Paper ID: 76915
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IAF SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

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INVESTIGATION ON COMBUSTION PERFORMANCE OF MACH 5 HYPERSONIC RAMJET WITH SUBSONIC COMBUSTION

Abstract

Abstract: A concept of Mach 5 hypersonic ramjet with subsonic combustion has been proposed in the published literature. The most critical aspect of ramjet performance calculation is the design of the combustion organization in combustion chamber. Therefore, this study proposes a combustion organization scheme of direct injection of fuel with a fuel injection ring in the head recirculation zone of the dump combustion chamber to verify the feasibility of the design of hypersonic ramjet based on subsonic combustion. With the LES model of the methods, flow field characteristics are stimulated. In order to optimize the combustion organization scheme, the effects of the changes of the fuel supply device layout on the combustion characteristics in the combustion chamber is obtained by analyzing the flow field in the combustion chamber. Reasearch shows the numerical simulation of an ignition process, that is, the process of flame spreading from a partial to an entire combustion chamber. After t > 0.003s, the combustion chamber almost reaches a stable combustion state. At the same time, the results also indicate that when the direct injector diameter varies from 0.6mm to 1.0mm, the change of its diameter has less effects on the combustion characteristics than the change of injection position does, which can be ignored relatively. As the diameter Φ of the fuel injection ring gradually increases from 0.5 times to 0.9 times of the diameter D of the combustion chamber. At the booster-to-ramjet transition point {Ma=3.5}, the high temperature region gradually varies from the downstream of the combustor to almost the whole region. The combustion efficiency first rises and then falls. At the design point {Ma=4.5}, the combustion efficiency increases. At the cruising point {Ma=5.0}, the combustion efficiency keeps almost constant. At the diving point {Ma=5.5}, it slowly decreases. The combustion organization scheme is improved, and the ramjet performance has been obtained as follows: the thrust coefficients at the booster-to-ramjet transition point, design point cruising point and diving point are 0.698, 0.608, 0.362 and 0.192, respectively. The specific impulses are 14145.3N·s/kg, 13395.6N·s/kg, 12213.9N·s/kg and 8111.7N·s/kg, respectively. The combustion efficiency was 86.4%, 91.7%, 94.0% and 90.6%, respectively. It can be concluded that it is feasible to apply the subsonic combustion to the Mach 5 hypersonic ramjet. Compared with the design of Scramjet in X-51A, which adopts complex supersonic combustion, the subsonic combustion technology adopted in the ramjet in this study offers another methodology for Mach 5 hypersonic ramjet.

Key words: hypersonic ramjet; subsonic combustion; LES; ramjet performance