EFFECT OF TURBULIZING GRID NEAR WAKE ON A BOUNDARY LAYER ON A WEDGE

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Introduction

The problem of flow about bodies with high free stream turbulence is very important for engineering, because these flows are frequently met in different technical devices and turbomachines. The recent researches [1] showed that a stationary system of longitudinal structures arose on the winward side of the wing from increasing level of free stream turbulence to 1%. Characteristic transversal size of these structures exceeded the boundary layer thickness in many times. The number of the structures was found to be dependent on the angle of attack and the distance from the wind tunnel nozzle. Those experiments were carried in the open test section and the flow about the wing was complicated because of transversal spread of the flow.

The present work is an experimental investigation of a similar phenomenon, which takes place in a boundary layer on the winward surface of two-dimensional wedge in close test section.

Experimental technique

The experiments were carried out in low-turbulence subsonic wind tunnel MT-324 of the Institute of Theoretical and Applied Mechanics, Novosibirsk. The models of two-dimensional wedge with apex angles (α) 30° and 45° were placed in close test section 200×200 mm^2. Free-stream velocity was in the range from 4 m/s to 6 m/s. To increase the level of free stream turbulence baffling grids were used. The mesh sizes of grids were 1, 2.5 and 5.5 mm. The distance from a grid to the leading edge of the model was in the range from 350 mm to 425 mm.

A boundary layer structure was visualized using optical effects in thermosensitive cholesteric liquid crystals. Liquid-crystal thermography bases on a strong temperature dependence of selective light reflection of an encapsulated liquid crystal. This method was used to visualize the temperature distribution on the surface of previously heated model during aerodynamic cooling [2].

The color images of liquid-crystal coating were recorded by a video-image processing system through the transparent wall of the test section. For temperature measurement one-parameter calibration $T=f(H)$ is usually used. Where H (hue) is a color coordinate in the HSI color system. Thus a distribution of Hue on the model surface allows us to make conclusions about a boundary layer structure. The liquid-crystal coating had the width of the temperature operation range $\Delta T=3°C$. To decrease a heat transfer in the body of the models they were made thin-walled from a heat-insulating material.

Results

The results of the present work indicate that a system of longitudinal structures origin on the wedge with the presence of turbulizing grid as in the work [1].

The first part of the work was an investigation of characteristic transversal size dependence on free-stream velocity and geometric parameters of the flow. The grid with 2.5-mm mesh size was used. A fragment of visualization image of a boundary layer structure on the wedge

Report Documentation Page

Report Date 23 Aug 2002	**Report Type** N/A	**Dates Covered (from... to)** -

Title and Subtitle Effect of Turbulizing Grid Near Wake on A Boundary Layer on A Wedge	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Institute of Theoretical and Applied Mechanics Institutskaya 4/1 Novosibirsk 530090 Russia	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) EOARD PSC 802 Box 14 FPO 09499-0014	**Sponsor/Monitor’s Acronym(s)**
	Sponsor/Monitor’s Report Number(s)

Distribution/Availability Statement
Approved for public release, distribution unlimited

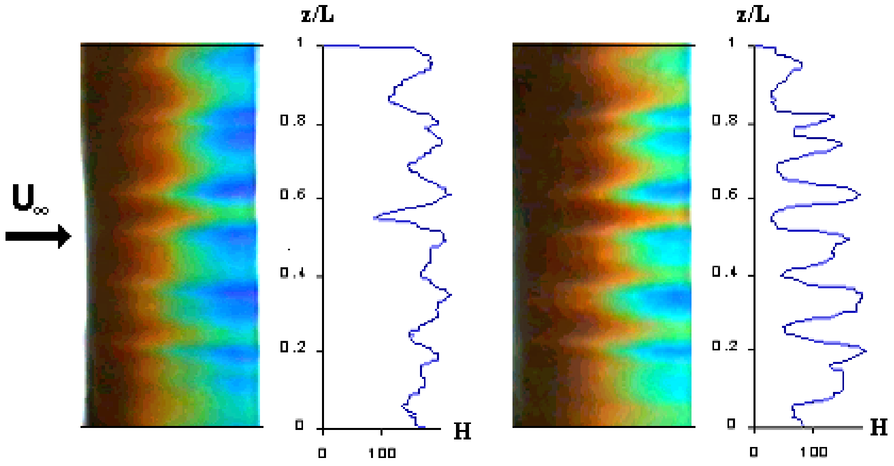
Supplementary Notes
See also ADM001433, Conference held International Conference on Methods of Aerophysical Research (11th) Held in Novosibirsk, Russia on 1-7 Jul 2002

Abstract

Subject Terms

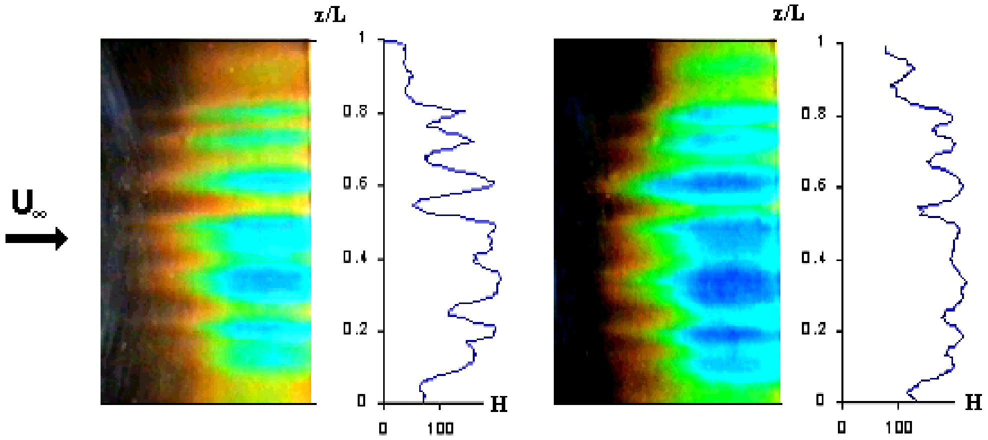
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU

Number of Pages
5



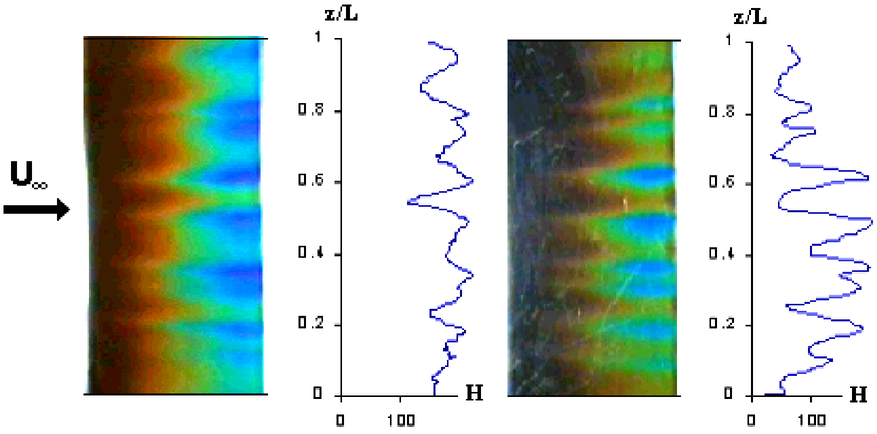
a) b)

Fig. 1. Visualization of the boundary layer structure on the wedge and corresponding curves of *H*. The mesh size of grid is 2.5 mm. The distance from the grid to the leading edge (*D*) is 350 mm. Transversal size of image fragment (*L*) is 120 mm. a) α=45°, U_∞=6 m/s. b) α=45°, U_∞=4 m/s.



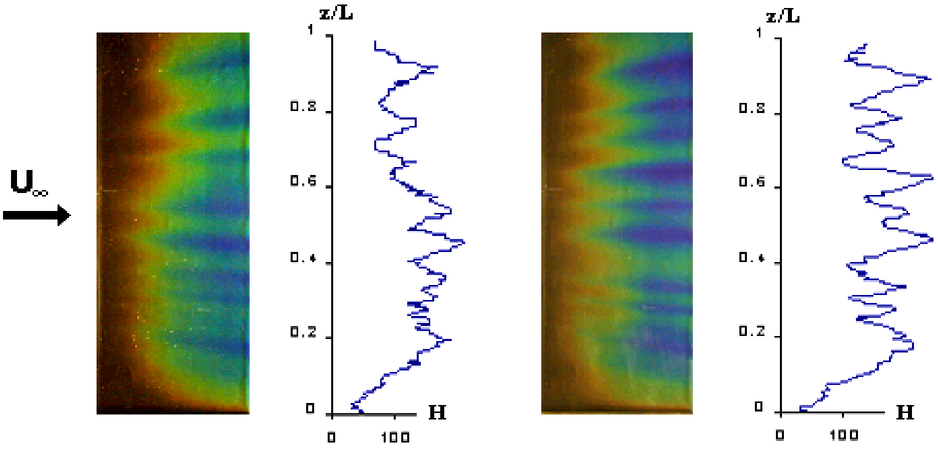
a) b)

Fig. 2. Visualization of the boundary layer structure on the wedge and corresponding curves of *H*. The mesh size of grid is 2.5 mm. *D*=350 mm. *L*=120 mm.
a) α=30°, U_∞=6 m/s. b) α=30°, U_∞=4 m/s.



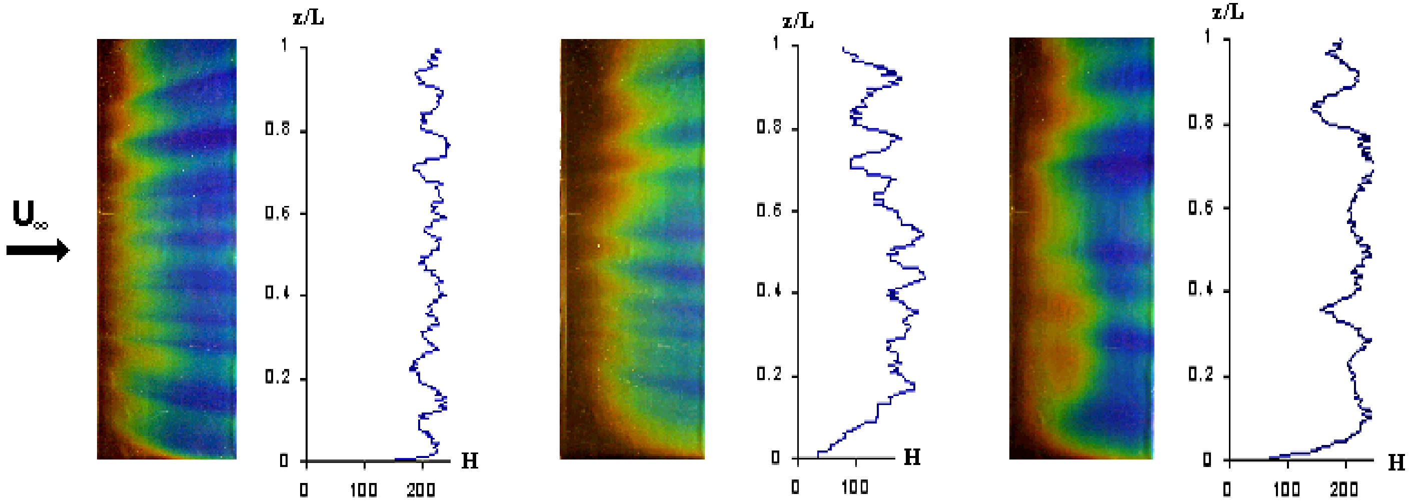
a) b)

Fig. 3. Visualization of the boundary layer structure on the wedge and corresponding curves of *H* at the distance from the grid to the leading edge 350 mm (a) and 425 mm (b). The mesh size of grid is 2.5 mm. α=45°. *L*=120 mm.



a) b)

Fig. 4. Change of the boundary layer structure when rotating grid by 90°. The mesh size of grid is 2.5 mm.



a) b) c)

Fig. 5. Visualization of the boundary layer structure on the wedge and corresponding curves of H at the mesh size of grid 1mm (a), 2.5 mm (b) and 5.5 mm (c). α=45°, U_∞=6 m/s. D=350 mm., L=150 mm.

with the apex angle (α) 45° is shown in Fig. 1. The visualization was made at two free stream velocities. The distance from the grid to the leading edge (D) was 350 mm. A free stream directs from left to right in all Figs. At the right of every image a typical curve of transversal distribution of H is shown. A greater magnitude of H correspond to a greater magnitude of surface temperature. Using the images and the curves we can do conclusions about number, size, and position of the structures. All images obtained at the same transversal co-ordinates z on the model surface.

Figures 1 and 2 show that the number and the position of the structures are independent from the apex angle and free stream velocity since the position of streaks at the images, peaks and valleys at the curves is the same. Defects of the leading edge could not affect on the position of structures because two different models were used. The qualitative structure of the boundary layer also did not change when increasing the distance from the grid to the leading edge (Fig. 3).

The position of the longitudinal structures changes when rotating the grid in the nozzle (Fig. 4), but their mean characteristic size does not change.

The second part of experiments was an investigation of dependence the characteristic transversal size of the longitudinal structures on the mesh size of turbulizing grid. The visualization results obtained using three grids with different mesh size are shown in Fig. 5. It is seen that the size of structures exceeds the characteristic scale of the grid in several times at all three images (the transversal size of the images is 150 mm). The size of structures increases with increasing of the mesh size. It is approximately 13.6 mm for 1-mm-mesh grid, 15 mm for 2.5-mm-mesh grid and 21.2 mm for the grid with 5.5-mm meshes.

Conclusion

The experimental research of longitudinal vortex structures on a wedge placed in channel at high free-stream turbulence for the first time was carried out. The originating structures are similar to the structures on the winward side of a wing at high free-stream turbulence. It is shown that the number and the size of the structures depend on the mesh size of turbulizing grid. However their size does not check with the size of meshes. This fact shows that either structures from the transversal instability band of flow are excited by high free-stream turbulence. At that free-stream velocity and the apex angle of the wedge have no influence on the number and the size of the vortex structures. It is not clear if the structures arise in the free flow or in the boundary layer. An additional research is necessary to find out the physical mechanism leading to their appearance.

Acknowledgement. This work was supported by the Russian Foundation for Basic Research (grants 00-15-96164 and 01-01-00828).

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