Comparative Numerical Studies of Scramjet Inlet Performance Parameters Using K-ε Turbulence Model with Adaptive Meshing

V. Gopal[1], R. Kolluru[1]

[1]BMS College of Engineering, Bangalore, Karnataka, India

Abstract

Scramjet inlet design remains as a key aspect for a hypersonic flight. To assess the design, multiple performance parameters are evaluated and inspected, which provides an insight into the flow field as it is cardinal to ensure that favourable flow regimes exist for combustion of a stable flight. The current study involves comparison of performance parameters for scramjet inlet which are evaluated as a result of FEM computation of 2-D turbulent flow field around four different scramjet inlet geometries. The salient geometrical parameters which are varied are; inlet ramp contour and cowl angle. The inlet ramp is either designed to be a double ramp or a smooth second degree curve while the cowl angle is either 0 or 10 degree, which all to-gather provides four different combinations. The design ensures to avoid any event of unstart by restricting the internal contraction ratio of scramjet to be less than Kantrowitz limit ref[1]. The 2-D computation of turbulent flow is obtained by implementing high Reynolds number k-epsilon compressible turbulent formulation ref[2] with constant turbulent Prandtl number of 0.89. The boundary and initial conditions are carefully selected to mimic the free stream conditions that pertain to a cruise altitude of 25km. The simulation is performed for both free stream Mach number 4 and 5.Thus from the obtained result a comparative study of vital performance parameters which quantify mass capture, spillage, pressure efficiency, kinetic efficiency and aerodynamic forces is carried out by parameterising geometrical variables and free stream Mach number. In the present work, the "Turbulent high Mach number flow" module using k-epsilon formulation with pseudo time stepping methodology and adaptive gridding technique is used to obtain a steady state solution by marching in time to capture the shocks occurring in the flow field. The simulations were performed for 8 cases and for each case the Euler solution was first obtained and then the same was made as the initial condition for simulation with turbulence. The preliminary computational results from COMSOL Multiphysics for turbulent flow are analysed, while the evaluation of performance parameters is under progress. The surface plots for Mach number with different geometries with free stream Mach number of 4 is plotted in figures (1-4).

Reference

[1]E.T. Curran, S.N.B Murthy, “Scramjet Propulsion”, Progress in Astronautics and Aeronautics”, AIAA Volume 189.

[2]Christopher J Roy and Frederick G Blottner, ”Assessment of One- and Two-Equation Turbulence Models For Hypersonic Transitional Flows”, Sandia National Laboratories, Albuquerque, New Mexico 87185,Journal of spacecraft and rockets, Vol.38,No.5,September October 2011.

Figures used in the abstract

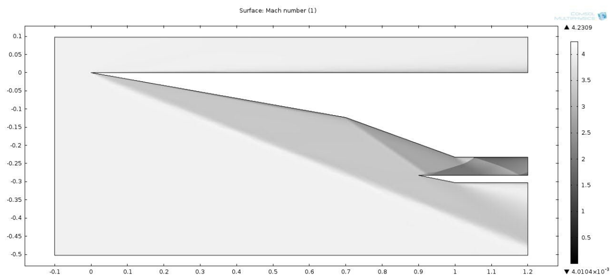

Figure 1: Surface plot of mach number for double ramp inlet with cowl angle =0 degree with free stream Mach number 4.

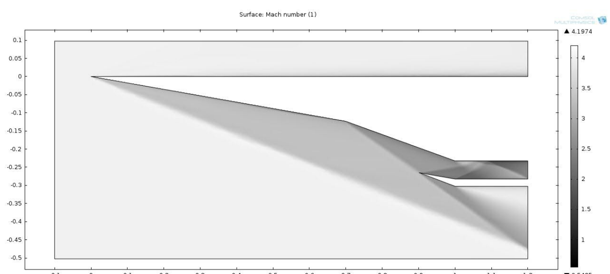

Figure 2: Surface plot of mach number for double ramp inlet with cowl angle =10 degrees with free stream Mach number 4.

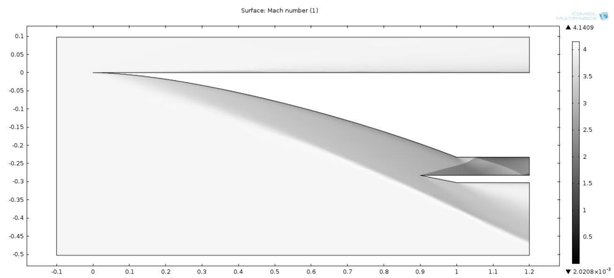

Figure 3: Surface plot of mach number for smooth second degree curve Ramp inlet with cowl angle =0 degree with free stream Mach number 4.

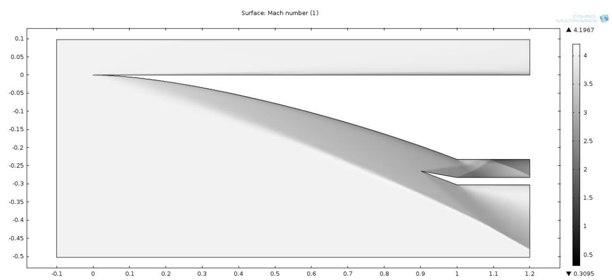

Figure 4: Surface plot of mach number for smooth second degree curve Ramp inlet with cowl angle =10 degrees with free stream Mach number 4