Heat flux control by tangential air blowing at high supersonic speeds

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Experimental and numerical results of an investigation of heat flux control over a sharp cone surface (*8 degrees* half-angle and *400 mm* full length along cone axis of symmetry) by means of ejection of cooling gas (air) through a tiny tangential slot (*61 mm* apart the cone nose, *3 degrees* half-angle, its axis being inclined at *10 degrees* with respect to cone surface) on the cone surface are presented. Hypersonic axisymmetric flow of viscous perfect gas at $M = 5$, $P_0 = 50\ bar$, $T_0 = 700\ K$ is investigated. The cooling gas (air) is considered at constant stagnation temperature *288 K* and at stagnation pressure varying in range from *1 bar* to *16 bar*. This variation range has been found to correspond the mass rate ratio G_{blow} / G_{midS} in range from $1.6 \cdot 10^{-3}$ to $13.6 \cdot 10^{-3}$, where G_{blow} is the coolant mass rate while G_{midS} is mass rate of free stream through the cone midsection. The critical section of the slot is at radius $r_{in} = 6.5\ mm$, while slot height is *0.3 mm*.

Streamed surface cooling efficiency is analyzed. Both complicated flow features near the slot and its effect on the outer flow is investigated elaborately. Numerical and experimental results are compared with theoretical estimations. An attempt is made to systemize the results obtained versus similarity parameter.

The coolant (air) ejection has been proved to result in considerable changes in cone flow pattern which are accompanied by forming of separation zones, shocks, mixing of outer and ejected gases, etc. The slot presence leads to early laminar-turbulent transition on the cone surface compared with the location of a solid cone transition under the same free stream conditions. It has been obtained that overall coolant ejection effect is positive, but in case of $G_{blow} / G_{midS} = 1.6 \cdot 10^{-3}$ (and apparently less) the ejection may lead to local increase in heat fluxes in the downstream vicinity of the slot.

All experiments are conducted in shock wind tunnel UT-1 (TsAGI) operating in Ludwig scheme. Thermal sensitive paint method is used to measure heat fluxes. Pressure shadow paint method is used for flow investigation. Ejection of the coolant (air) is performed with aid of a fast gas supply system synchronized with the moment of tunnel operation start.

A part of experimental runs is accompanied with numerical study performed by Ansys Fluent software. Numerical and experimental results are in good agreement.