Labor Windkanal/Strömungsmesstechnik

OSTBAYERISCHE TECHNISCHE HOCHSCHULE REGENSBURG

Dependence of Wing Section Characteristics on Spectral Turbulence Distribution of Onset Flow

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1. Outline

Wings in free flight and wing sections in wind tunnel test encounter different spectral turbulence distributions of onset. Thus, airfoil performance measured in wind tunnel tests may differ from those achieved in free flight. The difference arises from a different boundary layer development.

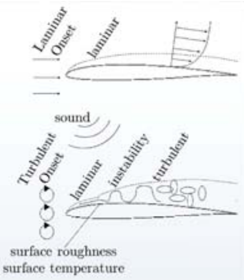

Fig. 1: Schematic of different boundary layer development due to different turbulence levels

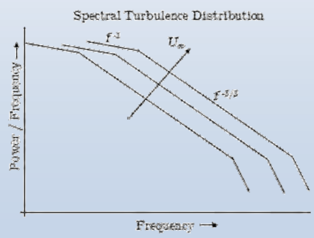

Fig. 2: Schematic of spectral turbulence distribution which can be shifted via wind speed

The spectral turbulence distribution of a wind tunnel can be influenced by varying the wind speed for example. The objective of the present master's thesis is to investigate the effect of a changed onset turbulence spectrum wing section characteristics obtained from wind tunnel tests.

2. Methods

In order to obtain data on the velocity dependence of spectral turbulence distribution in the closed test section of the RWT CTA measurements using a X-hot-wire probe are performed.

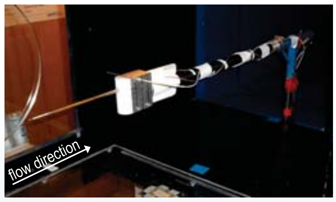

Fig. 3: Turbulence measurement setup in the closed test section

$$\frac{A(x)}{A_0} = e^{\int_x (-\alpha_i)\,\mathrm{d}x} = e^N$$

$$\frac{\mathrm{d}N}{\mathrm{d}x} = -\alpha_i$$

Boundary layer transition can be perceived as stability problem. To identify the frequencies an airfoil is sensitive to, a MATLAB program, employing methods from linear stability theory and XFOIL, is coded and used.

Changing the wind speed influences the onset turbulence spectrum. In order to prove the findings from turbulence measurements and stability computations performance characteristics of an airfoil versus free stream velocity are measured in the RWT.

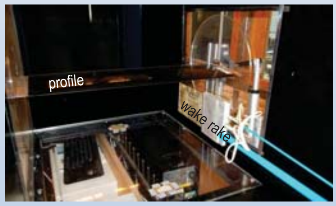

Fig. 4: The RG-15 airfoil in the closed test section of the RWT

3. Computations and Measurements

The turbulence measurements in the closed test section at different wind speeds using CTA show a typical turbulent decay which can be shifted by varying the wind speed. However, the change is distinct but not strongly pronounced within a velocity range of ± 10 %.

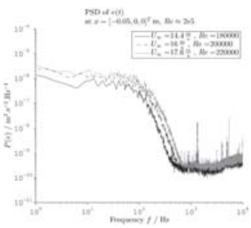

Fig. 5: Spectral turbulence distribution in the RWT at 16 m/s ± 10 %.

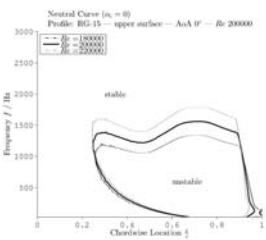

Fig. 6: Neutral curve, separating damped and amplified perturbations on the RG-15

The computations on boundary layer stability reveal a broad sensitivity range of the airfoil, which is changing significantly with angle of attack and free stream velocity. However, a certain frequency becoming unstable does not necessarily imply inducing transition.

If the N-factor reaches a certain value, boundary layer transition is initiated. The maximum N-values appear to be at frequencies approximately the one half of the frequencies becoming unstable first. Both properties are shifting with the free stream velocity and angle of attack.

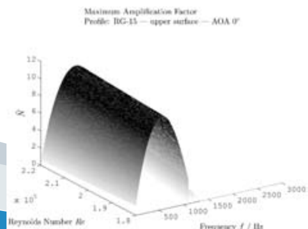

Fig. 7: N-factor, describing the perturbation amplitude ratio, versus Reynolds number

4. Results and Conclusion

The results of the turbulence measurements versus wind speed were fitted to a modified von Kármán model. The MATLAB code used for boundary layer stability investigations is ready for further use in extensive investigations.

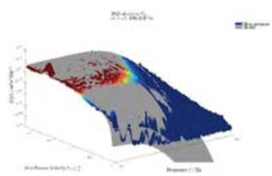

Fig. 8: Spectral turbulence distribution versus wind speed in the RWT, measurement and fitted model

The turbulence measurements prove the possibility of influencing the spectral turbulence distribution by varying the wind speed. However, the effect is quite small especially for higher velocities. Computations show that the sensitivity of airfoils changes also with free stream velocity, but more considerably with angle of attack.

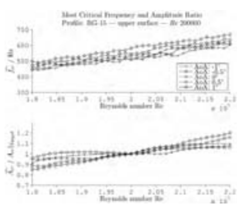

Fig. 9: Dependence of critical frequency on velocity and amplitude ratio w.r.t. target velocity

Measurements show that the effect of changing the wind speed by ± 10 % on lift and drag is negligible or below the resolution of the current measurement setup, respectively. Thus, no clear advice regarding improvement of future measurements in the closed test section of the RWT can be given.

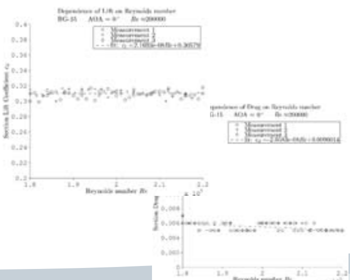

Fig. 10: c_l and c_d of RG-15 versus Reynolds number measured in the RWT