8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

PROBLEM OF VISCOUS DRAG REDUCTION: TSAGI EXPERIENCE AND INVESTIGATIONS

Sergey L. Chernyshev, *Alexander I. Ivanov, Andrey Ph. Kiselev and Alexander P. Kuryachii

Central Aerohydrodynamic Institute (TsAGI),
Zhukovsky, Moscow Region, 140180, Russia,
slc@tsagi.ru; ivanov_a_i@list.ru; a-ph-kiselev@ya.ru; kuryachii@aerocentr.msk.su

Key Words: *Viscous Drag Reduction, Flow Control, Boundary Layer Suction, Plasma Actuators.*

ABSTRACT

The presented paper is a brief overview of some main activities in a viscous drag reduction area performed in Central Aerohydrodynamic Institute named after prof. N.E. Zhukovsky during several last decades. These efforts initiated by prof. G.P. Svitschev and prof. V.V. Struminskii were focused both on the improvement of well known laminarization methods such as application of natural laminar geometry, laminar flow control by boundary layer suction or surface cooling, hybrid laminar flow control [1-3], and on the development of new ones [1,3-5]. The investigations mentioned above were based on theoretical, numerical and experimental (both wind tunnel and flight tests) techniques.

One of the new effective methods of viscous drag reduction consists of an increase in laminar boundary layer stability and subsequent delay of laminar-turbulent transition. Plasma actuators operating on a base of near-surface DC or AC electric discharges seem to be a suitable tool for realization of this drag reduction method. These actuators create volumetric electrostatic forces within a boundary layer and accelerate flow in it. Acceleration of the laminar boundary layer flow results in, at definite conditions, an increase in its stability i. e. attenuation or suppression of disturbances in it.

To estimate a possibility of this method, semi-empirical mathematical model of DC plasma actuator has been proposed. The model has been verified by comparison with published results of experimental study of DC corona discharge actuator. The proposed model permits to calculate distributions of gas velocity, volume charge density, and electric field strength in the boundary layer at given distance between electrodes, voltage, and total electric current. The calculated electrohydrodynamic flow has been investigated on stability in the framework of stated eigenvalue problem describing an evolution of small disturbances in unipolar charged laminar boundary layer. Calculated curves of the neutral stability of the flat plate boundary layer are presented in Fig. 1 in variables Reynolds number – disturbance wave number. The results are obtained at constant free stream velocity of 30 m/s, distance from flat plate leading edge up to

electrode-anode of 0.5 m ($Re_x=10^6$), distance between anode and cathode of 0.04 m, and different voltage of 20 kV and electric current of 0.05 mA/m (a), 30 kV and 0.1 mA/m correspondingly (b).

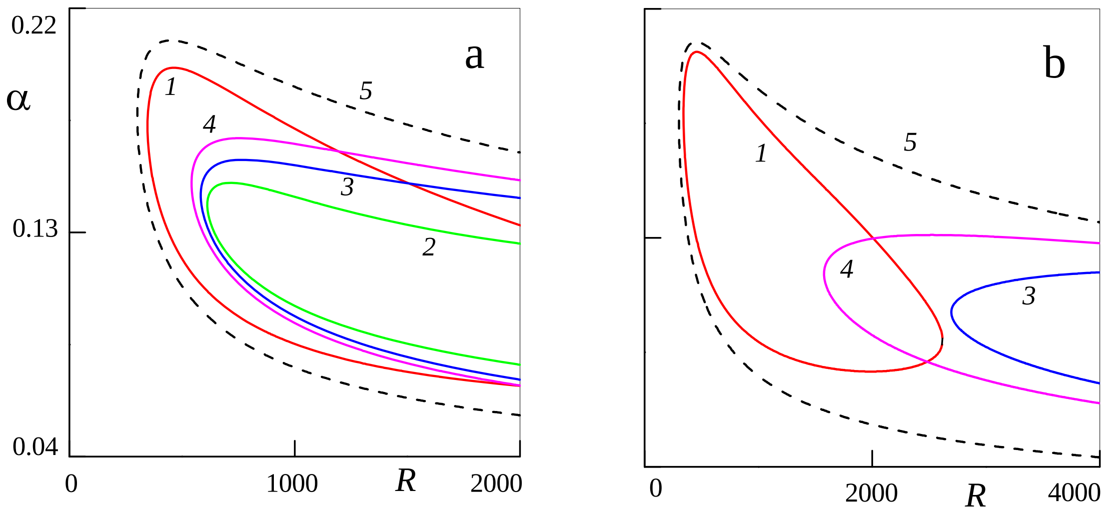

Fig. 1. Neutral curves at a distance from anode of 1, 2, 3, 4 cm (curves *1-4*), *5* – Blasius flow neutral curve.

The obtained results show that the impact of the DC plasma actuator can lead to significant increase in the critical Reynolds number and narrowing of the range of wave numbers of growing disturbances in the flat plate boundary layer.

REFERENCES

[1] V.V. Mikhaylov, "Laminar-turbulent transition and boundary layer control", *TsAGI – Principal Stages of Scientific Activities 1968- 1993*, pp. 367–371, 1996 (*in Russian*).

[2] V.G. Mikeladze, V.D. Bokser and A.Ph. Kiselev, "Skin friction drag reduction by flow laminarization", *Polyot (Flight)*, pp. 6–11, 1998 (*in Russian*).

[3] A.Ph. Kiselev and V.D. Bokser, "Investigations of swept wing laminarization", *TsAGI – Principal Stages of Scientific Activities 1993- 2003*, pp. 133–138, 2003 (*in Russian*).

[4] E.S. Asmolov, S.V. Manuylovich and M.V. Ustinov, "Boundary layer laminar-turbulent transition in incompressible fluid", *TsAGI – Principal Stages of Scientific Activities 1993- 2003*, pp. 439–445, 2003 (*in Russian*).

[5] M.N. Kogan, N.K. Makashev, V.V. Skvortsov, Yu.E. Kuznetsov, V.V. Ivanov and V.G. Shumilkin, "Investigations of perspectives of electric discharge using for aerodynamic drag reduction and flows control", *TsAGI – Principal Stages of Scientific Activities 1993- 2003*, pp. 457–459, 2003 (*in Russian*).