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ANALYTICAL RESEARCH OF THE FLOW IN COMPRESSED LAYER DOWNSTREAM THE INCIDENT SHOCK IN OVEREXPANDED JET

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Differential parameters of the flow in compressed layer downstream the incident shock AT (see Fig. 1) falling from the nozzle edge A into the overexpanded supersonic gas jet seem to be important being connected with several physical phenomena. For example, the geometrical curvature of a jet boundary AB influences on the possibility of Taylor-Göertler instability development. The strength $J = p_2/p_1$ of the incident shock (p_1 and p_2 are static pressures upstream and downstream the shock, correspondingly) usually increases with the distance from the edge. At the same time, the shock strength can diminish locally in the vicinity of the edge at small Mach numbers where von Neumann paradox in stationary jet flow exists. Stagnation pressure gradient and the vorticity direction are governed unambiguously by the shock strength alteration. Moreover, the inflections of the jet boundary and incident shock strength (Fig. 1,b) are theoretically possible.

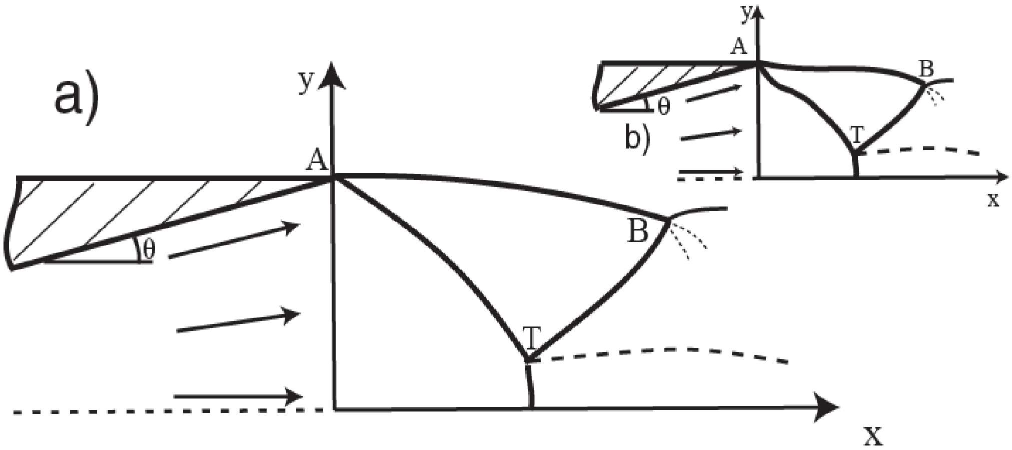

Fig. 1. The scheme of the first barrel in the overexpanded gas jet

In this work, the theoretical study of the differential flow parameters in the vicinity of the nozzle edge in two-dimensional (plane or axisymmetrical) inviscid jet is conducted. Differential conditions of flow compatibility at stationary shocks (Adrianov et al., 1995): $N_{2j} = C_j \sum_{i=1}^{5} A_{ji} N_i$ are concerned to inscribe the special features of the flow downstream the incident shock in the vicinity of the nozzle lip. Coefficients C_j and A_{ji} depend on flow Mach number M, shock strength $J = 1/n$ (n is jet incalculability), nozzle angle Θ, and the ratio γ of gas specific heats. Differential parameters N_{1j} ($N_{11} = \partial \ln p/\partial s$, $N_{13} = \partial \ln p_0/\partial n$, $N_{14} = \delta/y$; $\delta = 0$ at plane flow and $\delta = 1$ at axisymmetric one, N_{12} is streamline curvature,

N_{15} is the curvature of the shock) characterize the flow upstream the shock in natural coordinates and the similar parameters N_{2j} ($j=1..3$) describe the flow downstream it. When the flow parameters upstream the shock are known (for instance, in segmental spherical or cylindrical flow model), the isobaric condition ($N_{21}=0$) at the jet boundary defines the curvature of the shock and all spatial derivatives of the flow parameters downstream it.

The analysis of shock curvature alteration (see Fig. 2,a for axisymmetrical jet at $\gamma=1.4$, Fig. 2,b for plane one, Uskov et al., 2006) has shown that this key variable depends nonmonotonically and differently on the most easily changing parameter of the problem $J=1/n$ $. Dependence $N_{15}(J)$ is defined by other problem parameters (M and Θ). Convexity is especially strong at deep overexpansion where the flow separation is really inevitable. All special lines and points at the Fig. 2 correspond to analytical solutions. Investigation of other flow parameters downstream shock, such as boundary curvature, gradients of full and static pressures, Mach number downstream, disclosed the same original features of the flow, especially at the small supersonic Mach numbers.

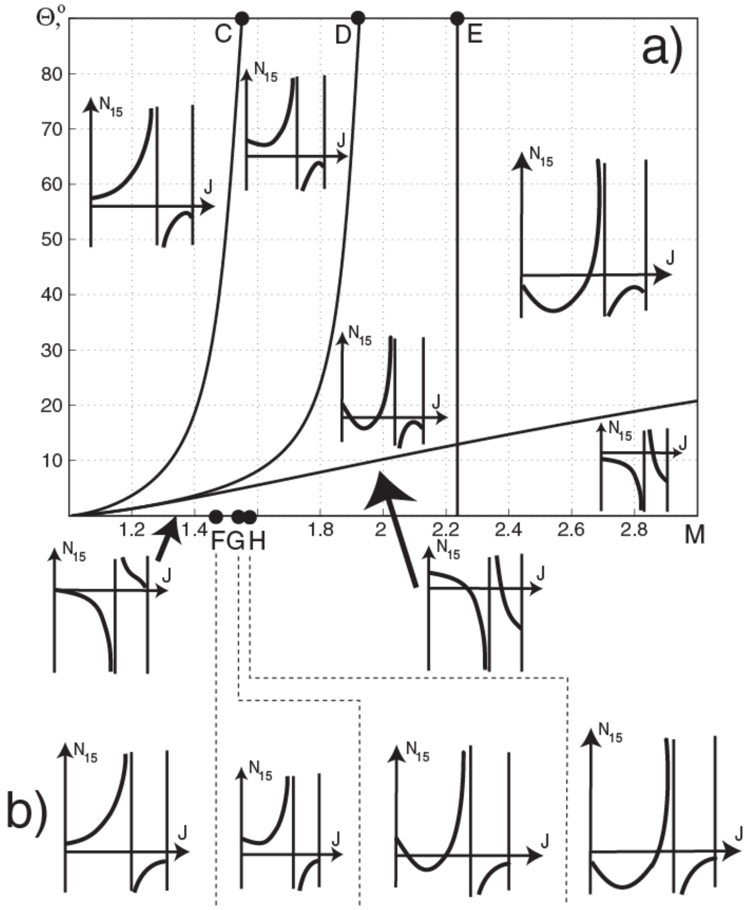

Fig. 2. Dependence of the shock curvature on its own strength (i.e., on jet incalculability) in the wide range of other flow parameters

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