Visualization of laminar-turbulent transition behind localized and two-dimensional roughness element on the leading edge of flying wing model

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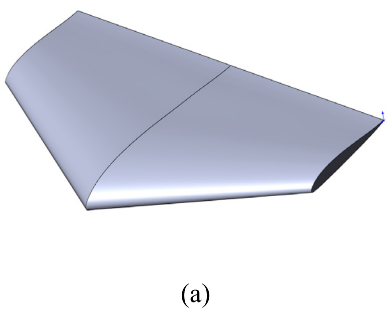
Abstract The paper given is devoted to the experimental studies of the development of stationary perturbations and the transition to turbulence behind a localized roughness element and two-dimensional roughness in the negative pressure gradient region of a flying wing model. Panoramic flow structure and parametric measurements were carried out using liquid crystal thermography technique with a heated surface by halogen lamp. With the help of hot-wire anemometry, the spatial characteristics of stationary perturbations were studied, and also the spectra of velocity pulsations spectra were obtained.
Keywords: flying wing, turbulent trace, cross-flow instability, laminar-turbulent transition, localized roughness, liquid-crystal thermography, hot-wire anemometry.
Acknowledgements This work was supported by the project of Russian Science Foundation № 18-79-00189.

1 Introduction

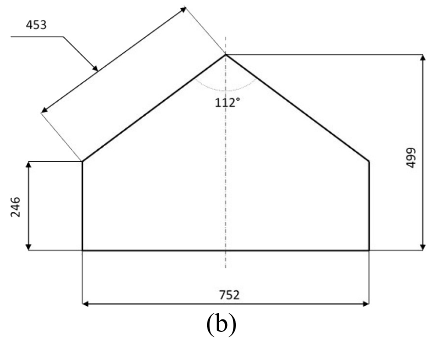
Nowadays UAV and drones are a very popular types of aircrafts. Reduction of aerodynamic resistance of the UAV by flow laminarization over stream-lined surfaces looks promising. The investigation of the flow structure over curved surfaces is a difficult challenge of the researchers. So, panoramic methods like liquid-crystal thermography can significantly ease these investigations and make it possible to carry out parametric studies. This work was aimed on investigation of physical mechanisms of laminar-turbulent transition on the flying wing in the negative pressure gradient region using liquid-crystal film and hot-wire anemometry.

2 Experimental setup

The experiment was carried out in the low-turbulent wind tunnel T–324 in the Institute of Theoretical and Applied Mechanics SB RAS. The cross section of the working area is 1000x1000 mm with length is 4000 mm. The level of the flow turbulence didn't exceed 0.03%. The Pitot-Prandtl tube connected to electronic manometer was used to monitor the free stream velocity. During experimental session freestream velocity was varied from $U_\infty = 7.2$ m/s to 15.1 m/s.
Model of the flying wing was used in the experiment. It was made out of wood and covered with lacquer. The sweep angle of the wing model was 34°. Wingspan is 752 mm and maximum chord of the wing is 499 mm. The angle of attack was 5° to form negative pressure gradient over the bottom surface of the wing.



(a)



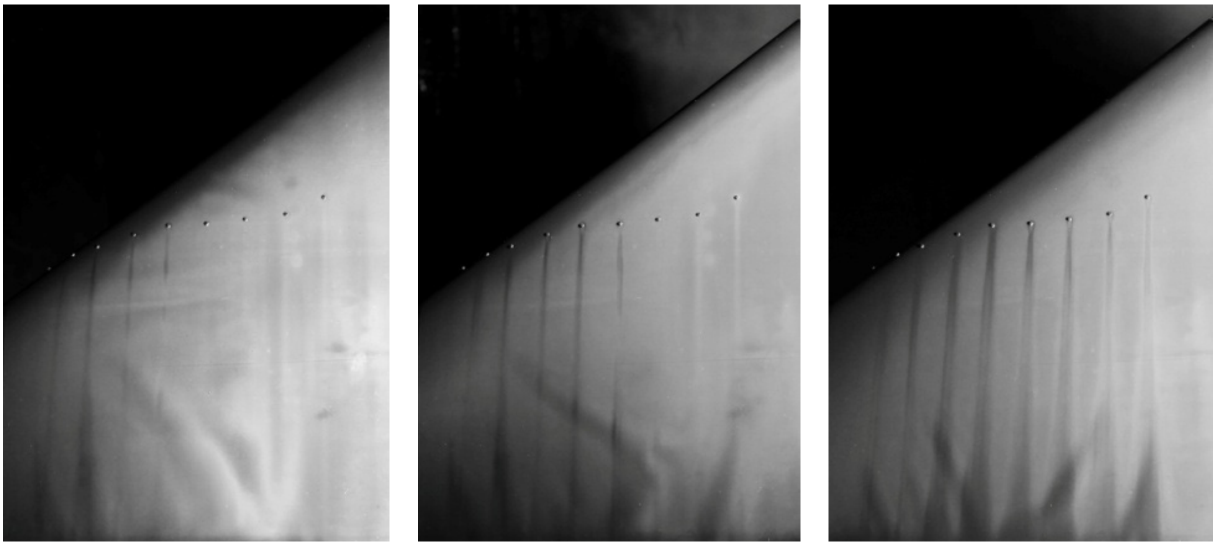
(b)

Fig.1. Flying wing (a) and its parameters in mm (b)

Carrying out the experiment stationary disturbances were excited by three and two-dimensional roughness element on the bottom surface of flying wing. 3-D element sizes: height is 0.98 mm and diameter is 0.8 mm. 2-D element sizes: width is 15 mm, length is 400 mm and height is 0.28-1.4 mm.

3 Results

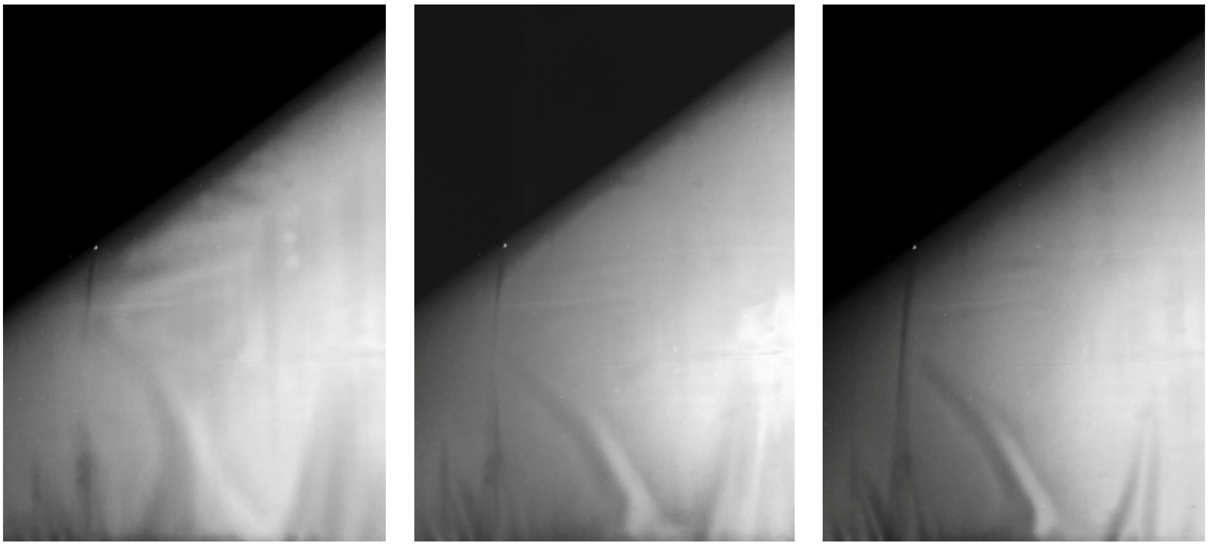
In the begging of the experiment the main goal was to find the area of maximum receptivity for flying wing model. For this purpose set of nine identical three-dimensional roughnesses was placed near the leading edge (Fig.2).



(a) (b) (c)

Fig. 2 Determination of the maximum receptivity area
(a) U_∞ = 7.2 m/s; (b) U_∞ = 10.2 m/s; (c) U_∞ = 15.1 m/s

It was found that third from left roughness was the most powerful one. So it was decided to carry out further work with this roughness.
Visualization of the structure forming behind localized three-dimensional roughness element was the next step in the experiment (Fig.3).



(a) (b) (c)

Fig.3 The three-dimensional roughness element on the leading edge of the flying wing and its influence on the flow
(a) U_∞ = 7.2 m/s; (b) U_∞ = 10.2 m/s; (c) U_∞ = 15.1 m/s

Quantitative agreement in results was found for swept and flying wing despite more complicated structure of the latter. The longitudinal structure behind three-dimensional roughness element becomes twisted downstream compared to the structures of the free-stream. The increasing of free-stream velocity leads to the increasing of the longitudinal structure dimensions. But noticeable change in the trajectory in the structure cannot be seen.