8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Aeroheating Prediction of 3-D Hypersonic Vehicles Using Inviscid Properties Calculated on Unstructured Grids

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Key Words: *Hypersonic, Aeroheating, Unstructured Grid, Axisymmetric Analog*

ABSTRACT

An engineering inviscid-boundary layer method for predicting the convective heating rate of three-dimensional hypersonic vehicles at angle of attack is described. The procedure is based on the axisymmetric analog [1] which allows axisymmetric boundary layer techniques to be applied to three dimensional flows provided the inviscid surface streamlines are known. The surface streamlines and metrics are calculated using the inviscid velocity components on the surface. Then, approximate convective heating equations are used to evaluate heating rates along the streamlines. This approach yields heating predictions to general three-dimensional body shapes.

In the previous researches [1, 2], the inviscid surface streamlines and the streamline metrics were obtained from the inviscid solution calculated on a structured grid. However, inviscid solution can be obtained on more complex geometries using unstructured grids. The application of the axisymmetric analog to the unstructured grids was started in an unfinished research by Riley and DeJarnette. DeJarnette, et. al. [3, 4] used inviscid flow properties from an unstructured grid to successfully calculate streamlines and metric coefficients.

In the present research, a new simple technique is developed for computing convective heating rates on general three-dimensional hypersonic vehicles using unstructured grids. In order to calculate the heating rates at any specific point on the surface, a technique is developed to calculate the inviscid surface streamlines in a backward manner. The metric coefficients are also calculated using a simple technique. Since the method is capable of using inviscid properties calculated on an unstructured grid, it is applicable to a variety of configurations and it requires much less computational effort than a Full Navier-Stokes code. The results of the present method are evaluated on different wing body configurations in laminar and turbulent hypersonic equilibrium air flows. In comparison to experimental data, the present results are found to be fairly accurate in the windward and leeward regions.

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FIGURES

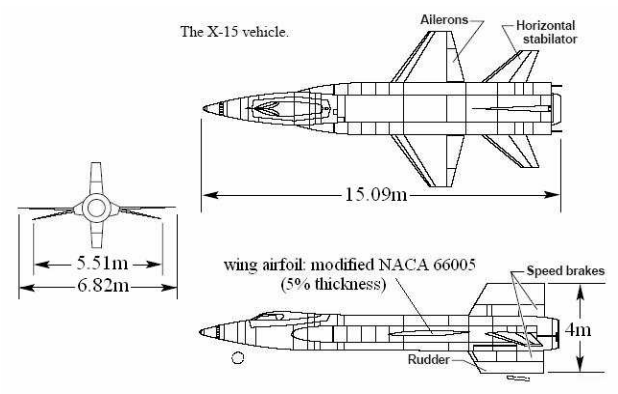

Fig. 1- Three-view drawing of X-15 hypersonic aircraft

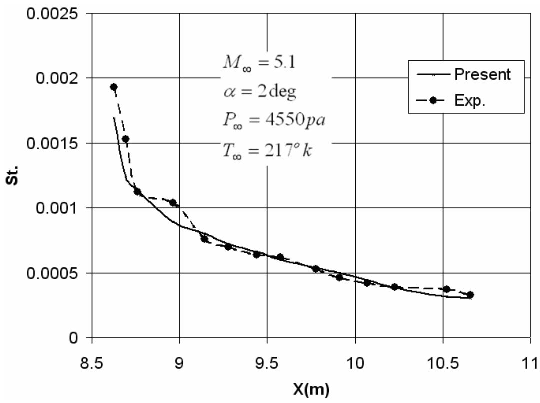

Fig. 2- Comparison of Stanton number on lower surface of X-15 wing

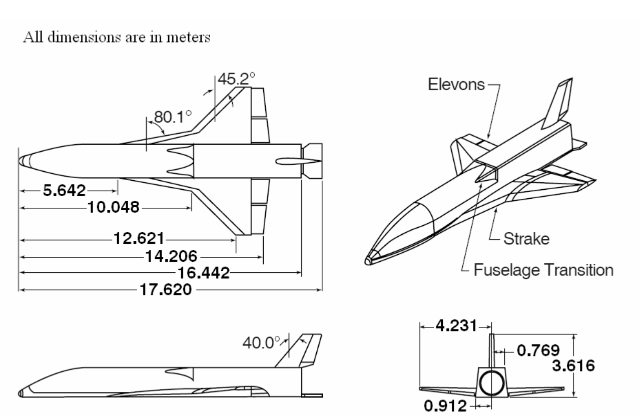

Fig. 3- Three-view drawing of X-34

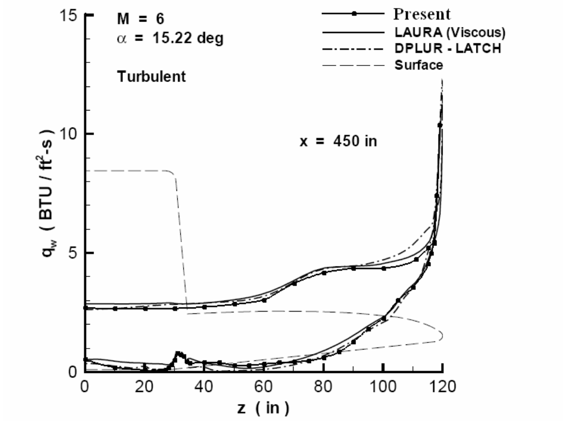

Fig. 4- Lateral turbulent heating distribution on X-34 at x=11.43m