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THE EFFECT OF A TYPE III AND TYPE IV SHOCK/SHOCK INTERACTION ON HEAT TRANSFER IN THE STAGNATION REGION

by

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One of the major engineering challenges in designing the National Aerospace Plane, NASP, is to overcome augmented heating on the intake cowl lip from shock/shock interactions. The shock/shock interation arises when the bow shock from the craft's nose interferes with the bow shock from the cowl lip. Considering only the region immediately around the cowl lip, the problem geometry may be simplified as that of an oblique shock impinging on a bow shock from a circular cylinder. Edney [1] classified six different interference patterns resulting from an oblique-shock/curved-bow-shock interaction. Of these six types, the Type III and Type IV are most significant in that augmented surface heat transfer may be ten to thirty times greater than the case without the shock/shock interaction [2].

Several researchers, [3] and [4], have attempted to numerically compute the flowfield created by the shock/shock interaction. Their results for the Type III and Type IV interactions have always underpredicted the maximum surface heat transfer in the stagnation region. Empirical correlations could be used, but again these relationships only interpolate known data for the range which experiments have been performed. If viscous effects are included, a global flowfield computation would require excessive computational time and grid points to accurately resolve the shear layer and boundary layer to obtain accurate surface flux quantities. A more rational approach which considers only the boundary layer and a finite number of parameters to characterize the shear layer is described in this abstract.

The objective of this research was to begin to develop a mathematical model which is capable of predicting the effect of a Type III and Type IV shock/shock interaction in the stagnation region of an arbitrary two-dimensional body. This model must be capable of predicting the maximum surface heat flux and the surface stagnation point pressure once the outer (effectively inviscid) flowfield is given. Therefore, it must capture the unsteady physics of the impinging shear layer.

The approach taken here will be to solve the unsteady equations for the stagnation-point region on the surface of a blunt body in a Type III shock/shock interaction flowfield. Figure 1 [4] displays a schematic of the overall flowfield for a Type III shock/shock interaction. Figure 2 displays in greater detail where the shear layer impinges upon the boundary layer. Essentially this is an oblique reattaching shear layer forming an unsteady stagnation-point flow. The key to the success of the method is to accurately characterize the large-scale, quasi-periodic structures in the impinging shear layer. Recent success with a simpler but physically similar flowfield, [5] and [6], gives cedibility to this approach.

The computational domain of interest is illustrated in Figure 2. To quantify the boundary layer edge condition of the computational domain the flow outside of the boundary layer is assumed to be inviscid. This assumption will allow the outer flow to be characterized by the compressible form of the Euler equations. The boundary-layer edge velocity is assumed to be composed of pulsations, oscillations, and a term to account for obliqueness and vorticity in the incoming flow. The details of constructing this phenomenological model are somewhat involved and are omitted from this abstract. It is important to point out that the parameters which appear in the edge velocity models will be determined a priori using experimental data from compressible shear layers. Ultimately, these model parameters will depend only upon the characteristic Mach numbers of the shear layer, M_2 and M_4, and the characteristic length of the shear layer. The near wall flowfield will be modeled using the unsteady, compressible forms of the Navier-Stokes and thermal energy equations as applied to a stagnation region.

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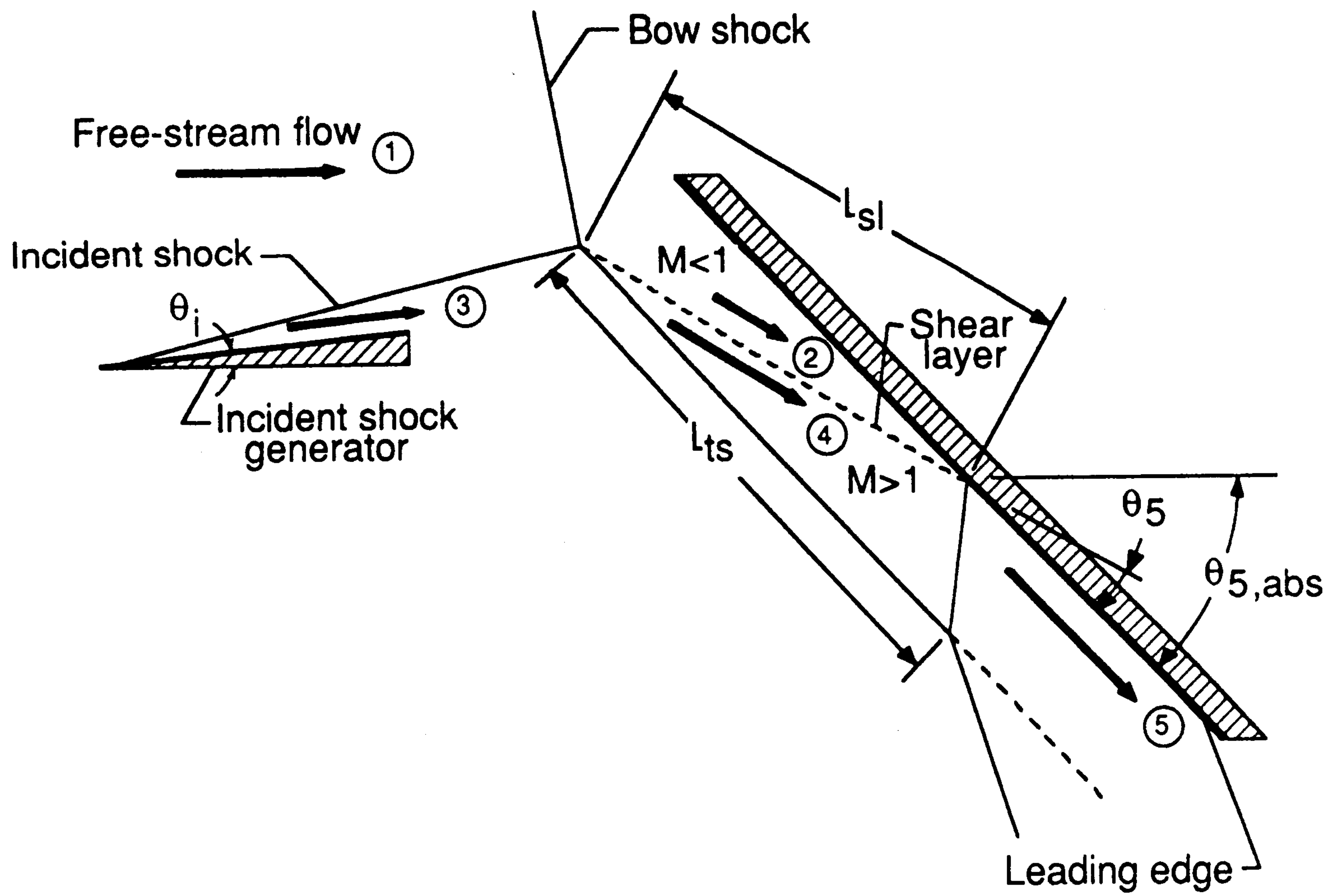

Figure 1: Overall flowfield for a Type III shock/shock interaction (from reference [4]).

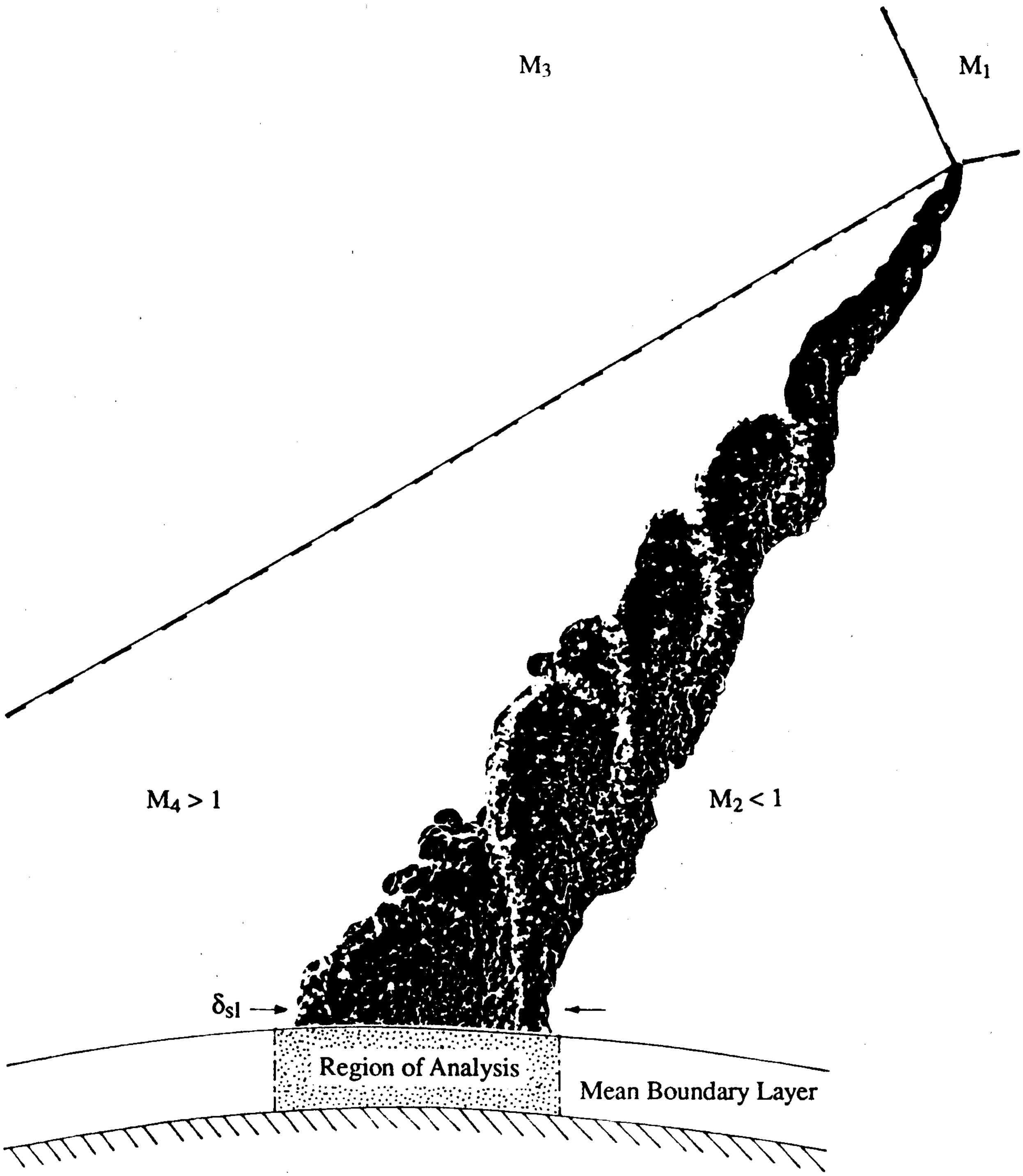

Figure 2: Schematic of the local flowfield in the stagnation region showing the impingement of the large-scale, quasi-periodic structures in the shear layer.