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NASA TECH BRIEF

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Computer Simulation of High-Frequency-Combustion Instability and its Suppression

The problem:

To develop a method to illustrate the effects of some of the variables on combustion instability and its suppression in the combustion chambers of liquid propellant rocket engines.

The solution:

A program for the simulation of gas motion due to combustion energy within a slab rocket motor. The program is based on numerically integrating the laws of inviscid fluid dynamics by a two-step Lax-Wendroff technique.

How it's done:

The slab motor for which the gas motion is to be simulated by the program would normally require all three dimensions (x, y, and z) to simulate the motion of the gas within the motor. However, if the width (z coordinate) is sufficiently small, the problem can be reduced to two dimensions by assuming the flow is zero in the z direction. A sound-absorbing (acoustic) liner can be installed within a combustion chamber to absorb part of the energy in a propagated wave. The transverse waves are, in general, the significant mode of vibration; the liner is installed at the periphery of the chamber to absorb these waves. The present acoustic liner design is based on the theory of the Helmholtz resonator for a wave striking the surface of the resonator. The objective of this program is to provide the method of coupling energy release to the suppression of the driven sound waves by the acoustic liner through the use of the nonhomogeneous conservation laws.

Because the equations used are nonlinear, their integration must be performed numerically. The numerical integration is accomplished using the two-step Lax-Wendroff technique. The numerical integration technique is based on the evaluation of a vector function at time = Δt from the values at time=0 for each point of a grid superimposed on the geometry considered. A two-step Lax-Wendroff scheme is one in which temporary values are generated by a first-order differential equation. These values are then used to generate a solution that is second-order accurate. The size of the mesh required to achieve convergence must be determined empirically.

The differential equations provide a means of calculating values for the arrangement of mesh points at successive time intervals. Special treatment is required to compute the functional values at grid points on rigid walls. To provide the necessary information to the differential equations, a "reflection" principle is employed to image the grid line immediately adjacent and parallel to the rigid wall onto a "virtual" grid line outside the boundary. The finally calculated flow field includes both a subsonic nozzle and a short section of a supersonic nozzle.

The first program performs the numerical integration to simulate the flow field for a lined as well as an unlined chamber. The second program converts the input data or computed results, usually a steady state, for a given mesh size into input data for a mesh half as large. The arrangement reduces the amount of input data cards necessary for small mesh sizes.

Selection of the mesh size should be based on the convergence of the solution. Several mesh sizes, in descending order, should be employed in separate calculations and the size selected so that the solution

(continued overleaf)

does not change appreciably when the size is further reduced.

The program is written with a fixed slope to the wall of the supersonic nozzle to simplify programming. The supersonic nozzle in the program provides a boundary condition only at the discharge end of the combustion chamber.

Notes:

1. This program is written in FORTRAN H language for use on the IBM-360 computer.
2. Inquiries concerning this program may be directed to:

COSMIC
Computer Center
University of Georgia
Athens, Georgia 30601
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Patent status:

No patent action is contemplated by NASA.

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