Influence of leading-edges bluntness on hypersonic flow in a generic internal-compression inlet

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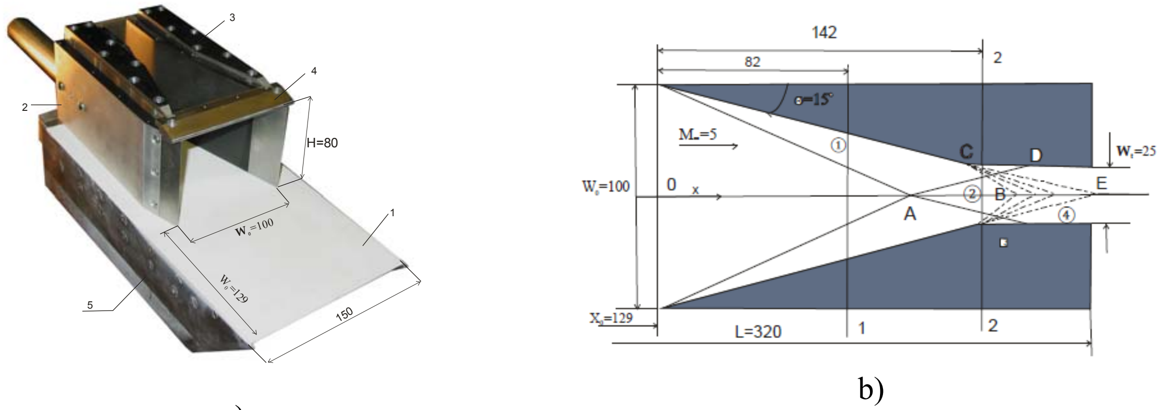
Aerodynamics of hypersonic inlet attracts attention of many researchers. However, just the few studies examined the effect of leading-edges bluntness on the inlet characteristics. In the present work, the influence of small leading-edge bluntness on the characteristics of a rectangular generic inlet located on a flat plate and on its starting is investigated experimentally.

Photograph and schematic of the model are presented in Figure 1. Shape of the inlet can be characterized by non-dimensional values: contraction ratio $W_o/W_t = 4$, height $H/W_o = 0.8$, inlet distance from the plate leading edge $X_o/W_o = 1.29$, where W_o is the inlet entrance width and W_t is the throat width.



a)

b)

Figure 1. Inlet model: *a* – photograph, *b* – cross section parallel to the plate

The experiments were performed in TsAGI' wind tunnel UT-1M working in the Ludwieg tube mode at Mach number $M_\infty = 5$ and Reynolds numbers based on the plate length L =320 mm $Re_{\infty L}=23\text{x}10^6$ and $13\text{x}10^6$. Steady flow duration is 40 ms.

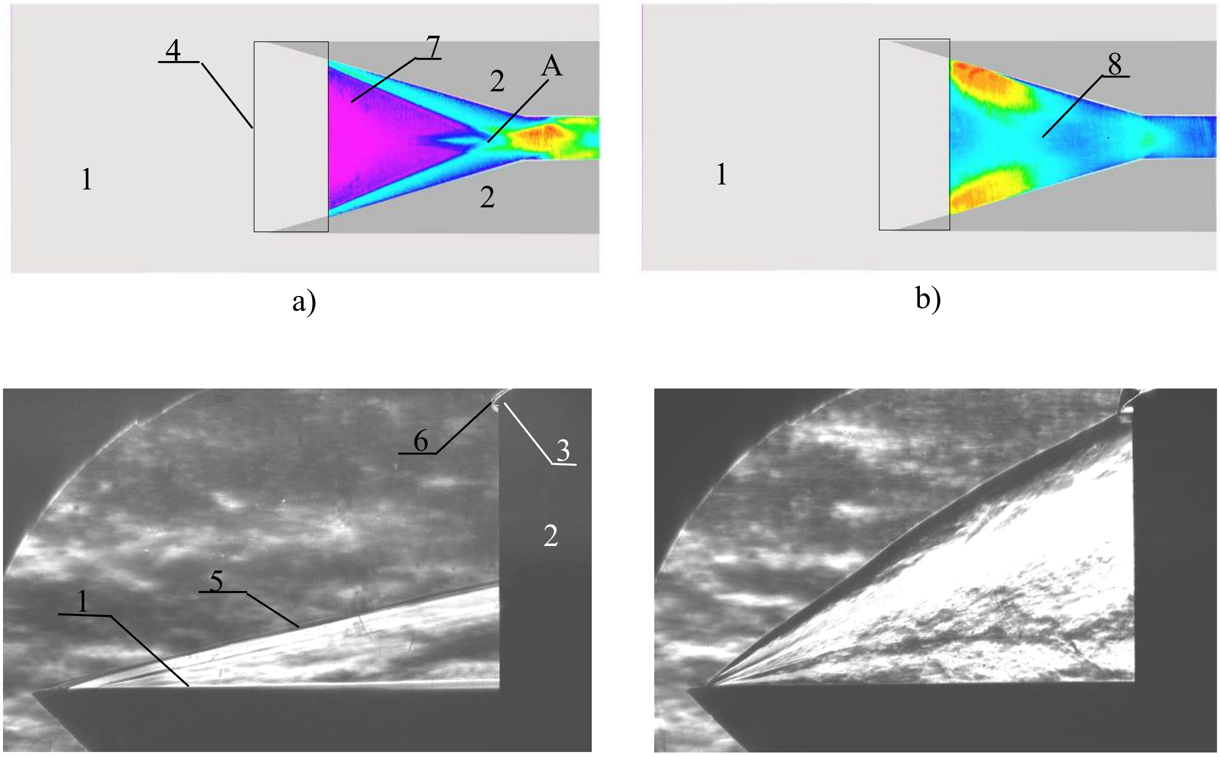
Heat flux distribution was measured by thin luminescent Temperature Sensitive Paint (TSP). Surface flow and shear stress visualization was performed by viscous coating containing luminophor particles. Optical methods were used for investigation of inner flow in an inlet for the first time. For this purpose, the cowl and one of two compressing wedges were made of a transparent material.

Stanton number distributions on the inner surface of the cowl and schlieren photos of the flow ahead the inlet with sharp plate ($r_1 = 0$) are shown in Figure 2. When the cowl is sharp or slightly blunted, the flow in the inlet is regular. If the cowl bluntness is relatively big (for example, at $r_2 =$ 2 mm), the inlet is blocked and extensive separation region is formed, despite the contraction ratio is not changed.

Figure 3 presents flow peculiarities and St-number distribution inside the inlet with sharp plate and significantly blunted cowl. Small separation zone on the cowl and large separation zone on the plate are visible, although the plate is sharp.

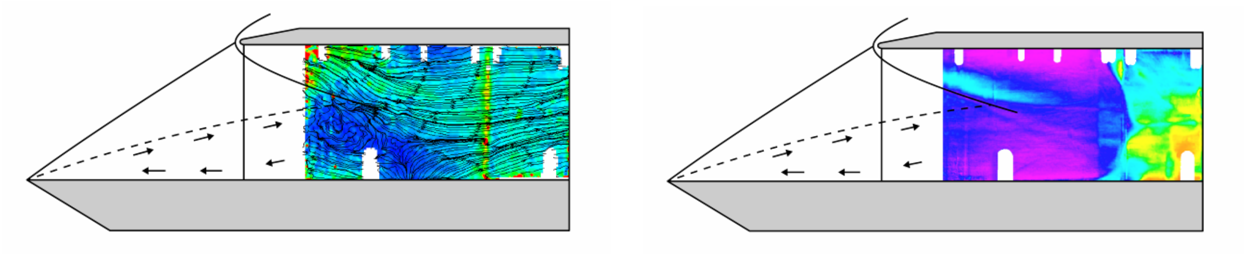
The investigation shows that at high contraction ratio (at $W_o/W_t = 4$), an increase of plate or cowl bluntness up to some critical value leads to sudden change of the flow structure: large separation zone is formed in the inlet that can begin at the plate leading edge and occupy significant part of the inlet channel. The separation zone generates an intensive separation shock in front of the inlet and causes significant heat transfer increase. Some part of the incoming flow goes out of the inlet in this case. This phenomenon is caused by high momentum losses in the entropy and boundary layers.

The critical bluntness radius decreases with increase of Mach number and reduction of Reynolds number.



a) b) c) d)

Figure 2. Flow in the inlet with sharp and blunted cowl (on the sharp plate).
a – St-distribution on the sharp cowl (r_2=0), *b* – the same on the blunt cowl (r_2=2 mm),
c - Schlieren photo at r_2 = 0.5 mm, *d* - the same at r_2 = 2 mm



a) b)

Figure 3. Gas flow and heat transfer inside the inlet with sharp plate (r_1=0) and blunted cowl (r_2=2 mm):
a – surface flow and shear stress visualization on the wedge,
b – St-number distribution on the wedge