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# NUMERICAL MODELLING OF LAMINAR FLOW CONTROL ON A SWEPT WING BY MEANS OF PLASMA ACTUATORS

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The presented work is devoted to theoretical modelling of the electrogasdynamic method of laminar-turbulent transition delay on a swept wing proposed at TsAGI [1]. The physical concept of the method consists in volumetric force impact on boundary layer flow in the vicinity of the swept wing leading edge. This impact is created by surface plasma actuators and is directed predominantly along the leading edge from root to tip of a wing. Flow acceleration in the mentioned direction results in a decrease of the cross-flow velocity in the boundary layer and, as a consequence, an attenuation of the cross-flow-type instability [2].

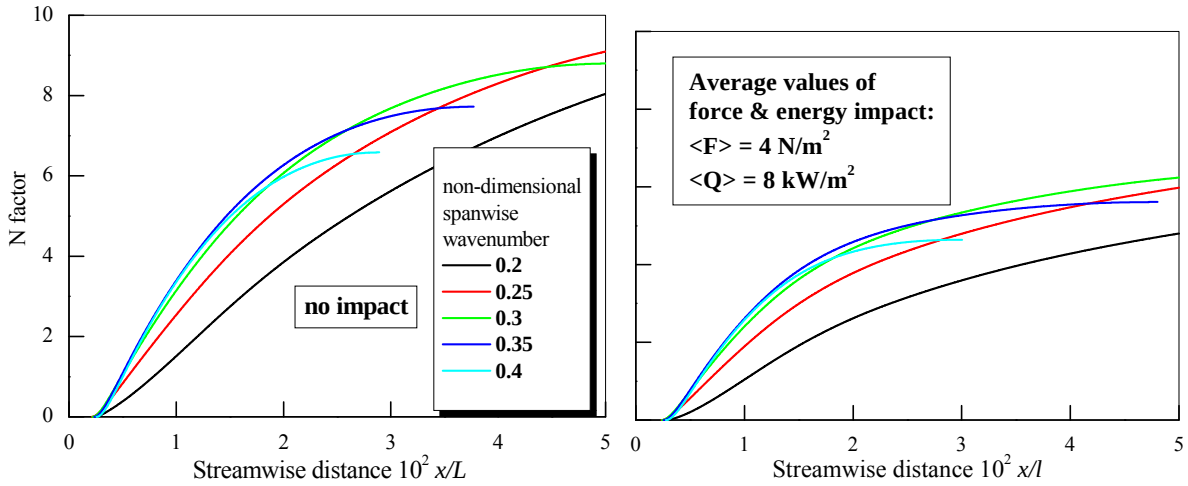
The main purpose of the present work consisted in the estimation of the main parameters of force and heat impact of plasma actuators which would be sufficient for a removal of the laminar-turbulent transition caused by cross-flow-type instability on a swept wing at typical subsonic cruise flight conditions. The proposed modelling includes numerical solution of the following problems.

The inviscid flow over an infinite span swept wing with a given airfoil is calculated on the base of the Euler equations. Then the calculated inviscid flow functions on a wing surface are used as external conditions in calculations of 3D compressible boundary layer spatially modulated along a wing span due to non-uniform volumetric force and heat impact of plasma actuators. This impact is approximated by stationary source terms in momentum and energy equations. These terms are taken in analytic form taking into account characteristic features of the force and energy input distributions obtained on the base of previous numerical modelling of the dielectric barrier discharge actuators [2]. The equation system of 3D compressible boundary layer includes additional equation for average energy of vibrational degrees of freedom of nitrogen molecules. The vibrational-translational relaxation is simulated in the simplest approximation of the mode kinetics.

The analysis of the linear stability of the spatially modulated boundary layer flow with respect to stationary cross-flow-type disturbances is carried out in the framework of usual equation system of Dunn-Lin for spanwise averaged flow [3]. The $e^N$ method and the strategy of fixed spanwise wavenumber are used for the estimation of the position of laminar-turbulent transition.

Two variants of plasma actuators arrangement on a wing surface are considered. Calculations executed for the free-stream Mach number $M_\infty = 0.8$, the wing sweep angle $\chi = 30^o$, the wing

chord L = 3 m, the flight altitude H = 10 km demonstrate that the average density of the volumetric force per unit of a wing surface of 4 N/m$^2$ seems to be sufficient for the elimination of the laminar-turbulent transition at the mentioned flight conditions.




Streamwise distributions of N factors for various spanwise wavenumbers.

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