THE RANKINE-HUGONIOT EQUATIONS: THEIR EXTENSIONS AND INVERSIONS RELATED TO BLAST WAVES

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The Rankine-Hugoniot equations were developed in their original forms independently by Rankine (1870a, b) and Hugoniot (1887, 1889). The equations describe the relationships between the physical properties in the two possible states of a moving compressible gas for which mass, momentum and energy are conserved. The contact surface between these two states is a shock front. In their original forms, the equations described the relationships for a supersonic gas passing through a stationary shock into a subsonic state. For blast wave applications, the equations are transformed to describe the physical properties of the gas behind a shock moving into a stationary ambient atmosphere, in terms of the Mach number of the shock.

Assuming the ratio of specific heats of air to be 1.4, the Rankine-Hugoniot equations provide exact values of the physical properties behind the primary shock of a blast wave, such that this is the preferred method to calibrate electronic transducers. For overpressures above about 10 atm, additional degrees of freedom of the air molecules are excited, and the ratio of specific heats must be modified to allow for these real-gas effects.

The most commonly used forms of the equations relate the hydrostatic overpressure, density and particle velocity to the shock Mach number. In this paper, these equations are extended to give eleven different physical properties in terms of the ratio of specific heats, γ, and for $\gamma = 1.4$. In the latter case, the equations are also inverted to provide the shock Mach number, and thus the other ten properties, in terms of a specified physical property.

To simplify the use of these relationships, they have been incorporated into a series of spreadsheets that provide all of the physical properties behind a shock in terms of any specified property. The properties may be expressed in terms of the ambient conditions ahead of the shock, or in Imperial or SI units. The spreadsheets, which will be demonstrated, can be used on any desktop, laptop or palmtop computer, and are available for licensing.

References

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