Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: AEROFLIPHY / CFDMPS

Corresponding author: ESPOSITO Salvatore
e-mail of corresponding author: salvatore_esposito@polito.it

Type: Oral
Status of corresponding author: Student
For student corresponding author: student member of one of the following:
3AF / AAAR / AIAE / AIDAA / CzAeS / DGLR / FTF / NVvL / PSAA / RAeS / SVFW / EUROAVIA

Title
A Study on Plasma Formation on Hypersonic Vehicles using Computational Fluid Dynamics

Authors
Salvatore ESPOSITO [1], Domenic D'AMBROSIO [2]*

** Corresponding author*
[1] Politecnico di Torino, DET, Corso Duca degli Abruzzi, 24, 10129 TORINO, Italy, salvatore_esposito@polito.it
[2] Politecnico di Torino, DIMEAS, Corso Duca degli Abruzzi, 24, 10129 TORINO, Italy, domenic.dambrosio@polito.it

Abstract
In the hypersonic regime, objects traveling at speeds far surpassing the speed of sound generate temperatures that significantly affect the surrounding flow field. These elevated temperatures stem from the transfer of kinetic energy from the object to the gas, primarily through an intense bow shock wave. The resulting energetic gas can undergo chemical reactions and air ionization, forming a plasma that can impact radio communications and radar tracking. Improving our understanding and ability to predict plasma formation around hypersonic vehicles is essential for evaluating their radio communication capabilities, obtaining reliable data for radiation heating simulations, and accurately tracking such objects.

This study employs Computational Fluid Dynamics (CFD) to enhance our understanding of high temperature effects in the hypersonic regime and improve the accuracy of plasma formation predictions. The simulations incorporate reference chemical-kinetic models [1] and more recent versions [2] that consider chemical-kinetic parameters derived from precise shock tube experiments. The research also focuses on the impact of the assumed air mixture composition and examines air models consisting of either 7 or 11 chemical species. The results generated from these models are validated with experimental data from the RAM C-II during its re-entry phase and verified through comparison with numerical simulations in the literature.

Alongside the validation and comparison of chemical-kinetic models in predicting plasma formation, this study aims to quantify the plasma presence as a function of flight speed, altitude, and vehicle size. The study intends to highlight any differences that may arise in the prediction of plasma formation and spatial distribution resulting from the use of different chemical-kinetic models. This analysis considers axisymmetric blunt cone geometries similar to RAM C-II.

The ultimate objective of the study is to provide a deeper understanding of high-temperature effects in the hypersonic regime and improve the accuracy of plasma formation predictions, which is crucial for the advancement of hypersonic aircraft and related areas of research, such as materials and thermal protection systems.

References
[1] C. Park, Review of chemical-kinetic problems of future NASA missions. I-Earth entries, J. Thermophys Heat Transfer 7 (3) (1993) 385–398.

[2] Kim, Jae Gang, and Sung Min Jo. "Modification of chemical-kinetic parameters for 11-air species in re-entry flows." International Journal of Heat and Mass Transfer 169 (2021) : 120950.