NUMERICAL SIMULATION OF SUPERSONIC FLOW AROUND A DIMPLED SURFACE

S. A. Isaev[1], A. I. Leontiev[2], A. G. Sudakov[1], P. A. Baranov[1]

[1]*St.-Petersburg State University of Civil Aviation, 38 Pilotov Str., St.-Petersburg, 196210, Russia*
[2]*Baumann Moscow State Technical University, 5 Second Baumann Str., Moscow, 107105, Russia*

Over many decades systematic studies on the modeling of tornado-like heat and mass transfer processes involving flow past surfaces with concaves [1] have been made. Up to now, it is still urgent to analyze the physical mechanism of enhancement of heat transfer from dimpled-surfaces at a substantially lesser growth of hydraulic losses. The thing is that controlling processes occur in a narrow wall layer, as a rule, of small size, which hampers their experimental investigation. What is more, the considered problem is many-parameter in nature. In addition to such initial geometrical sizes as relative values of depth, edge rounding off, longitudinal and transverse pitch (in the case of a bank of spherical dimples), the vortex dynamics and heat transfer are essentially affected by the relative boundary layer thickness and the turbulence degree of an incoming flow [2].

In the recent year the Institute of Mechanics at Moscow State University has used heat images in experimental studies of the cooling effect of a curvilinear surface on a temperature wall in hypersonic flow. The present work is aimed at developing this research trend in numerical experiment with due regard to the gained experience in modeling of heat transfer in the vicinity of concaves made on the wall.

Numerical study of super- and hypersonic viscous gas flow around a curvilinear surface is based on developing multiblock technologies used for calculation of separated flows of incompressible viscous liquid. These technologies based on the idea of splitting the whole process into physical processes when correcting pressure are not widespread for solution of compressible liquid problems. However, from the standpoint of keeping a unique approach to solution of a wide variety of problems, as well as of using a major accumulated experience in calculation of separated flows of incompressible liquid, it is of interest to realize a generalized approach to solution of hydrodynamics and energy equations. Besides, the description of technology and experiment, in this work space is given to the verification of the computational model for test problems that have experimental analogs.

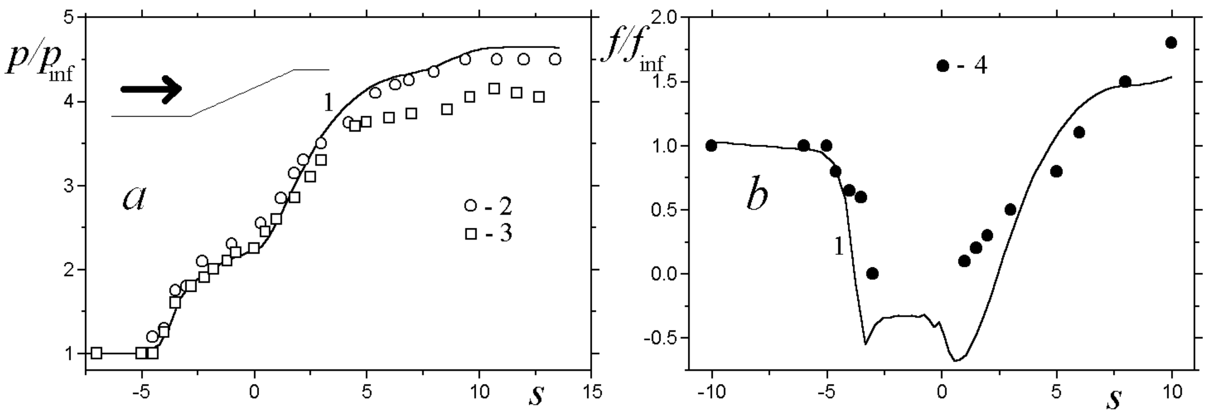

Fig. 1. Comparison of predicted (1) and experimental (2-4) distributions of relative values of pressure *(a)* and friction *(b)* in the vicinity of a 24-degree compression angle at M=2.85. 2-4 [3]

The compression angle is calculated using the modified program for modeling of a supersonic channel flow. The upper symmetry plane is replaced by the solid wall, while the lower wall – by the symmetry plane that is moved away at an assigned distance from the upper wall. As seen from Figure 1, there is a good agreement between the predicted and experimental results for the compression angle at moderate Mach numbers. As a whole, the predictions of the test problems supported the validity of the chosen turbulence model – MSST used for calculation of separated flows of a compressible gas.

A modified computational package VP2/3 is used for calculating compressible viscous gas turbulent separated flow past the relief created by dimples and trenches. Depending on the height of lumps or the depth of trenches, two flow regimes are seen: with attached shock waves in the case close to non-separated flow past the relief and with detached (or shedding) waves in developed separated wall flow with periodic recirculation zones. These flow regimes differ in heat loads, the local peaks of heat fluxes in the second case being essentially lower.

The cooling action of the relief created by concaves at super- and hypersonic low velocities (Figure 2) that has been experimentally revealed at the Institute of Mechanics at MSU is supported numerically. It is shown that a 2.5 – 3-fold (as compared to the flat wall) increase in drag is accompanied by a decrease in heat transfer (of the order of 8%) for relieves with many rows, trenches and dimples. The honeycomb dimpled relieves that have better characteristics than those with spherical dimples are proposed.

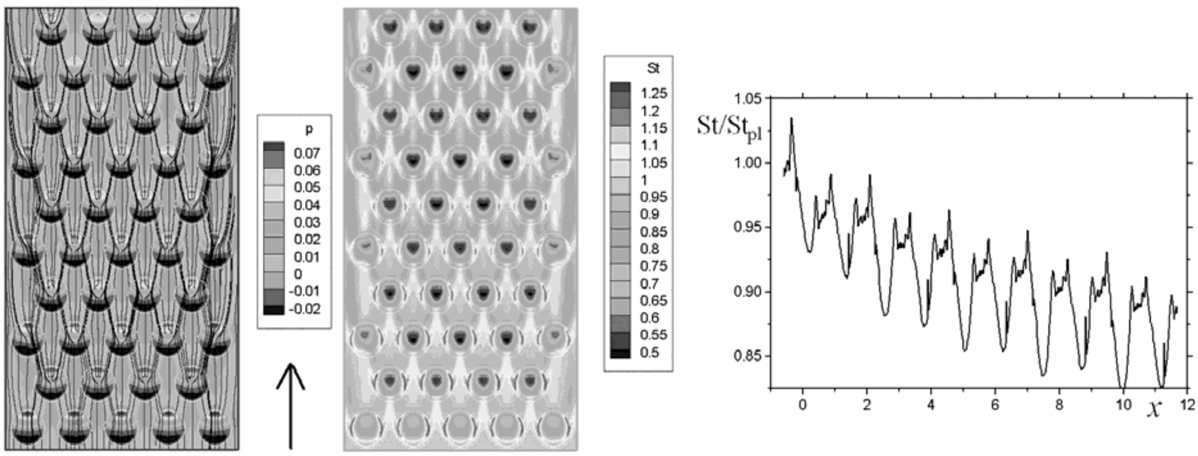

Fig. 2. Pictures of isobars and isolines of Stanton numbers and also the longitudinal distribution of relative St, averaged over a site with 45 dimples at Δ=0.08, r=0.25, M=4, Re=2×10^5

Acknowledgements

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