Transition and Shock Boundary Layer Interaction in Hypersonic Flows

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HYPER-X AT MACH 7: This computational fluid dynamic (CFD) image is of the Hyper-X vehicle at the Mach 7 test condition with the engine operating.

Motivation

•Accurate estimation and physical understanding of transition, turbulence, and shock boundary layer interaction in high speed flows.

•Design of vehicles, propulsion systems, and thermal protection systems.

•Accurate prediction of aerodynamic forces and surface heating.

Objectives:

▪ Improve numerical methods, accurately resolve interaction between turbulence and shocks/species discontinuities in hypersonic propulsion system flows.

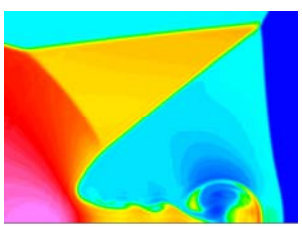
▪Improve the prediction of transition to turbulence for high-speed non-equilibrium flows.

▪Model the unsteady, nonlinear flow associated with shock boundary layer interaction.

▪Understand how the inaccuracies of physical models affect computational results and interact with numerical errors.

Numerical Approaches

▪High-order compact difference scheme with localized hyper-diffusivity scheme
▪Adaptive Local Grid Refinement
▪Hybrid RANS, LES

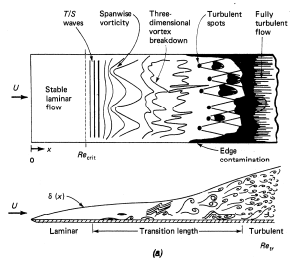


High-Order Discontinuity Capturing Scheme

Mars Entry: Transition to Turbulence

Basic Problems

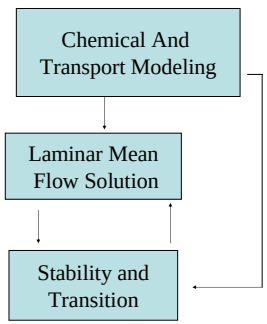
▪Hypersonic transition mechanisms poorly understood and difficult for experimental study.
▪Chemical modeling has large amount of uncertainty.



Boundary Layer Transition (*Viscous Fluid Flow*, White)

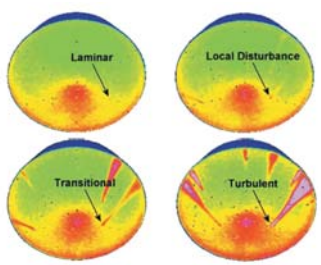
Approach

•Sensitivity studies of stagnation line boundary layer.
•Computational studies of distributed and/or discrete surface roughness.



Long Term Goal

Better understanding may lead to less conservative designs.

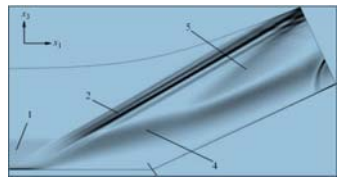


Effect of Surface Cavities on Heating for Mars Science Laboratory (*Edquist et al, 2006*)

Shock Boundary Layer Interaction

Basic Problems

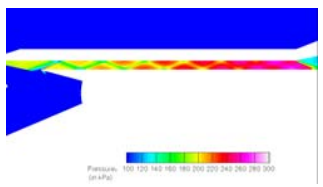
•Unsteady interaction between turbulent boundary layer and complex shock structure.
•Inlet unstart.



Shock-Boundary Layer Interaction (*Loginov, JFM 2006*)

Approach

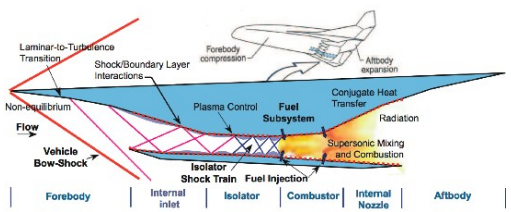
•Hybrid RANS/LES
•Integrated into larger hypersonic project at Stanford.



Shock Train in Combustion Chamber of Hypersonic Vehicle

Long Term Goal

Detailed Analysis of Atmospheric Hypersonic Vehicle.



Hypersonic Vehicle Schematic

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