NASA TECH BRIEF

Langley Research Center

Numerical Program for Analysis of Three-Dimensional Supersonic Exhaust Flow Fields (CHAR 3D)

The problem:

The achieving of optimum performance in a scramjet-powered hypersonic aircraft, where the propulsion system is a dominant portion of the vehicle structure, requires sophisticated vehicle-propulsion system integration. The engine exhaust may be underexpanded due to physical area limitations, thus requiring the use of the vehicle undersurface to provide additional expansion. This results in an interacting internal flow/external flow, three-dimensional, nozzle flow field.

The solution:

A numerical method based on a reference plane characteristic technique is used to analyze this flow.

How it's done:

In the reference plane method, the orientation of the reference planes is chosen so that the primary flow variations occur within the reference planes while the coordinate normal to them describes the local cross-flow. The governing equations are written in this reference coordinate system, with the terms representing derivatives normal to the reference planes treated as forcing functions. The characteristic directions are those of the two-dimensional system in the reference plane, and the compatibility relations differ from those of the two-dimensional system by the inclusion of cross-derivative terms. Flow variations must be continuous in the crossflow direction, while wavelike discontinuous flow is permissible in the reference planes.

The choice of the reference plane orientation depends on the specific nozzle geometry, with different configurations requiring different reference plane systems. In addition, for a given configuration several reference systems may be used in different regions of the flow field, so that each system is locally alined with the flow. The numerical procedure in a given reference plane employs a Hartree-type numerical grid, with the streamline projections being traced in the individual reference planes. This approach affords excellent flow visualization through the tracing of these quasi-streamlines and provides self-enforced mesh controls.

The gas mixture considered consists of air and combustion products (with hydrogen as the fuel) and is assumed to be inviscid and in chemical equilibrium. Three parameter curve fits (p, ϕ, and h) have been developed for the necessary thermodynamic properties. The flow may be rotational and nonhomentropic. The overall numerical approach is second order.

Notes:

1. This program was written in FORTRAN IV for the CDC 6000-series computers.
2. Inquiries concerning this program should be directed to:

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