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DRAG REDUCTION OF A SWEPT WING BY MEANS OF PLASMA ACTUATORS

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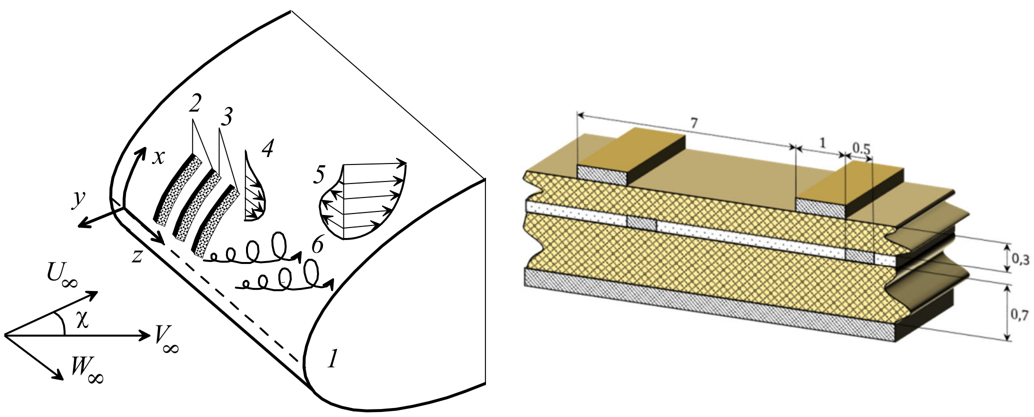
ABSTRACT

This work presents some recent results of theoretical and experimental study of innovative laminar flow control method on a swept wing based on electrogasdynamic impact on boundary layer flow. Experimental verification of this method is supposed to be carried out in near future in low-turbulence subsonic wind tunnel with the use of new multi-discharge plasma actuator system.

Keywords: swept wing, laminar-to-turbulent transition, dielectric barrier discharge actuator.

INTRODUCTION

Development of energy-saving and environmentally appropriate technologies in civil aviation remains one of the industries major objectives. Laminar-to-turbulent transition delay in a boundary layer on an airplane wing is one of the effective methods of friction drag reduction (up to 8÷16 % of total airplane drag) and, consequently, fuel consumption and atmospheric pollution decrease (Schrauf, 2005). The concept of laminar flow control (LFC) method proposed at TsAGI (Chernyshev, 2011) and based on electrogasdynamic (EGD) body-force impact on boundary layer flow on a swept wing is illustrated in Figure 1(a).



(a) (b)

Fig. 1 - (a) the concept of EGD LFC; (b) the design of multi-SDBD actuator system

A swept wing *1* in subsonic flow V_∞ is equipped by multi-discharge actuator system with exposed electrodes *2* creating surface dielectric barrier discharge (SDBD) *3* near one edge of every electrode. The body-force arising in SDBD induces a flow *4* directed mainly opposite to the cross-flow *5* which exists in three-dimensional boundary layer and is responsible for its high instability. An attenuation of the cross-flow *5* due to EGD impact results in a decrease of increments of spatial growth of the cross-flow-type instability vortices *6* responsible for laminar-to-turbulent transition. If this decrease is significant, the transition can be delayed downstream or removed.

RESULTS AND CONCLUSIONS

Theoretical assessments of EGD LFC method have been obtained for airflow parameters corresponding to typical cruise flight conditions of a civil airplane (Kuryachii, 2014). The essential problem in practical realization of this method is a development of optimal multi-SDBD actuator system capable of unidirectional force impact along a whole wing leading edge in very thin boundary layer. The multi-SDBD system developed at TsAGI and shown in Figure 1(b) differs from known systems (Benard, 2014) by more simple design and by a possibility of its essential miniaturization. The proposed system consists of the lower grounded electrode, two dielectric layers, and a set of pairs of electrically linked exposed and buried shielding electrodes.

Experimental justification of the EGD LFC method will be carried out in low-turbulence subsonic wind tunnel with the working cross-section of 1×1 m^2 on a swept wing model. The multi-actuator system has been manufactured for these experiments with the discharge area of 300×150 mm^2 and the spatial period (the distance between the active edges of adjacent exposed electrodes) of 5 mm. The operability of the created multi-actuator system is confirmed by the photo of the discharge at high alternating voltage amplitude of 4 kV and frequency of 10 kHz in Figure 2.

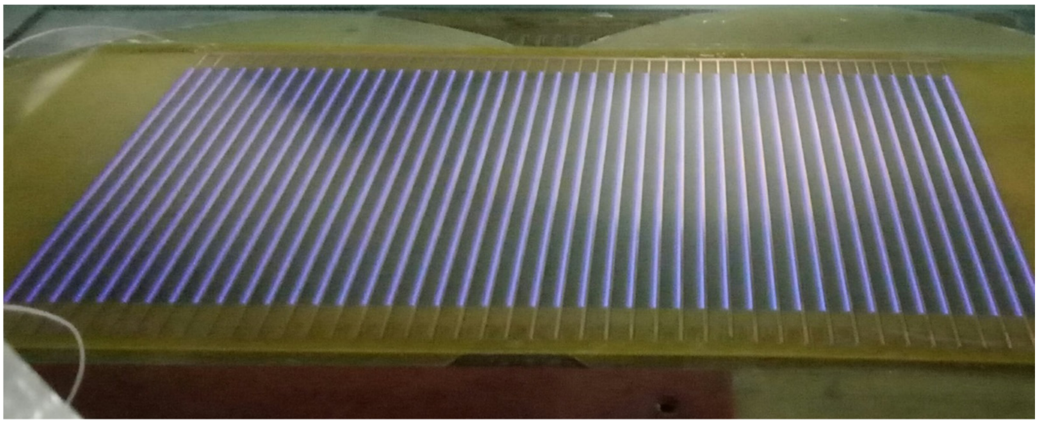


Fig. 2 - Photo of SDBD on multi-actuator system

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