NASA TECH BRIEF
Marshall Space Flight Center

A Theoretical Study of Aerodynamic Noise Generation

This theoretical study is part of the effort to understand the noise generated by aircraft and rockets. Entitled "Analysis of Unsteady Entropic Flow Process", it focuses on the physical mechanism of waves in a fluid such as air. It is shown that there is a strong interaction between the energy of the wave and that of fluid particle motion. This interaction causes the energy of the wave to be dissipated. The dissipation is shown to depend not only upon momentum, time-rate, and force, but also upon the nature and magnitude of entropic-flow effects. This is a direct result of the energy coupling between the fluid particles and the entropic waves.

The analysis employs a thermodynamic function for the flux density or rate of flow of a quantity, in this case entropy. The form used being

$$\frac{dp}{\rho} = dJp - \frac{B_p^2}{C_p} ds$$

where ρ is the density
p is pressure
s is the entropy
C_p is the heat capacity at constant pressure
Jp is the flux density motion variable
and
B_p^2 is a constant dependent upon temperature, energy, and heat capacities

This formulation is based upon the known methods of analysis of frictional adiabatic duct flow, but a suitable entropy function had to be derived by using a quasi-static system-reservoir interaction.

The equations of motion (continuity, energy, and momentum conservation) are derived for a gaseous motion in a one-dimensional unsteady region of entropy production. The medium is assumed to be an ideal gas under frictional adiabatic flow. The expressions are then reformulated in terms of the thermodynamic J function. The solutions to this system of equations indicate that, here, the velocity of sound propagation is an entropic process. The next step is to determine the characteristic equations for the equations of state for fluid particles.

An analytical expression for the entropy function is derived by considering the quasi-static heat and kinetic energy exchange between the system and an energy reservoir. From this, the system-particle state variables are interrelated, and an interaction equation is derived. It is this interaction equation that shows the energy coupling between the wave energy and the fluid particles. This interaction equation is then coupled with the remaining equations of motion to form a hyperbolic system representing the physical mechanism of finite amplitude entropic waves.

Note:

Requests for further information on this and other studies of aerodynamic noise generation may be directed to:

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Reference: B73-10209

Source: A. C. Peter of
Rockwell International Corp.
under contract to
Marshall Space Flight Center
(MFS-24167)