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Corresponding author: Sasi Kiran Palateerdham
e-mail of corresponding author: Antonella.Ingenito@uniroma1.it
Type: **Oral** / Poster
Status of corresponding author: **Regular** / **Student**
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Numerical investigation of the impact of injectors location on fuel mixing in the HIFiRE 2 Scramjet combustor

Authors

*Sasi Kiran Palateerdham *[1], Lakshmi Narayana Phaneendra Peri [2], Antonella Ingenito [3], Ashish Vashishtha [4]*
** Corresponding author*
[1] *PhD student, School of Aerospace Engineering, Sapienza University of Rome, Italy, sasikiran.palateerdham@uniroma1.it*
[2] *Research Fellow, School of Aerospace Engineering, Sapienza University of Rome, Italy, phanindra.p123@gmail.com*
[3] *Professor, School of Aerospace Engineering, Sapienza University of Rome, Italy, Antonella.ingenito@uniroma1.it*
[4] *Lecturer, South East Technological University, Carlow Campus, Ireland, ashish.vashishtha@setu.ie*

Abstract

The residence time in a supersonic combustion ramjet, or scramjet, combustor is commonly known to be of the order of fractions of millisecond. In such a short amount of time, injected fuel must accomplish efficient mixing with the incoming supersonic air to facilitating flame anchoring. In the supersonic combustion, a vast range of phenomena can occur, which results from interactions between injector flows, shock waves, boundary layers, and cavity flow. The combustion efficiency in scramjet combustor is highly sensitive that even minor losses owing to ineffective combustion, coupled with large friction losses, boundary layer/shock wave interactions, and overall total pressure losses, might result in low or even negative engine efficiency. Assuring a good ignition and flame stability while avoiding excessive total pressure losses has long been one of the goals of scramjet combustion research. [1]. The theoretical (physical) understanding on this area is quite limited. Various current studies focus on efficient fuel-air mixing and enhancing combustion efficiency in supersonic flows . In scramjet systems, the fuel is injected into supersonic stream, a bow shock form in front of injected fuel jet in supersonic crossflow. The position and direction of the injectors plays a crucial role in the bow shock strength, in fact, fuel mixing and thrust potential completely depends on it. [2]

Fuel injection is still a potential topic of research to be addressed, an effective fuel injection strategy is critical for realizing effective fuel-air mixing. and results in improving combustion stability and overall combustor performance. The position of the fuel injectors in a cavity scramjet has a potential influence on the fuel and air mixing processes in the supersonic flow[3-5]. In this regard, the research work provides more information on physical phenomena by altering the positions of the injectors in the HIFiRE 2 combustor through the comparison of the numerical results of the supersonic flow field inside the combustor before injection (cold flow simulations without fuel injection), once injected before ignition (cold flow simulations with injection), and after ignition (hot flow conditions), using 3D RANS and LES simulations. These simulations in different flow conditions shows the direct and mutual effects of the shock waves interaction, the heat addition, friction, mixing, boundary layer separation on the total pressure losses, that is a very important parameter: in fact, if the total pressure reduces, the performance of the engine reduces as well.

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