INFLUENCE OF SMALL SPATIAL PERTURBATIONS ON HEAT TRANSFER AT HYPERSONIC FLOW

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The problem of studying the influence of small perturbations on the heat transfer at hypersonic flow over blunt bodies is of great theoretical and practical interest. Particularly, with earth-bound tests in wind tunnels, there are perturbations of various nature and intensity in the test section which can affect the measured characteristics. Results of experimental investigations of the flow structure on the cylinder front surface at Mach numbers M=3,5,6 are presented by Lapina & Bashkin [1983], Bae S. et al [2000] , where the spatial periodicity of limit streamlines and heat-flux distribution along the transverse coordinate are demonstrated. The amplitude of the oscillations in the heat-flux distribution reached 25% or more.

The first problem, considered in the present paper, is the investigation of the three-dimensional flow in the shock layer in hypersonic transverse flow over the cylinder front surface (M=6.1; 8, Re=3240, γ=1.4, $T_w=T_0/2$, Pr=0.71) under small spatially-periodic perturbations along the transverse coordinate. Based on the numerical solution (Bashkin & Egorov [2012]) of the unsteady three-dimensional Navier-Stokes equations, it is shown that small imposed perturbations on the free stream velocity (0.5-3 %) along the transverse coordinate lead to shock front curvature, to the formation of vortex structures in the shock wave area and to the formation of significant perturbations of the heat flux on the surface (more than 50%). This can explain the experimental results by Lapina & Bashkin [1983], Bae S. et al [2000] on the heat flux.

The second problem is the investigation of free stream entropy perturbations influence on heat exchange on hypersonic flow over a sphere is carried out to analyze spatial effects. Calculations for three-dimensional flow over a sphere are fulfilled for small free stream temperature perturbations in y-coordinate $T=T_\infty[1-2A\exp(-y/\sigma)]$ at M=8, Re=5524, $T_w/T_0=0.39$. This temperature distribution in free stream leads to Mach number distribution $M=M_\infty(1-2A\exp(-y/\sigma))^{-0.5}$. For small perturbations A<<1 it correspond to Mach number perturbations with amplitude A. Analog of wavelength here is a parameter $\lambda=2\sigma$ (σ - is a half-width). At A=0.5% in front critical point heat flux increase to 10% and at A= –0.5% - decrease to 10% (Fig. 1) correspondingly are observed.

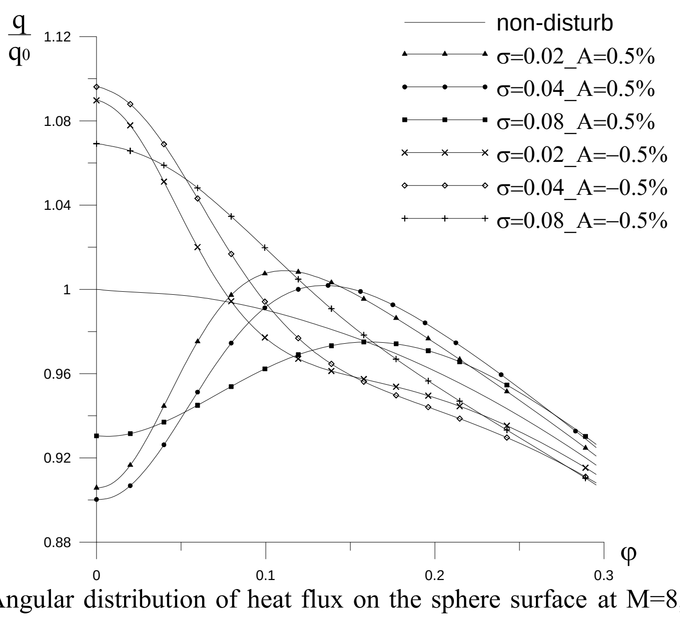

Fig.1. Angular distribution of heat flux on the sphere surface at M=8, Re=5524, $T_w/T_0=0.39$, σ = 0.02;0.04;0.08, A = -0.5%; 0.5%.

References

1. *Lapina, N.G. and Bashkin, V.A.* [1983], Experimental investigation of the flow pattern and heat transfer in the vicinity of the spreading line of a circular cylinder in a supersonic transverse flow with Mach numbers M=3, 5, and 6, *Trudy TsAGI (TsAGI Proceedings)*, Issue 2203, pp 44 – 49 [in Russian].
2. *Bae S., Lele S.K., Sung H.J.,* [2000], Influence of inflow disturbances on stagnation-region heat transfer, Journal heat transfer, Vol. 122, No. 2, pp 258-265.
3. *Bashkin V.A., Egorov I.V.,* [2012], "Numerical simulation of viscous perfect gas flow", Moscow: Fizmatlit (in Russian) 2012. 372 p.