Proceedings of CHT-17
ICHMT International Symposium on Advances in Computational Heat Transfer

May 28-June 1, 2017, Napoli, Italy

CHT-17-085

STUDYING HEAT TRANSFER AT FLOW SEPARATION BEHIND THE BACKWARD FACING STEP UNDER THE INFLUENCE OF LONGITUDINAL PRESSURE GRADIENT

Viktor Terekhov, Tatyana Bogatko§, Aleksey Dyachenko, Yaroslav Smulsky.
Kutateladze Institute of Thermophysics SB RAS,
630090, Lavrent'ev Avenue, 1, Novosibirsk, Russia
§Correspondence author. Email: bogatko1@mail.ru

This report contains the results of a joint numerical and experimental study of the separated flow behind a backward-facing step in a flat channel with flow acceleration and deceleration. The gradient is created by the position of the upper channel wall behind the step. Data available in the literature on similar themes concern the flow dynamics [1-3], and data on heat transfer are absent. The calculations are performed within the model of incompressible fluid based on the system of stationary equations of Navier-Stokes and energy equations, averaged on Reynolds (RANS). The calculations are performed using the turbulence model k-ω SST [4], the most adequately describing turbulent separated flows. The problem statement is two-dimensional, and the flow is steady-state. The results of calculations and experiments have good qualitative agreement.

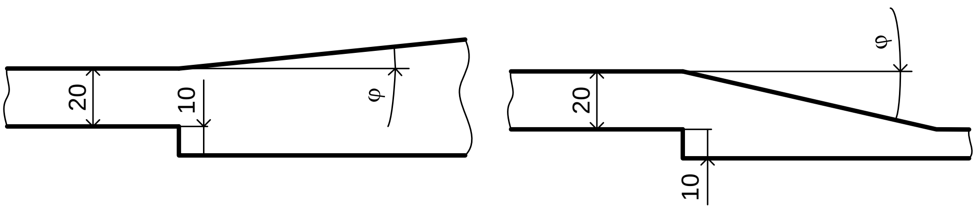

Fig. 1. Scheme of the test section in the expanding (left) and converging (right) channels.

Fig. 1 shows schemes of experimental measurements in expanding and converging channels. With the channel expansion the angle of rotation of the upper cover is 1.43; 2.86 and 4^o, and with the channel convergence the rotation angle is 3; 5.67 and 7.5^o.

Fig. 2 shows the flow patterns in the region of sudden expansion and the field of the longitudinal velocity component. It is seen that the length of the recirculation zone increases with increasing adverse pressure gradient and greatly reduces at imposed favorable pressure gradient. In addition, this figure clearly shows the deceleration and acceleration of the flow at a turn of the upper cover of the channel. In this section of the channel convergence there is a significant, two-fold acceleration of the flow.

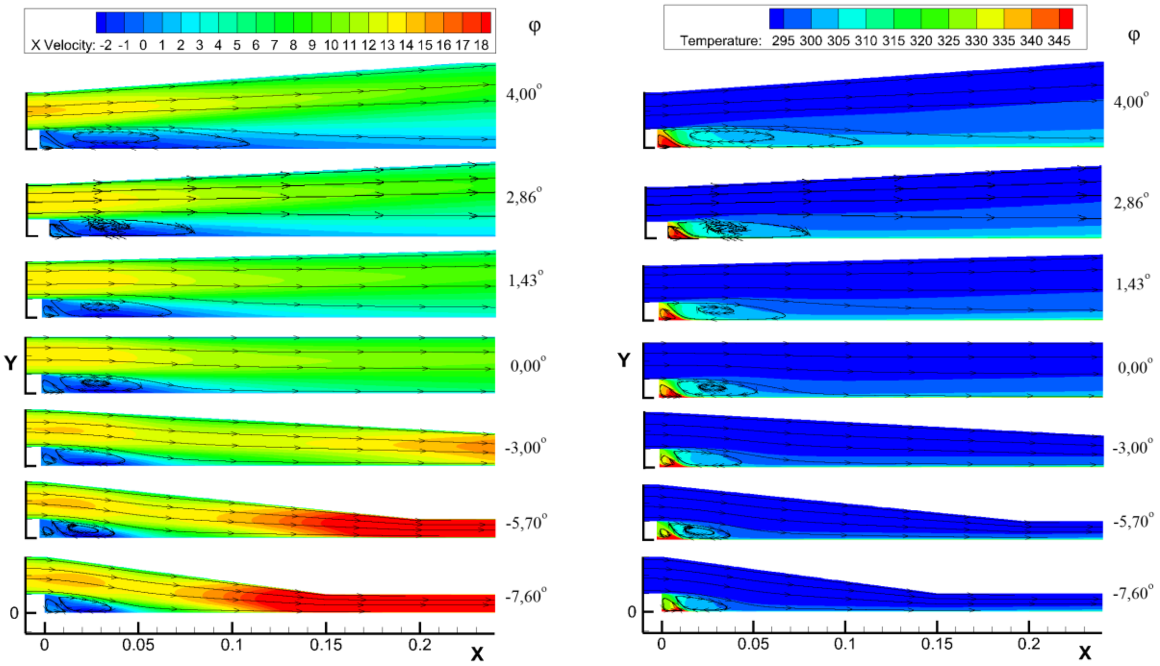

Fig. 2. Fields of velocity (left) and temperature (right) in the channel with a back ledge with superimposed pressure gradient, Re=8000.

Experiments were carried out at Reynolds numbers, calculated on the height of the step and inlet velocity, Re = 4 000; 8 000; 12 000.

An important parameter in the separation flow is the length of the reverse flow area, which correlates with the length of the maximum heat transfer x_{max}. In accordance with Fig. 3, x_R/H increases with the growth of the positive pressure gradient and decreases with the increase of the negative one.

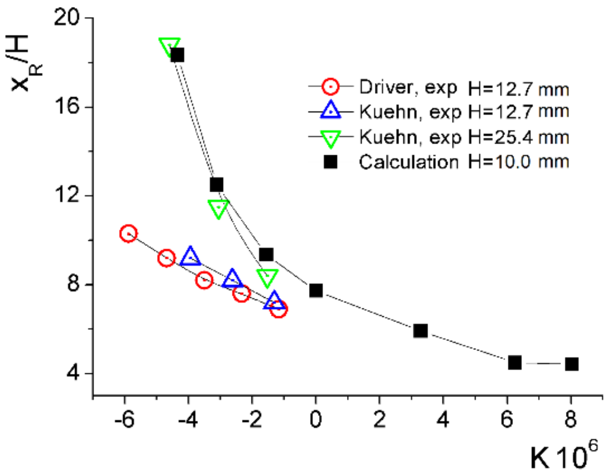

Fig. 3. The relative length of the recirculation region. Comparison with experimental data of works [2, 3].

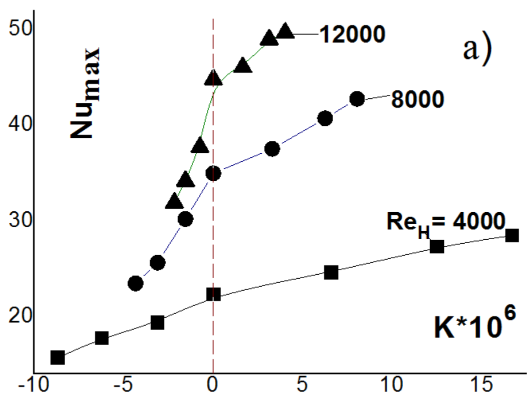

Fig. 4. The distribution of the maximum heat transfer coefficient in the expanding (K<0) and converging (K>0) channels.

Fig. 4 presents the maximum values of Nu, selected from the local distributions of heat transfer coefficients. The data are presented in Kays variables $K = \frac{\nu}{U_0^{\,2}} \frac{dU_0}{dx}$ [5]. The zero parameter of Kays corresponds to a gradientless flow. For a converging channel, the maximum value of Nusselt number increases with the increase of pressure gradient and decreases for the expanding channel. The dependence of the Nusselt number on the Reynolds number is clearly seen. At a higher Reynolds number in the converging channel, the growth rate is higher, and in the expanding channel, the rate of decline is steeper.

Acknowledgements: The work was financially supported by the Russian Foundation for Basic Research (grant 15-08-05662 A).

REFERENCES

1. Lo, Kin Pong, Christopher J. Elkins, and John K. Eaton. Separation control in a conical diffuser with an annular inlet: center body wake separation // Experiments in fluids. 2012. Vol. 53, No. 5. P. 1317-1326.
2. Driver D. M., Seegmiller H. L. Features of a reattaching turbulent shear layer in divergent channelflow //AIAA journal. 1985. Vol. 23, №. 2. P. 163-171.
3. Kuehn D. A. D. Effects of adverse pressure gradient on the incompressible reattaching flow over a rearward-facing step //AIAA journal. 1980. Vol. 18, №. 3. P. 343-344.
4. Metnter F.R. 2-equation eddy-viscosity turbulence models for engineering applications// *AIAA J.* 1994. Vol. 32, N 8. P. 1598-1605.
5. Kays W.M. Convective heat and mass transfer. McGraw-Hill, NewYork.