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# INVESTIGATIONS OF REAL-FLUID CHARACTERISTICS IN HIGH-PRESSURE LIQUID ROCKET ENGINES

**Abstract**

Raising performance in liquid rocket engines (LREs) has driven the pressure of combustion chamber upwards enormously. Extensive studies have clearly demonstrated that the physicochemical mechanism of flow and combustion under supercritical conditions dramatically differed from those under subcritical conditions, in that the thermodynamic non-ideality and anomalous transport properties under high-pressure conditions, which obviously departed from ideal-gas behavior, would induce significant impacts on flow and combustion. Therefore, using ideal-gas models and methods developed under low-pressure conditions would lead to erroneous results for typical high-pressure LREs. Real-fluid characteristics and their impacts on flow and combustion in high-pressure chamber of LREs would be analyzed thoroughly in this paper. Several real-fluid models are employed for typical cryogenic propellants, such as O2, CH4, and hydrocarbon C12H26 over a wide range of thermodynamic regimes, and the results would be compared with those obtained from ideal-gas models and NIST database. As a result, firstly, enormous errors would be produced from ideal-gas equation of state (EoS) owing to without considering compressibility factor, especially in low-temperature regimes, while SRK EoS could correctly predict the p-V-T behavior of small molecules with higher critical compressibility factor Zc, and PR EoS seems relatively suitable for bigger hydrocarbons with lower Zc. It is noteworthy that consistently exact results could be obtained by MBWR EoS in conjunction with the extended corresponding-state (ECS) principle. As fluid temperature is heated to high sufficiently, however, where the real-fluid effects become negligible, the p-V-T behavior approaches ideal-gas characteristics. Secondly, remarkable variation of heat capacities near critical point could be correctly predicted by departure functions based on cubic EoS due to high-pressure correction. Thirdly, viscosity and thermal conductivity of small molecules could be predicted correctly by Chung method which, however, is not appropriated for bigger hydrocarbon, whereas ECS is proven to be satisfying for not only small molecules but also bigger hydrocarbon. Finally, although several sophisticated models such as ECS are quite exact, they have scarcely been implemented into CFD codes because of complex non-linear forms and computational inefficiency, whereas cubic EoS are easier to be implemented. Therefore, a compromise between precision and efficiency should be chosen to account for the real-fluid characteristics in high-pressure LREs.