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# Design of a new urban wind turbine airfoil using a pressure-load inverse method

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ABSTRACT

This paper presents the design methodology of a new wind turbine airfoil that achieves high performance in urban environment by increasing the maximum lift. For this purpose, an inverse method was applied to obtain a new wind turbine blade section with constant pressure-load along the chord, at the design inlet angle. In comparison with conventional blade section designs, the new airfoil has increased maximum lift, reduced leading edge suction peak and controlled soft-stall behaviour, due to a reduction of the adverse pressure gradient on the suction side. Wind tunnel experimental results confirmed the computational results.



## 1. Introduction

Within a urban environment, where the average mean wind speed is quite lower than in open rural or mountainous areas, it is of major relevance to have wind turbines with low cut-in speed, in order to increase the annual energy production from this micro-generation renewable energy technology. For fixed pitch turbines, this requires high-lift blade sections to increase the starting torque [1]. Although the overall performance of a wind rotor turbine is influenced by three-dimensional and unsteady effects, substancial gains can be achieved by improving the blade sections design [2].

Many early designs of wind turbine airfoils were based on laminar or low Reynolds number sections such as the Wortman FX-77 or the NASA LS(1) [3]. Another common practice was to use the NACA 44XX and the NACA $63_2$-XXX sections to design wind turbine blades.

In the mid 1980's, NREL started a joint work with Tangler and Somers from Airfoils Inc. for the development of several series of airfoils specifically for wind turbines [4]. In the following decade, the Delft University also embraced the increased efforts for the development of new airfoils. A summary of that research, together with the aerodynamic characteristics of several wind turbine airfoils developed at Delft, can be found in [5]. In [6], Giguère and Selig present a literature review about airfoil design and report four improved airfoils especially tailored for small wind turbines.

The desired airfoil aerodynamic characteristics for horizontal axis wind turbines have evolved through the years [7]. A modern perspective of the current design trends is given by Fuglsang and Bak [3] and the references therein. In [3], it is also presented the major contribution of the Risø Laboratory to the design of wind turbine airfoils and the aerodynamic characteristics of three new series.

There are two distinct strategies for the design of turbine blade sections: the direct and the inverse methods [8]. The first, uses a "cut-and-try" approach where the results are validated experimentally or with the help of analysis codes. This procedure is usually slow, cumbersome and relies heavily on the experience of the designer. Opposite to this type of methods, the so-called inverse or indirect methods aim to calculate the blade geometry that provides certain conditions for the flow specified as initial data for the problem. Three major trends have been developed for the solution of the inverse problem: optimization techniques, pure inverse formulation methods and iterative use of analysis (or direct) codes. When using optimization techniques [9], the blade section is described in terms of some parameters and a search is initiated in the design range, looking for the set of parameters that give the computed flow features as close as possible to the ones specified, or that lead to an optimum regarding some flow field conditions. Pure inverse methods [10–12] determine directly the geometry of the blade section that will achieve certain desired flow conditions. This is done by means of a problem formulation that makes immediate use of the information supplied by these desired flow conditions, for example, by using the imposed flow conditions as boundary conditions. For a more complete review of the current blade design methods see [13] and the references therein.

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