SYNOPTIC: Energy-Momentum Coupling in Radiating Shock Layers about a Blunt Body, Y. S. Chou and L. H. Blake, Lockheed Palo Alto Research Lab., Palo Alto, Calif., *AIAA Journal*, Vol. 8, Vol. 9, Sept. 1970, pp. 1680–1681.

Radiatively Coupled Flows and Heat Transfer

Theme

This study is a theoretical assessment of the influence of coupling between the viscous and energy transport mechanisms in the thin-radiating shock layer away from the stagnation point. The influence of these coupling mechansims upon the calculated convective and/or radiative wall heat fluxes is evaluated. This coupling analysis determines the effect of the boundary layer on the radiative heating to the body, the effect of the radiative transport on the velocity field and the coupling between the radiative loss and the convective heating. Results are presented at the stagnation point and around the body to the sonic line (~45°).

Content

The radiating flow was described by a Blasius series formulation; solutions were obtained for three terms in the series. For the flight conditions considered, the three term series solutions were shown to converge numerically for body angles approaching the sonic line (~45°). Transport models were used which retained the basic interaction influences but allowed for a simplified analysis. A real gas (air) model was considered around a cold, nonablating spherical body. The radiative transfer was described by the well-known differential approximation. A three-band continuum radiation model was assumed where analytical expressions are available for the absorption coefficient in each band. Solutions were obtained for both viscous and inviscid models at three sets of flight conditions which included extremes of the viscous and transport parameters.

The coupling between the momentum and energy transport was evaluated by comparisons of the convective and radiative flux distributions at and away from the stagnation point. This coupling analysis indicated that the influence of viscosity on the radiative heat flux was small (<15%). The radiative transport was shown to affect the convective heat flux more strongly. The convective heating may be increased by 35% near the sonic line when the radiative transport is neglected. The influence of the radiative transport on the velocity field was shown to be small. The radiative flux results obtained by using a velocity obtained from a nonradiating flow calculation was shown to agree very closely with the results of the fully coupled analysis. These results suggest that an accurate description of the radiation heating about a blunt body (thin shock layer) can be obtained from an uncoupled solution of the energy equation with an adiabatic inviscid description of the velocity field.

Figure 1 illustrates the influence of the radiative transport upon the velocity field for both the viscous and inviscid models. As the heating distribution is of prime importance, this coupling is shown indirectly by comparing the influence of the two velocity fields upon the radiative flux. The "momentum without radiation" results are solutions of the energy equation using a momentum field obtained from a nonradiating flow calculation. For the inviscid model, this velocity field represents the closed form adiabatic series solution of Chou.[1] For the viscous case, the velocity field was determined from a solution of the complete energy and momentum equations without radiation. The results of Fig. 1 indicate the weak coupling of the radiative transport on the velocity field as the latter influences the radiative flux away from the stagnation point.

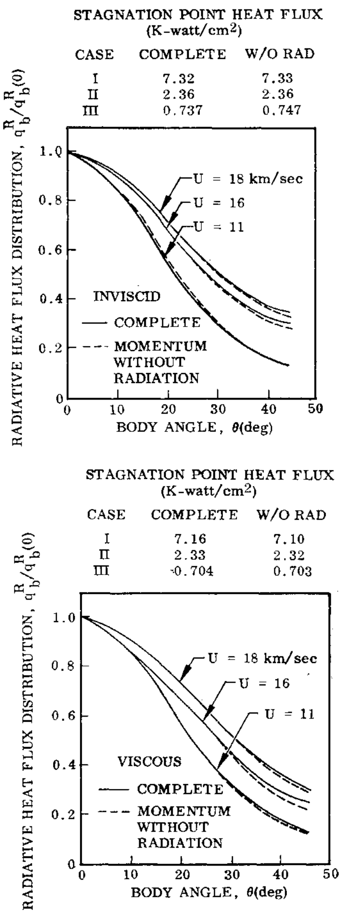

Fig. 1. Coupling of radiative transport to the velocity field.

Reference

[1] Chow, Y. S., "Inviscid Hypersonic Flow past Blunt Bodies," *AIAA Journal*, Vol. 7, No. 1, Jan. 1969, pp. 149–150.