Thermografic Analysis of Mechanical Disturbances Effects

on Laminar Separation Bubble

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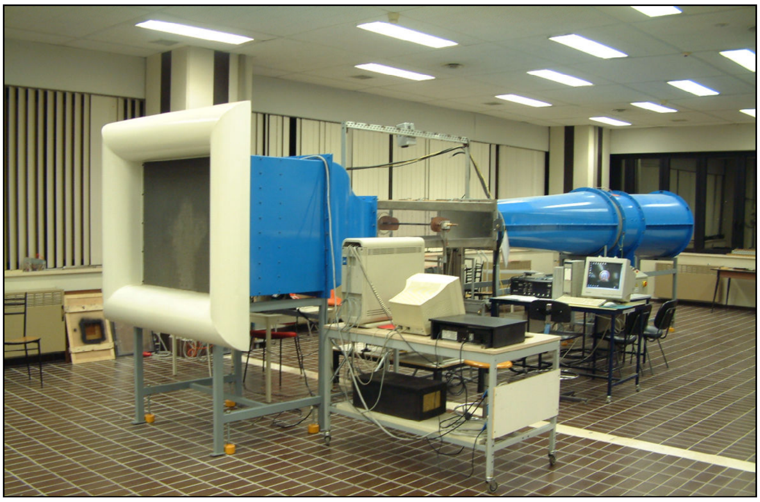
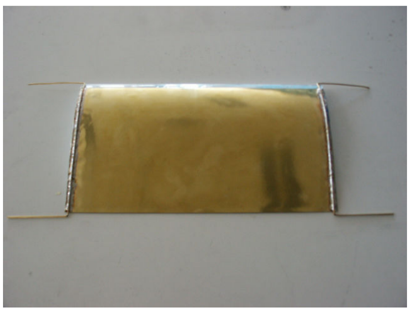
Abstract:

The Laminar Bubble is a local boundary layer separation phenomenon that may occur on aerodynamic body surfaces operating at low Reynolds numbers. The effect of acoustic disturbances on the laminar bubble behavior was illustrated in a previous work (Qirt 2006); in this paper are instead presented the results obtained by means of a M.E.M.S placed inside the tested airfoil. The analyzed wing section is designed for the root of a small wind turbine blade, where the tangential velocity $u = \omega \cdot R$ is low; moreover the wind turbine is designed for low wind speed sites. So the airfoil will frequently operate at low Reynolds numbers.

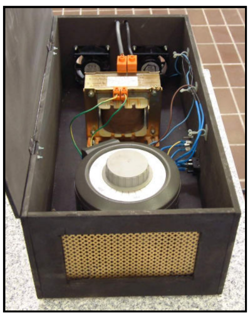


The Wind Tunnel of the "Università Politecnica delle Marche"

The experimental analyses were carried out in the aeronautical wind tunnel of the "Università Politecnica delle Marche" - Department of Energetic. This facility provides flow velocities in the range 0 – 30 m/s with a flow turbulence level lesser than 0.3%. The wing section was analyzed by using: the pressure distribution analysis, a three axis load balance, oil visualizations and the Infrared Thermography analysis.



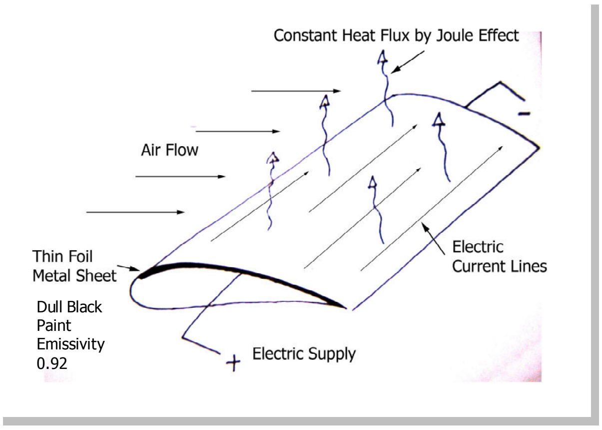
An example of airfoil coating



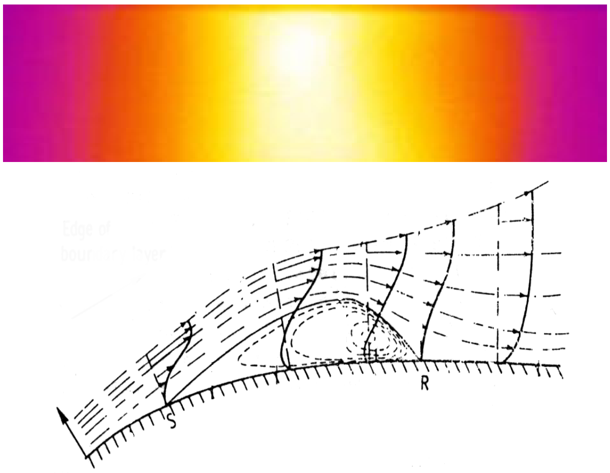
The airfoil power supply

The SC3000 IR Camera

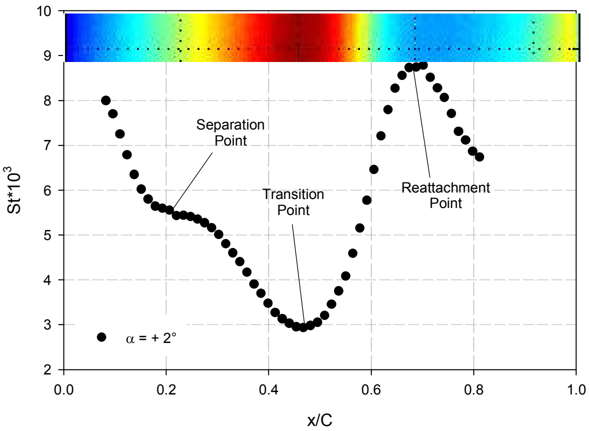
In order to carry out the IR visualizations, the wind surface was coated with a thin metal foil electrically supplied; this allows to obtain a constant surface heat flux condition as prescribed by the thin foil technique. The temperature distribution observed by the FLIR SC3000 IR camera is post-processed by using a Matlab code that allows to obtain the local Stanton number distribution over the airfoil surface; by analyzing this distribution is possible to observe the locations of the boundary layer separation, transition and reattachment points. This analysis is performed by varying the airfoil angle of attack and the operating Reynolds number.



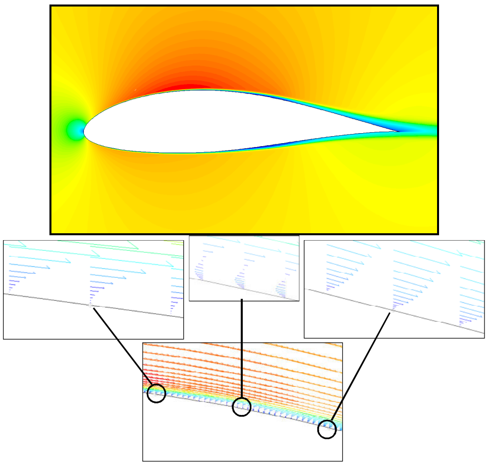
The Heated Thin Foil Technique



The local temperature increase due to the Bubble Presence



The typical Stanton Number Distribution in presence of a Laminar Bubble



The Laminar bubble observed with a numerical analysis for the tested airfoil

The results show a laminar bubble reduction by using the M.E.M.S. disturbance effect; the reduction is related to the frequency of the disturbances and to the bubble position on the airfoil surface. This is due to the boundary layer receptivity for the wave disturbances induced by the M.E.M.S; the adverse pressure gradient related to the airfoil angle of attack and the local Reynolds number (based on the momentum thickness) are the main parameters that influence the wave disturbance development inside the boundary layer.

For the tested angles of attack and Reynolds number the bubble presence is not avoided but there is a marked longitudinal extension reduction: this is clearly observed by the thermographic results.

Also numerical analyses were carried out for the tested airfoil and the results showed the presence of the laminar bubble on the airfoil extrados; the bubble position and dimension are in good agreement with the experimental results.