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# EFFECTS OF NONEQUILIBRIUM DISSOCIATION ON BLUNT BODY FLOWS

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The flow of nitrogen over a blunt body is considered in the case when the free stream kinetic energy is comparable with the dissociation energy. The ambient conditions are taken to be such that the characteristic length scale introduced by the rate at which molecules dissociate after traversing the bow shock is comparable to the body size.

Using existing numerical methods an attempt is made here to map out the dependence of the solution on the parameters of the problem, of which there are four for characterising the kinetic energy, density, temperature and dissociation fraction of the free stream and two for characterising the speed and temperature dependence of the dissociation rate.

The specific points of interest in this problem are: the influence of the dimensionless reaction rate parameter, $\Lambda$ on the flow; the extent and shape of the region affected by the dissociation and its dependence on $\Lambda$; and the dependence of the flow on the free stream dissociation fraction.

The particular numerical methods chosen here were developed by the N.A.S.A. Ames Laboratory (equilibrium and frozen flow) and by Cornell Aerolabs. (non-equilibrium flow.) Both use the inverse technique, in which the shock shape is assumed known and the body shape emerges as part of the solution.

The results of a large number of calculations using these methods show that the pressure field around the front part of a blunt body is virtually independent of the reaction rate, and that the contours of pressure, p, run predominantly at right angles to the shock. The contours of dissociation fraction, $\alpha$, and temperature, T, are predominantly parallel to the shock. The contours of dissociation fraction, $\alpha$, and temperature, T, are predominantly parallel to the shock and their spacing is very sensitive to reaction rate. On the other hand the contours of density change their shape very strongly with reaction rate, being predominantly parallel to the $\alpha$-contours where $\alpha$ varies rapidly, and mainly parallel to the contours of p where $\alpha$ varies slowly. Thus one can separate the two influences on density by virtue of their difference in direction.

The density pattern is thus a very useful quantity to characterise reaction effects, especially because it can also be obtained experimentally in the form of an interferogram. It was found by selecting solutions with similar density patterns and ordering them from very slow to very fast reaction rate, that the pattern could be correlated in terms of the dissociation rate, $\Omega$, immediately behind the normal shock. By plotting dimensionless shock stand-off distance, scaled by the density ratio across the normal shock against $\Omega$, it was found that this also was correlated by $\Omega$. This gives, among other things, the dependence of stand-off distance on free stream dissociation.

The variation of the density pattern shows that the form of the contours is the same for both infinite and zero reaction rate, while there is a continuous change in the pattern throughout the range of $\Omega$. The extent of the region affected by dissociation can also be recognised from the density contours. This region grows from a thin layer near the shock at the equilibrium end of the range to a broad region across the whole shock-layer and shrinks into the stagnation point atzero reaction rate.

Some of these theoretical results are compared with experimental interferograms obtained in the large free piston shock tunnel at A.N.U., on circular cylinders in cross flow. In these experimental results, $\Omega$ was varied by altering the body size and free stream conditions. The theoretical calculations compared favourably with the interferograms if a reaction rate slightly lower than currently accepted values was used.