WIND TURBINE AIRFOIL DESIGN AND TESTING

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1. Introduction

In the late seventies, the eighties and early nineties of the last century wind turbine manufacturers used existing airfoil families originally developed for general aviation like the 4 digit NACA 44 series, the 5 digit 230 family and the 6 digit NACA 63 series [1] for the design of wind turbine blades. Figure 1.1 shows the measured aerodynamic characteristics of airfoils from the 44-series with relative thickness between 15% and 24%.

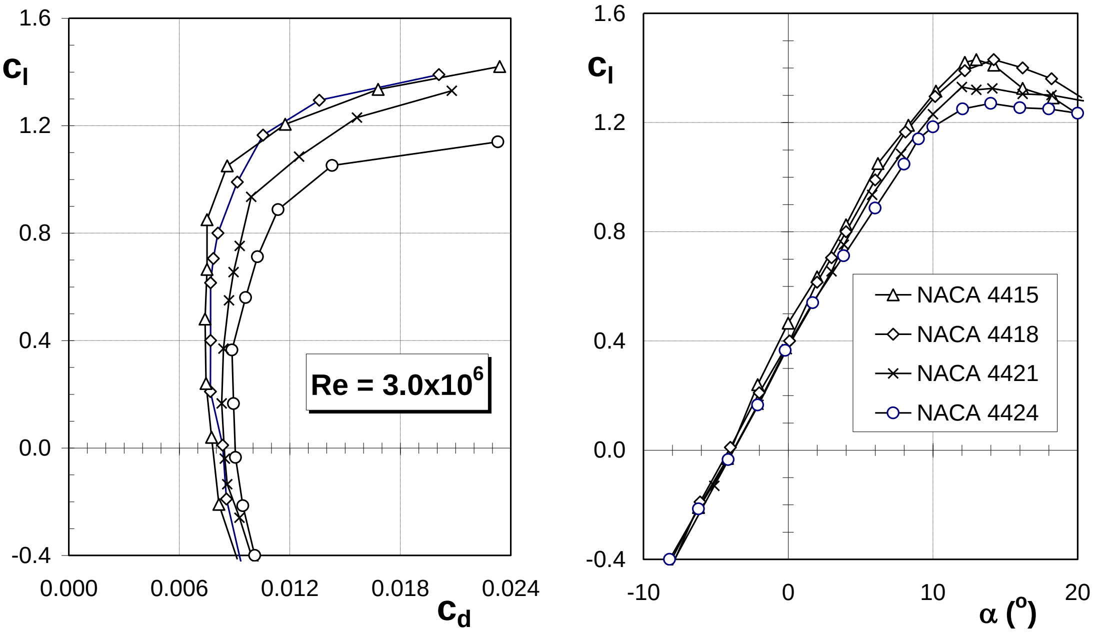

Figure 1.1: The measured characteristics of the NACA 44 series of airfoils with varying thickness [1].

The required thickness in the blade root was achieved by linearly scaling the coordinates from airfoils with smaller thickness.
It appeared, however, that the thick members of the NACA airfoil families suffer from a severe degradation of the performance as a result of a soiled leading edge. In figure 1.2 the two-dimensional characteristics of airfoil NACA $63_{(421)}$-425 are depicted, measured in the 1.25x 1.80 m Delft University low-speed wind tunnel with a 0.60 m chord model.
The tape used in the wind tunnel test introduces premature transition of the boundary layer from laminar to turbulent, and increases the thickness of the boundary layer.
It is clear that the zigzag tape roughness heavily de-cambers this airfoil and leads to a severe loss of lift.

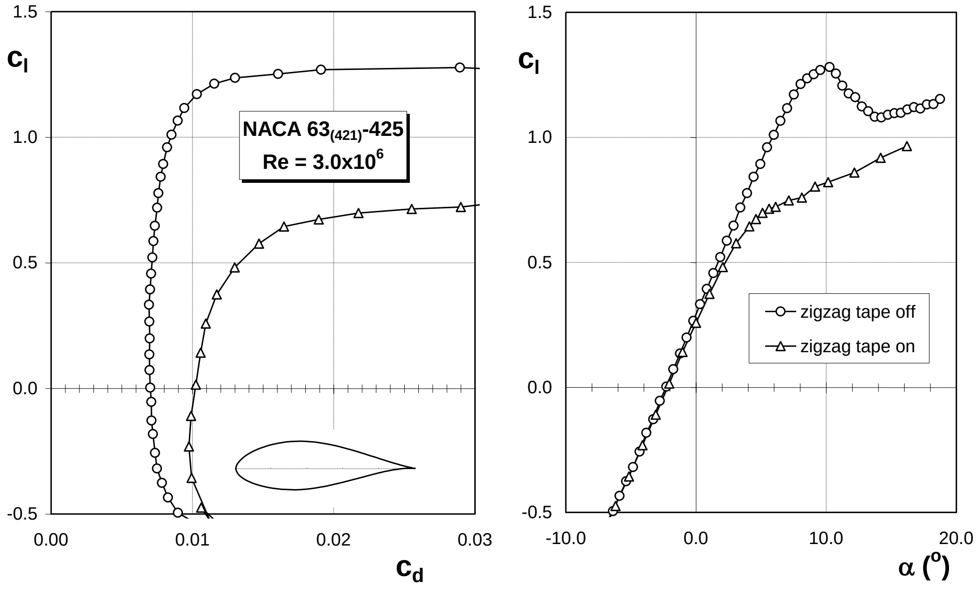

Figure 1.2: The effect of roughness on the performance of airfoil NACA 63-425. Zigzag tape had 0.35 mm thickness, x/c=.05 upper surface.

1.1 Early dedicated designs

In the seventies F.X. Wortmann at the University of Stuttgart designed a number of airfoils to be used in the blade of the Growian, a German first generation 3MW 100 m diameter turbine from the late seventies [2]. Figure1.3 presents the characteristics of an inboard airfoil from this series, showing some undesirable features. Due to stall the airfoil loses about 30% of its lift. Trip wires on both the upper and lower surface leading edge even halve the maximum lift capacity of the airfoil

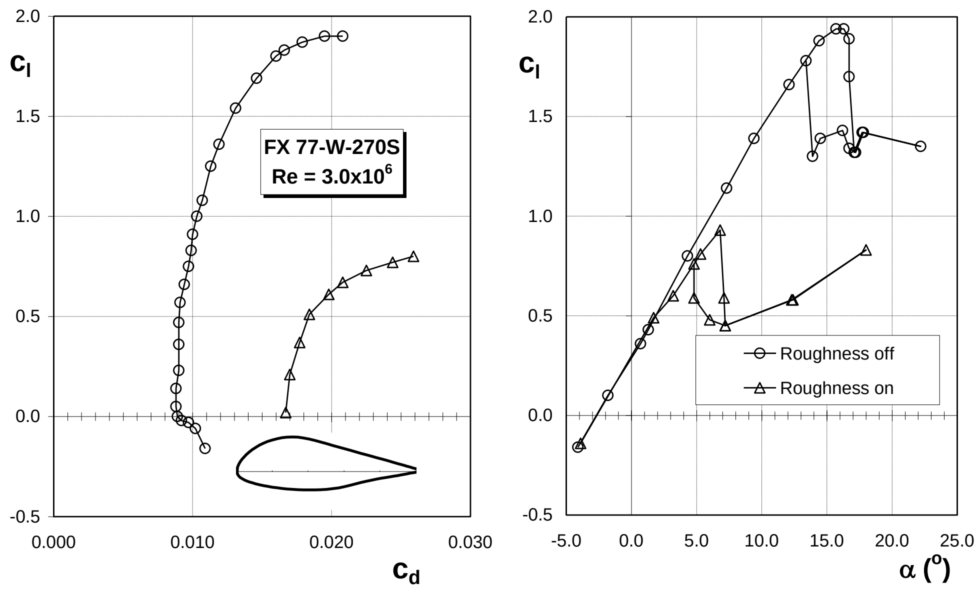

Figure 1.3: The clean and rough performance of airfoil FX 77-W-270S. Roughness consisted of trip wires at 3% chord on upper and lower surface