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Lewis Research Center

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Analysis and Computer Programs to Calculate Acoustic Wave Properties of Baffled Chambers

Analytical methods and four computer programs have been developed for calculating the wave motion in closed, baffled chambers with rigid and nonrigid boundaries. Application of these methods to the design of injector-face baffles in liquid-propellant engines will provide significant insight into the effects of baffles on combustion stability.

Approximate solutions to the wave equation, with essentially continuous pressure distributions, were obtained for closed, two-dimensional chambers containing an unrestricted number of equal length and equally spaced baffles. Solutions were obtained by converting the wave equation and boundary conditions to an integral equation; this integral equation was solved with a combination of variation and iteration methods. The mathematical techniques used to obtain these solutions apply equally well to cylindrical or annular chambers, and to unequal baffle lengths or spacing, although with some increase in complexity.

These methods encompass solving the wave equation for the baffled chamber by converting the differential equation and boundary conditions to an integral equation which, in turn, is solved by approximate means. A variational technique in combination with an iterated approximation was used to solve the integral equation. Numerical results were obtained for two-dimensional chambers containing one or several equal length and equally spaced baffles. The results show an essentially continuous pressure distribution along the baffle tips. Requirements for continuity of velocity and energy flux are automatically met with this method. Furthermore, the effects of a single baffle on the stability of a chamber with non-rigid walls, i.e., gain/loss type boundary conditions, have been successfully analyzed for one particular two-dimensional geometry. Thus, the ability to generalize the method for nonzero boundary conditions has also been demonstrated.

The first computer program was written to solve the iterative characteristic equation for the rigid boundary case. The method used to solve this equation was to calculate the value of the function while incrementally changing the wave characteristic and frequency until the value of the function changed signs. The usual practice was to calculate the characteristic equation over a large interval by taking large increments for the wave characteristic. After noting the interval in which the value of the function changed signs, that interval was subdivided into small increments. The procedure was repeated until an accurate value of the wave characteristic was obtained.

The second program calculates the pressure across the baffle tips on the main chamber side of the interface across the baffle tips. With the wave characteristic fixed for a given set of parameters, it is possible to determine the relationship between pressure and the position coordinate. Pressure at the baffle tips was calculated across the width of the chamber.

The third program was used to calculate the pressure at the baffle tips on the compartment side of the interface. Considering the pressure as a function of the position coordinate, it is possible to determine the pressure for a given wave characteristic.

The fourth program was written to determine the stability limit of a combustion chamber with active boundaries located at both ends. The characteristic equation is in complex notation, and the root of the characteristic equation is a complex eigenvalue (the real part is the nondimensional frequency and the imaginary part is the nondimensional damping coefficient). Thus, for a given set of parameters, nozzle admittance, and injector admittance, the complex root which satisfies the characteristic equation specifies the frequency and the damping coefficient of the system. The acoustic admittance obtained defines the maximum amount of acoustic energy (related to the admittance) that can

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be pumped into the system and still have the system stable. This avenue was taken to evaluate the stability limit.

Note:

1. These programs were written in FORTRAN IV for use on a GE 420 time sharing computer system.
2. Inquiries concerning this program should be directed to:

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   112 Barrow Hall
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   Reference: LEW-11529

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