LAMINAR – TURBULENT TRANSITION ZONE IN THE BOUNDARY LAYER

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ABSTRACT
This paper is a study of the turbulence and the surface roughness influences about the laminar – turbulent transition in the boundary layer, for NACA 4412 airfoil, which have the chord L = 0.6 m. The mean velocity distribution is experimental determinate in the aerodynamic tunnel, for attack angle $\alpha = 0^\circ$.

KEYWORDS
Laminar – turbulent transition zone, flow, turbulence, rough, boundary layer, Reynolds number, airfoil.

NOMENCLATURE
$U$ [m/s] mean velocity  
$U_{ref}$ [m/s] reference velocity  
x [m] abscise  
$L$ [m] chord of airfoil  
$Re$ [-] Reynolds number  
$v$ [m$^2$/s] viscosity coefficient  
$H$ [-] boundary layer parameter  
$\varepsilon$ [-] turbulence degraded  
$\delta_1$ [m] displacement thickness  
$\theta$ [m] energy thickness  
d [m] high of rough  
$A, B, C$ know constant value

Subscripts and Superscripts
$tr$ transition  
s separation  
$H$ calculated value by $H$ parameter

1. INTRODUCTION
During the work of reversible hydraulic machines and wind turbine, it often appears situations when the same airfoil must work at big angles of attack. In this case, the knowledge of airfoils behaviour is very important because it appears separations of the flow from the wing, which can influence the machine’s work as a system. Separating flow over the airfoil is a very complex process. His study is necessary because flow separation is significantly influence about the hydraulic machine work. Laminar – turbulent transition zone in the boundary layer is a very important zone, because to know the flow behaviour in this zone permitted to find the solution where offer possibility to move his near trailing edge.

Some most of interesting aerodynamic problem of real fluid flow are laminar – turbulent transition in the boundary layer. Because this laminar – turbulent transition in the boundary layer is caused by more factor, finding the position of transition zone is not good outlined and not permanently. The experimental studies indicate that the Reynolds number in laminar – turbulent transition zone of the boundary layer are depending of the flow turbulence, curved and roughness of the surface, longitudinal pressure gradient, relation between body surface temperature and the fluid flow temperature, acoustic perturbation, etc.

The surface roughness is one of the most important factor who determinate the point position of laminar – turbulent transition in the boundary layer. This is the reason that the study of the roughness influence at the apparition of the turbulent boundary layer, are very interesting.
2. VELOCITY DISTRIBUTION

The NACA 4412 airfoil, for $\alpha=0^\circ$ angle of attack has been placed in the work zone in the Aerodynamic tunnel for boundary layer. For Reynolds number $Re = 9.6 \cdot 10^6$, has been obtained, at the upper airfoil surface, velocity distribution present in the fig. 1.

![Velocity Distribution](image)

Figure 1. The velocity distribution at the upper surface of the airfoil

3. THE INFLUENCE OF THE TURBULENCE DEGREE ON THE FLOW ABOUT THE LAMINAR – TURBULENT TRANSITION IN BOUNDARY LAYER

L.F. Kozlov is proposing determination of the laminar – turbulent transition point in the boundary layer at the crossing of the curves $Re$ and $Re_{tr}$ where is calculated with relation (1), and $Re_{tr}$ is calculated with relation (2).

$$Re_{x} = \frac{U \cdot x}{\nu} \quad (1)$$

$$Re_{tr} = Re_H + C(f_s + f)^{1/2} \cdot \varepsilon^{-5/4} \quad (2)$$

$$f = \frac{\theta^2}{\nu} \cdot \frac{dU}{dx} \quad (3)$$

$$Re_H = \exp(A - B \cdot H) \quad (4)$$

$$H = \frac{\delta_1}{\theta} \quad (5)$$

Using a DISA anemometer and DISA probe, has been measured velocity profile in the boundary layer at the upper surface of airfoil, and has been calculated $\delta_1$, $\theta$, and $H$. Measuring velocity distribution with the aid of a DISA constant temperature anemometer, auxiliary DISA devices, we have obtained velocity distributions, which confirm flow separation at the trailing edge. In fig. 2 is presented the variation of the $H$ parameter determinate with experimental data.

![Velocity Distribution](image)

Fig. 2. Variation of the $H$ parameter with $x/L$ abscise

4. THE INFLUENCE OF THE SURFACE ROUGHNESS ON THE LAMINAR – TURBULENT TRANSITION IN BOUNDARY LAYER

Noted with $d$ highness of the roughness element an considering the vorticity dimension proportional with $d$, Kozlov propose for $Re_{tr}$ the relation (6):

$$Re_{tr} = f^2 \cdot \exp(Re_H)$$

Analyzing the dependency of the $Re_{tr}$ in function of the $f$ boundary layer parameter, it was obtained the fig. 3. diagram. We found the increase of the $f$ parameter with increase of the $Re_{tr}$.

![Dependency of the $Re_{tr}$ number in function of the $f$ parameter](image)

Fig.3. Dependency of the $Re_{tr}$ number in function of the $f$ parameter

Taking for the $d/\theta$ parameter values between 2 and 6, in the fig. 4 resulting $Re_{tr}$ value lowed with the increase of the of the $d/\theta$ parameter.
To obtain the boundary layer laminar turbulent transition point abscise caused by the surface roughness, it is calculated $Re_{tr}$ value for $d/\theta = 2 \ldots 6$.

Overlap the obtained curved for $Re_{tr}$ and $Re_x$ it is obtained fig. 5 diagram.

For $d/\theta = 2 \ldots 6$ it was found for NACA 4412 airfoil at $\alpha=0^\circ$ angle of attack the boundary layer laminar – turbulent transition point is situated nearly the $x/L \cong 0,35$ value. The increase of the roughness is not significantly influence by determination of the boundary layer laminar – turbulent transition point.

4. CONCLUSION

4.1. The boundary layer laminar – turbulent transition is influenced by many factors, two of the most important are the flow turbulence and the surface roughness.

4.2. For NACA 4412 airfoil, at $\alpha=0^\circ$ angle of attack, considerate only the flow turbulence, it was found that the boundary layer laminar – turbulent transition point is at $x_{tr}/L \cong 0,375$.

4.3. For NACA 4412 airfoil, at $\alpha=0^\circ$ angle of attack, considerate only the surface roughness, it was found that the boundary layer laminar – turbulent transition point is at $x_{tr}/L \cong 0,35$ for $d/\theta=2\ldots6$.

4.4. For NACA 4412 airfoil, at $\alpha=0^\circ$ angle of attack, the surface roughness, determinates the boundary layer laminar – turbulent transition point nearly the leading edge that the flow turbulence.
REFERENCES


