An Aerothermodynamic Heat and Mass Transfer Analysis of Impinging Supersonic Jet on Curved Surfaces

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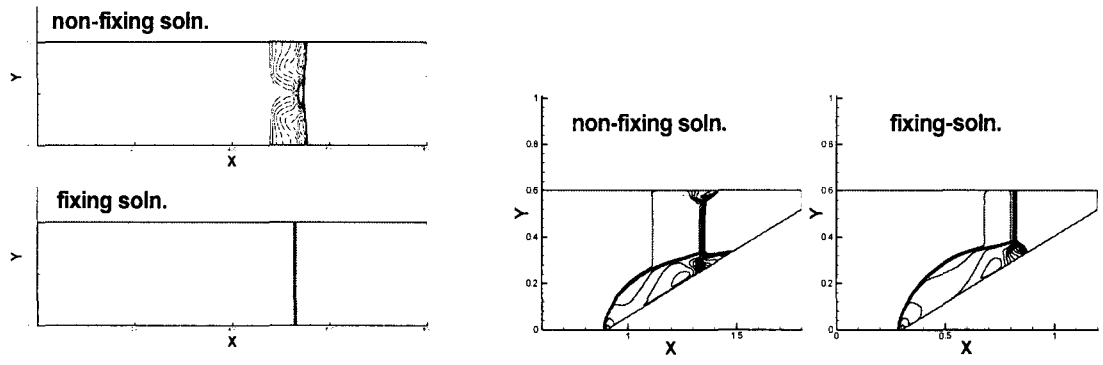
Abstract

A numerical analysis has been performed to predict the thermal response and ablation rate of thermal protection material used in thermal protection system of vertical launching system. To obtain the thermal boundary conditions, i.e., cold wall heat transfer rate and recovery enthalpy for Material Transport Analysis[1], which includes a 2-D/axisymmetric heat conduction equation solver, surface energy conservation solver, and chemical equilibrium computer program, a numerical analysis of axisymmetric high temperature supersonic impinging jet flows of exhaust gas from combustor on concave and convex surfaces has been accomplished. A modified CSCM Upwind Navier-Stokes method[2] which is able to cure the carbuncle phenomena has been developed and tested to study strong shock wave structure and thermodynamic wall properties also.

The results show that the maximum heat transfer rate which is the most important parameter affecting thermo-chemical surface ablation on the plate did not occur at the center of jet impingement, but rather on a circle slightly away from the center of impingement by shear layer effect at the nozzle exit and the shear stress distribution along the wall is similar to the wall heat transfer rate distribution. And surface shapes affected flow expansion in radial direction, so the location of the maximum heat transfer rates slightly moved from the center, but that of the maximum pressure did not..

Keyword: *ablation, MTA, CSCM method, jet impingement, carbuncle phenomena*



(a) OED problem **(b) DMR problem**

Fig. Density contour plot comparisons between Carbuncle fixing and non-fixing solutions of the (a) Odd-Even Decoupling problem and (b) Double-Mach Reflection problem

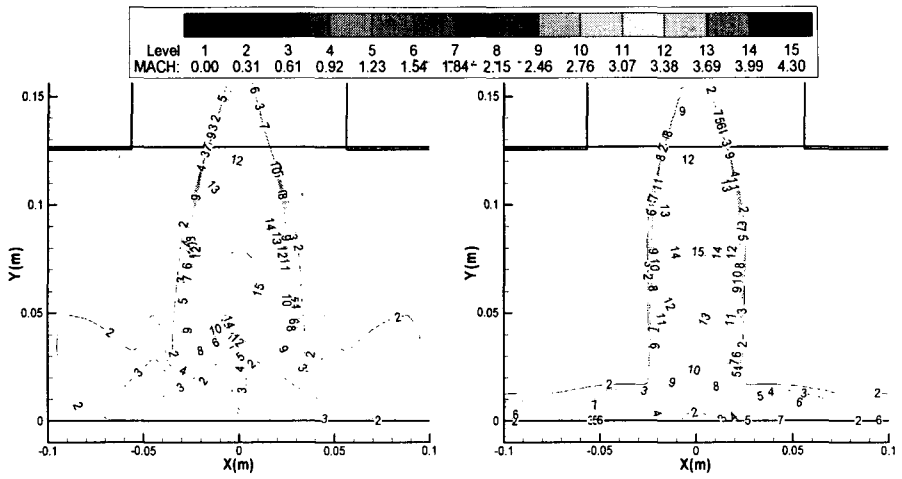
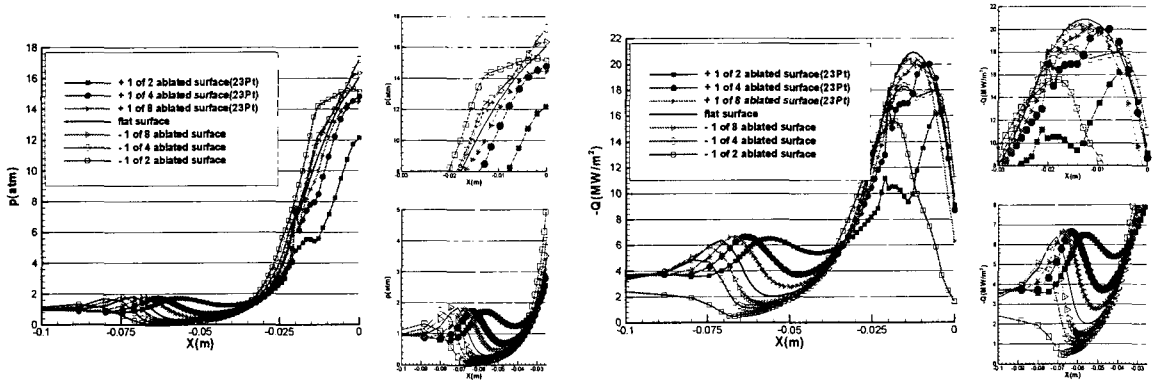


Fig. Heat transfer rate comparison plots among different surface shapes(concave surface cases) over impinging region



(a) (b)

Fig. (a) Wall pressure and (b) Heat transfer rate comparison plots among different surface shapes

References

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[2] Seo, J. I., Jeong, J. H., and Song, D. J., "A Numerical Study of Heat and Mass Transfer in Supersonic Impinging Jet Flow on a Flat Plate," *The 23rd International Symposium on Shock Waves*, pp. 203, Fort Worth, Texas, USA, July 23-27, 2001