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TRANSIENT RESPONSES OF TURBULENT HEAT TRANSFER OF N-DECANE AT SUPERCRITICAL PRESSURE AND TEMPERATURE BELOW 800 K

Abstract

Regenerative cooling has been the conventional method for cooling liquid rocket engines for a long time. Prior to fuel injection and burning, the hydrocarbon fuel would be circulated in mini cooling channels surrounding the combustor chamber in order to cooling the engine. Regenerative cooling process commonly occurs at a high pressure above the critical point of the fuel, thus convective heat transfer at supercritical pressures comes about.

Up to now, numerical and experimental works mainly focus on the steady-state heat transfer process at supercritical pressures, and very few studies have been conducted under unsteady-state. Heat transfer at a stepwise change in surface heat flux and a steady fluid flow rate is one of the simplest cases of unsteady heat transfer. But even in this case the underlying mechanisms are still not fully understood. Since the transient phenomena in engine cooling channels might influence the stability of fuel injection and subsequent combustion process, detailed numerical studies on transient heat transfer processes at supercritical pressures are needed to be carried out in order to look deeper into the thermophysical and transport mechanisms.

In this paper, a numerical study has been conducted to investigate transient responding behaviors of fluid flow and heat transfer of n-decane at a supercritical pressure and temperature below 800 K, at which point the pyrolysis process can be neglected. The extended corresponding states (ECS) method is applied for accurately calculating strong variations of the thermophysical properties of n-decane, including fluid density, constant-pressure heat capacity, and viscosity. A steady-state cold flow is instantly enforced with a constant surface heat flux to activate the transient heat transfer process. The effects of surface heat flux on transient responses are examined in detail.

Results indicate that during transient heat transfer process, the increased fluid temperature leads to the significantly decreased fluid density at a supercritical pressure and consequently causes a strong fluid-expansion, which brings about an initial overshoot of the velocity and pressure from its final steady-state values. The subsequent correction, on the other hand, leads to an undershoot, then the thermally-induced flow oscillations are produced. Flow oscillations become stronger and last longer under a higher surface heat flux. For all the tested cases investigated in this paper, the maximum transient response time is around 80 ms.