi-species un-reacted flow models which yield close results to that of the reaction model yet applicable to simulating the radiation effects of liquid rocket exhaust plume. At first, the reference model deals with 9 species with 14 equation; the Case 2 is single-species un-reacted model that employs specific heat of the plume model; the three-species un-reacted model that deals with only three most important radiated gases, i.e. H2O, CO2, CO is concerned as Case 3; the five-species un-reacted model that employs five primary radiated gases, i.e. H2O, CO2, CO, H2, O2 and matches the specific heat to that of the reaction model is Case 4; and finally, Case 5 builds the four-species un-reacted model that adds the specific heat-corrected plume to the three-species un-reacted model to make the specific heat similar to that of Case 2. The results indicate that the four-species un-reacted model yields the closest Mach number and temperature distributions to those of the reaction model, reference one. Even for the off-center condition, although minor error is inevitable, the results from this model is much closer to the reference model than the single-species un-reacted model. Therefore, it is concluded that the four-species un-reacted model suits best for future works that evaluate temperature distribution of three dimensional exhaust plume inside the flame deflector.