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Detecting the Laminar/Turbulence Transition in the Boundary Layer by Optical and Acoustical Means

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1. Introduction

Topic of this work is the detection of the laminar/turbulence transition in the boundary layer of different airfoils.

The target ís to detect and analyze the transition with simple measurement equipment (microphone).
In this case different measurement setups and programmes have been developed and tested. Furthermore a thermography process was used to detect the boundary layer and verify the acoustics measurement.

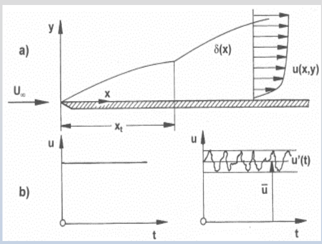

Fig. 1: Boundary layer of a flat plate, schematic;
a) sequence of the boundary layer thickness;
b) chronological sequence of the velocity in a laminar and turbulent boundary layer [HHW02]

As seen in figure 1b the velocity of the turbulent flow field is highly fluctuating. The onset flow is superposed by a fluctuation velocity u' and v' [HHW02]. So there is also a time depend local pressure fluctuation which is characteristically for the turbulent flow. This oscillation can be detected and analyzed with a microphone.
The velocity fluctuation also changes the heat transfer coefficient. So the transition can be detected with a thermography process.

2. Acoustics Setup

An acoustic measurement system has been developed with the following specs:

Fig. 2: Measurement equipment for dectecting the boundary layer with a microphone

- realized with laboratory equipment (cheap)
- simple in use
- high resolution and accuracy
- collect high data volume
- get calibrated simply

Main target was to design and to develop a Labview software (fig. 3) which can handle the acquired data.
The software has a real time FFT and works with high sample rates. The raw data can be saved for subsequent analyzes in Matlab.

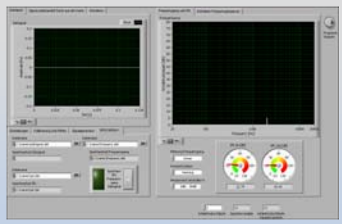

Fig. 3: Frontend from SPL.vi

3. Thermography

Fig. 4: Flir Thermacam B2

A thermography camera was used to verify the acoustic measurement system (fig. 4).
It should be kept in mind that the model has to get cooled or heated to increase the temperature difference between the flow field and the model.
This measurement system has the advantage to show a a plane view of the whole object. So you can see the result immediately.

4. Laminar separation bubble

For low Reynolds numbers there might occur a laminar separation bubble on an airfoil.
In one case the two described measurement system has been checked if they can detect such a bubble.
For this aim the separation bubble first has been visualized by a smoke tube setup (Fig. 5).

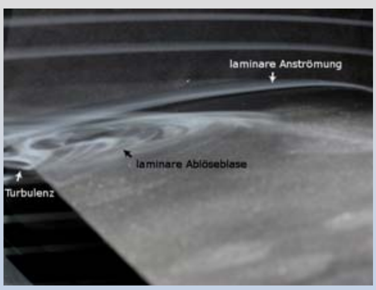

Fig. 5: Laminar separation bubble on a PK121-3 attack angle 0°, u=3m/s (Re ca. 40000)

5. Conclusions

The measurements show that a detection of the laminar/turbulent boundary layer transition is possible by optical and acoustical means.

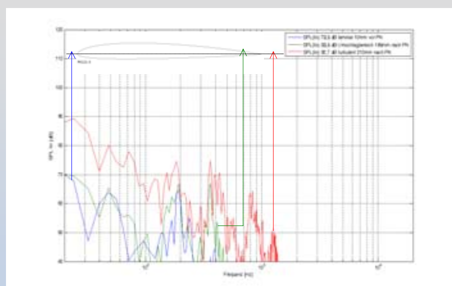

Fig. 6: Frequency response from a PK121-3 attack angle 0°, u=10m/s (Re ca. 130000)

Figure 6 shows the frequency response of a PK121-3 airfoil by an angle of attack (AOA) of 0°. The measurements has been performed in different distances from the airfoil nose to detect the boundary transition.

Figure 7 shows a thermography shot with the boundary layer flap.
It should be kept in mind that the inhomogeneity of the airfoil causes a increasing heat transfer downstream. This fact predicts the transition somewhat forward.

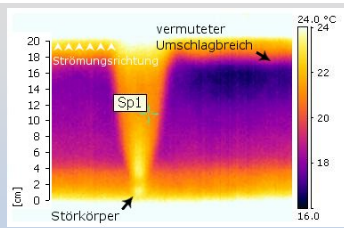

Abb 7: Thermography shot of a PK121-3 attack angle 0°, u=10m/s (Re ca. 130000), (cooled down before mesurement)

Both processes seemed not to be able to detect a laminar separation bubble. To do this there are other processes like smoke tubes or laser optical measurement systems.

References: [HHW02] Wolf-Heinrich Hucho "Die Aerodynamik des stumpfen Körpers“, 1. Auflage, Vieweg Verlag, Braunschweig/Wiesbaden, 2002