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An Airfoil Parameterization Method for the Representation and Optimization of Wind Turbine Special Airfoil

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A new airfoil shape parameterization method is developed, which extended the Bezier curve to the generalized form with adjustable shape parameters. The local control parameters at airfoil leading and trailing edge regions are enhanced, where have significant effect on the aerodynamic performance of wind turbine. The results show this improved parameterization method has advantages in the fitting characteristics of geometry shape and aerodynamic performance comparing with other three common airfoil parameterization methods. The new parameterization method is then applied to airfoil shape optimization for wind turbine using Genetic Algorithm (GA), and the wind turbine special airfoil, DU93-W-210, is optimized to achieve the favorable Cl/Cd at specified flow conditions. The aerodynamic characteristic of the optimum airfoil is obtained by solving the RANS equations in computational fluid dynamics (CFD) method, and the optimization convergence curves show that the new parameterization method has good convergence rate in less number of generations comparing with other methods. It is concluded that the new method not only has well controllability and completeness in airfoil shape representation and provides more flexibility in expressing the airfoil geometry shape, but also is capable to find efficient and optimal wind turbine airfoil. Additionally, it is shown that a suitable parameterization method is helpful for improving the convergence rate of the optimization algorithm.

Keywords: wind turbine; airfoil; parameterization method; optimization

Introduction

With the deepening conflict between ever growing energy demand and the stringent limits of pollution, the need for clean and renewable energy sources increases rapidly. Wind energy, as one of the most economic green energy, provides an efficiency and effective solution to reduce fuel consumption as well as pollutant emission. As a foundational process of the wind turbine optimization, airfoil parameterization not only has significant influence on design efficiency, but also has profound impact on the aerodynamic performance of wind turbine [1]. Two main principles should be included in the criterion of airfoil parameterization method [2-4]: One is the completeness, the other is controllability. In the past decades, the researches have been conducted in the field of airfoil shape optimization and relevant methods have been devised to represent airfoil geometry shape and conducted parametric optimization studies [5-11]. Four common airfoil parametric methods, including Bezier curve, PARSEC, Hicks-Henne and B-spline method are widely used in airfoil representation.

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Nomenclature

R_{le}	leading edge radius	P_i	control points in Bezier method
Y_{up}	upper crest point	$B_{i,j}$	Bernstein basis function
X_{up}	position of upper crest	$bi_{,j}$	Bernstein function
Y_{XXup}	upper crest curvature	$\varphi(x,y)$	expression of implicit curve
Y_{lo}	lower crest point	Cd	draft coefficient
X_{lo}	position of lower crest	Cl	lift coefficient
Y_{XXlo}	lower crest curvature	CAGD	Computer Aided Geometric Design
α_{TE}	trailing edge direction angle	CFD	Computational Fluid Dynamic
β_{TE}	trailing edge wedge angle	GA	Genetic Algorithm
T_{TE}	trailing edge thickness	TFI	Algebraic interpolation
T_{off}	trailing edge offset		

One of the most popular methods is the Bezier curve, which defines the airfoil shape by introducing control points around the geometry [12, 13]. The main disadvantage of this method is that the number of control points and their locations are not knowable a priori, which does not provide full control over the shape of the fitted curve and in some cases may lead to unreasonable shape [14]. Another common method is PARSEC method. Since Sobieczky [15, 16] presented this airfoil parametric method, it has been successfully applied to airfoil design optimization. To improve the controllability of airfoil shape, this technique has been developed to directly control the main aerodynamic features by capturing finite design parameters. However, PARSEC does not provide enough control points over the leading and trailing edge shape where important flow phenomena occurs, particularly, it is prone to overlap between upper and lower airfoil surfaces along the trailing edge. Additionally, Hicks-Henne [17] is one of the more popular airfoil parameterization methods. It employs perturbed functions to parameterize the design airfoil space, which greatly reduces the number of design variables and enhances the explicit control of some geometric constraints, thus it is convenient for the local airfoil optimization. The disadvantages of these functions are not orthogonal. It contains significant controllability, but lack of completeness. Sometimes it even cannot find the optimal solution, especially when solves the inverse problem, the actual pressure distribution on the airfoil does not necessarily ensure the availability design geometric solution to the inverse problem. B-spline curves are widely used in today's industrial shape design process. Denmark RISΦ National Laboratory adopts B-spline curves for the integrated optimization of wind turbine airfoil and obtains a series of wind turbine special airfoil [18]. B-spline parametric method has good theoretical completeness and well local adjustable feature. However, the application of B-spline curve requires numerous geometry control variables, generally, up to 20. Therefore, the main challenge in optimization is the selection of the mathematical representation of airfoil design variables that provides a wide variety of possible airfoil shapes.

Many different methods have been used for airfoil parameterization in aerodynamic shape design. However, most of them are not suitable for airfoil shape optimization in wind turbine applications. The objective of present work is to develop a new method for the airfoil shape parameterization that overcomes the deficiencies of the four parametric airfoil shape methods discussed before. Firstly, according to computational geometry theory [19,20], the Bezier curve with completeness and endpoint characteristic is extended to the generalized form with a deformable parameter, so that it can maintain constant control polygon to make the airfoil shape adjustable. Then, a new parameterization method is developed, which based on these curves and combines with the characteristics of the wind turbine special airfoil to enhance the controllability, and the effectiveness of this method is validated in geometry shape, aerodynamic performance and airfoil optimization. Finally, the airfoil shape optimization is conducted by Genetic Algorithm based on the new parameterization method.

Airfoil Shape Parameterization Methods

PARSEC Method

As aforementioned, one of the most common methods for airfoil representation is PARSEC method. It selects eleven parameters as the control variables for the airfoil representation which is effective in the optimization design. Fig.1 illustrates the basic parameters of PARSEC method, which are the radius of leading edge (R_{le}), the upper crest point (Y_{up}), the position of upper crest (X_{up}), the upper crest curvature (Y_{XXup}), the lower crest point (Y_{lo}), the position of lower crest (X_{lo}), the lower crest curvature (Y_{XXlo}), the trailing edge direction angle (α_{TE}), the trailing edge wedge angle (β_{TE}), the trailing edge thickness (T_{TE}), the trailing edge offset (T_{off}). A linear combination of shape functions is used to present the airfoil shape in this method [13,21]:

$$y_u = \sum_{n=1}^{6} a_n x_u^{\frac{n-1}{2}},\ y_l = \sum_{n=1}^{6} b_n x_l^{\frac{n-1}{2}} \tag{1}$$

where, y_u stands for the parameter of upper airfoil line, y_l stands for the parameter of lower airfoil line.

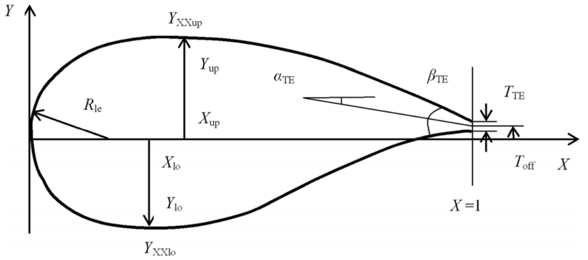


Fig. 1 Control parameters for PARSEC method [13]

For the PARSEC representation method, eleven control parameters are required to define an airfoil shape completely. It can effectively control the maximum curvature of the upper and lower surfaces and their locations. However, at the trailing edge of the airfoil, PARSEC fits a smooth curve between the maximum thickness point and the trailing edge which in turn disables the necessary changes in the curvature close to the trailing edge. Therefore, in spite of its advantages on controlling the important parameters on the upper and lower surfaces, PARSEC does not provide enough control over the trailing edge shape where important flow phenomena occurs.

Hicks-Henne Bump Functions

In Hicks-Henne bump function method, the shape of airfoil curve is assumed to be the sum of basic shape defined by sine function. It is given by [21,22]:

$$y = y_b + \sum_{i=1}^{n} \alpha_i f_i(x) \tag{2}$$

$$f_i(x) = \left(\sin \pi x^{\lambda}\right)^{t},\ 0 \le x \le 1,\ \lambda = \frac{\log 0.5}{\log t_1} \tag{3}$$

where, t_1 locates the maximum point of bump and t_2 controls the width of the bump. The design variables are the weight of α_i multiplying each Hicks-Henne bump function. This flexibility allows one to place the bump at strategic points where a redesign is preferred while leaves other parts of the airfoil intact. The Hicks-Henne bump functions are shown in Fig.2.

B-spline Method

Given n data points (x, y), the piecewise cubic polynomial curve can be used to fit the $n-1$ intervals. For each internal, the assumed form of cubic polynomial [23] is:

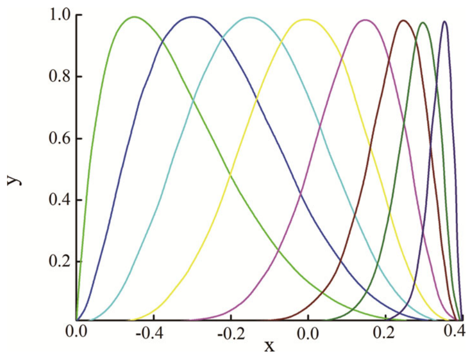


Fig. 2 Hicks-Henne bump functions

$$s_i = a_i\left(x - x_i\right)^3 + b_i\left(x - x_i\right)^2 + c_i\left(x - x_i\right) + d_i \tag{4}$$

where, the spacing for each interval is:

$$h_i = x_{i+1} - x_i \tag{5}$$

To determine the $4(n-1)$ unknown coefficients for $n-1$ segments, three types of conditions are required:

1) interpolating property, $s(x_i) = y_i$, $i = 1, \cdots, n$;

2) continuity property, $s_{i-1}(x_i) = s_i(x_i)$, $i=2, \cdots, n-1$;

3) twice continuous differentiable, $s'_{i-1}(x_i) = s'_i(x_i)$, and $s''_{i-1}(x_i) = s''_i(x_i)$, $i = 2, \cdots, n-1$.

These give $4n-6$ conditions, the remaining two conditions required can be imposed upon at specifying different conditions at two end points. With all the constraints determined, the coefficients in Equation 4 can be solved to give a piecewise cubic interpolation of the data. It can be seen that a tangent of infinity cannot be achieved at the end points.

Bezier Curve Method

As a polynomial parametric curve, Bezier curve is based on Bernstein polynomial. It is defined by a set of control points which has superior geometry completeness [24]. The degree of representation depends on the number of control points. The original Bezier curves with control points P_i are defined by:

$$P(t) = \sum_{i=0}^{n} \hat{B}_{i,n}(t) P_i \tag{6}$$

where,

$$\hat{B}_{i,n}(t) = C_n^i t^i (1-t)^{n-i},\ t \in [0,1],\ i = 0,1,\cdots,n \tag{7}$$

is the ith Bernstein basis function in degree n.

$$C_n^i = \frac{n!}{i!(n-i)!}$$

These curves have been widely applied in Computer Aided Geometric Design (CAGD) with the advantages of its symmetry, convex hull, and geometry invariability. However, the deficiencies of these curves are also obvious. First, the choice of basic functions directly affects the accuracy of curve approximation. Second, the global variables at curve are changed much with a small local adjustment of the Bezier curve, which is so-called ‘one moving, hundreds moving’.

A Generalized Bezier Curve with Shape Parameters

To overcome these deficiencies, a group of base functions are developed by adding the parametric polynomial to Bernstein functions combined with the design demand of wind turbine special airfoil, and the Bezier curves are extended to the generalized form with deformable parameters. This extension based on the condition of the extended basic function is still free curve function, which preserves the completeness and the endpoint characteristic of Bezier curve. The free curve function should satisfy the following two conditions:

1) $\sum_{j=0}^{n} B_{i,j}(t) = 1$;

2) $B_{i,j}(t) \geq 0 \ \left(t \in [0,1],\ j = 0,1,\cdots\right)$.

where, $t \in [0,1], B_{n,j}(j = 0,1,...,n)$ are free curve functions, n is the order of base function.

According to the characteristic of wind turbine airfoil, the generalized Bezier curves in section 1.4 are extended to 8 times polynomial with 8 control points, and the expression is written as follows:

$$\begin{cases} B_{7,0}(t) = b_{7,0} - \mu t(1-t)^7 \\ B_{7,1}(t) = b_{7,1} + \mu t(1-t)^6(1-5t) \\ B_{7,2}(t) = b_{7,2} + \mu(1-t)^5 t^2(4-9t) \\ B_{7,3}(t) = b_{7,3} + 5\mu t^3(1-t)^5 \\ B_{7,4}(t) = b_{7,4} + 5\mu t^4(1-t)^3 \\ B_{7,5}(t) = b_{7,5} - \mu(1-t)^2 t^5(5-9t) \\ B_{7,6}(t) = b_{7,6} - \mu t^6(1-t)(4-5t) \\ B_{7,7}(t) = b_{7,7} - \mu t^7(1-t) \end{cases} \tag{8}$$

where, $t \in [0,1], b_{7,j}\left(j = 0,1,\cdots,7\right)$ are Bernstein functions, $-7 \leq \mu \leq 1$ are variable shape parameters.

As the good completeness of this kind of expression curve, the improvement in this method for wind turbine airfoil mainly focuses on control ability. First, the airfoil lines are divided into two parts, the starting point is at the leading edge point (0, 0), and the abscissa value of the terminal point is 1, while the abscissas in other control points are fixed accordingly. Then, the other parameters will be simplified and improved in the three different regions: the leading edge, the middle and the trailing edge region.

To improve the control ability at the leading edge of airfoil, two structure characteristics should be satisfied. Firstly, the shape line should include all the endpoints of airfoil leading edge. Secondly, the tangent of leading edge is vertical to the chord of the airfoil and transports smoothly along arc-shaped line from the leading edge to middle region of the airfoil, as shown in Fig.3. For the upper airfoil line, the first feature edge is vertical to the chord; the second feature edge is parallel to the chord; both sides are fixed in a proportion and the range is (1.11~1.18). The lower airfoil line is symmetrical to the upper airfoil line, thus ensure the second order continuous at leading edge. By this way, the overall leading edge area can be controlled simply by adjusting the vertical rectangular side. Its length R is slightly larger than the leading edge radius with an approximate expression, so that it is convenient for the optimization control. Meanwhile, by adjusting the deformation parameters, the approximate expression will approach to the precise value, thus inhibits the interference to the deformation of other areas and makes the expression more completeness. By improving the leading edge region in this way, the control variables are reduced, the control ability is increased.

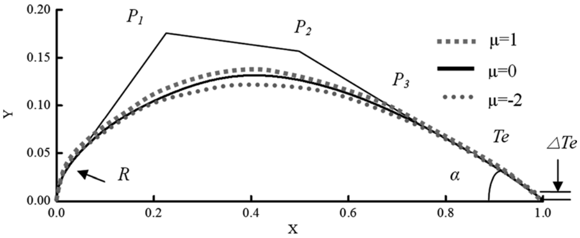


Fig. 3 Sketch of control parameters for improved Bezier method

Due to the endpoint characteristic at the trailing edge, the control variables for the reinforcement of trailing edge mainly focus on the trailing edge angle α, the trailing edge thickness △Te, the trailing edge coordinate Te, refers to Fig.3. In addition, the smooth transition of this curve can satisfy the suitable requirements for the trailing edge of airfoil. The introduction of deformation parameters can also suppress the influence of the trailing edge on related deformation in the other parts of airfoil, and enhance the flexibility airfoil shape optimum.

In airfoil middle region, three control points are introduced after the modification of the leading edge and the trailing edge. Thus it is easy to constraint the variables and inhibit the fluctuation of airfoil line. Combination with the characteristics of characteristic polygon curve, the linear program is given by Equation 9, which is based on the degree of deviation between P_1 and the straight line P_1P_3 according to the discriminant condition of implicit curve.

$$\delta_1 \leq \varphi(x,y)|_{P_2} \leq \delta_2 \tag{9}$$

where, $\varphi(x, y)$ is the expression of the implicit curve, δ_1

and δ_2 are the constraints of upper and lower boundary respectively.

After the above improvements, the parameters for airfoil shape are significantly reduced. Namely, three control points of the upper, three control points of lower airfoil line, one adjustable shape parameter, one control parameter of the leading edge, four characteristic parameters of trailing edge, and the number of total parameters are 12.

Airfoil Aerodynamic Optimization

Genetic Algorithm

Among optimization algorithms, Genetic Algorithms are well-known techniques that seek to find the global optimum and are attractive for aerodynamic optimization design. In this work, a self-program code of the Genetic Algorithm is applied to optimize a special airfoil of wind turbine. Design parameters are set by the variable of the improved Bezier method introduced in Section 1.5. The aerodynamic efficiency factor (Cl/Cd) is set as the objective function. A new wind turbine airfoil is obtained by adjusting the radius of leading edge and the upper and lower surface of airfoil based on the original DU93-W-210 airfoil. A penalty function is used to limit the airfoil thickness in order to avoid impractical shape. The total population of each generation is set to 20 and design parameters are bounded to create reasonable shape.

Flow Solver and Mesh

The flow characteristics of airfoil shapes are evaluated based on the numerical simulation of turbulent viscous flows governed by the RANS equations. The second order upwind scheme is adopted as space discrete, and the S-A turbulence model is used. In the process of optimization, the computational mesh will be constantly adjusted with the change of airfoil geometry. Among the mesh deformation methods, algebraic interpolation (TFI) has been widely used in aeroelastic study [25]. When solving the sensitive derivative, in each iteration step, the large deformation mesh of a two-dimensional airfoil is generated, using a TFI mesh deformation method. Then, the mesh quality is improved by solving the Poisson equation with an initial mesh deformation. Because the mesh deformation is performed gradually by each iteration step, the change of mesh deformation between the initial TFI generation and the results of solving Poisson equation is relatively small, so that every step of the grid generation is faster. In the present work, the primary mesh generated around the initial airfoil is moved to fit the new generated airfoil by using a spring analogy. Since the boundary layer meshes are fine, they may interfere during the movement of the grid. To avoid the interference between boundary layer meshes during movement and to prevent the destruction of the boundary layer mesh, the boundary layer mesh is moved rigidly with the airfoil boundary. The C-type computing mesh, and the distance of the wall adjacent to the first layer mesh is 0.005, the mesh is 20 times the radial side of the blade chord, as shown in Fig. 4.

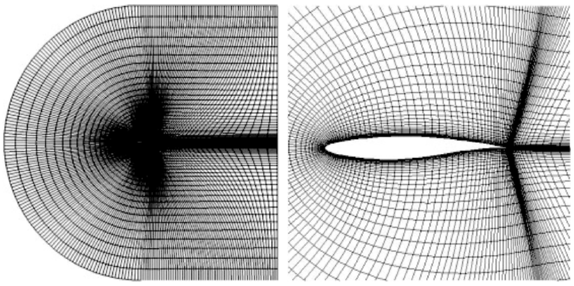


Fig. 4 Computing mesh of airfoil

Results and Discussion

Validation for the Parameterization Method

Fitting Characteristics of Airfoil Shape

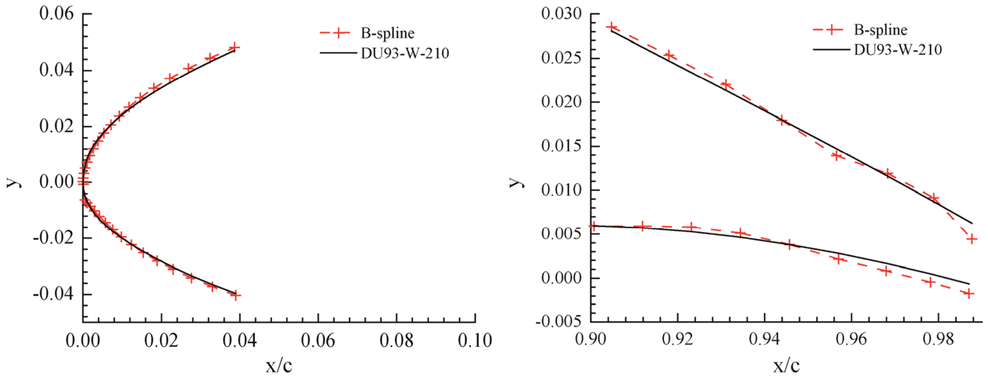
Compared with other parametric methods (PARSEC, Hicks-Henne and B-spline), the advantage of the new Bezier method in airfoil shape fitting performance is verified in least-squares fitting. For the wind turbine airfoil, four typical airfoil series are selected, including S series of NREL airfoil, NACA63, Sweden FFA-W2, and DU airfoil. The fitting precision of the four kinds of typical wind turbine airfoils in various parametric representation methods are listed in Table 1. The precision was defined by the standard deviation of the fitting residual. Considering the comparability of various parametric methods, the same control variable of 12 is chosen.

Table 1 Fitting deviation of different parametric methods

Airfoil	Parametric method $\times 10^{-4}$			
	PARSEC	Hicks-Henne	B-spline	New Bezier
NREL -S809	12.14	13.64	10.26	12.78
NACA63-215	8.40	13.36	4.89	4.26
FFA-W2-301	7.94	24.37	9.41	7.36
DU93-W-210	7.90	8.92	7.79	4.99

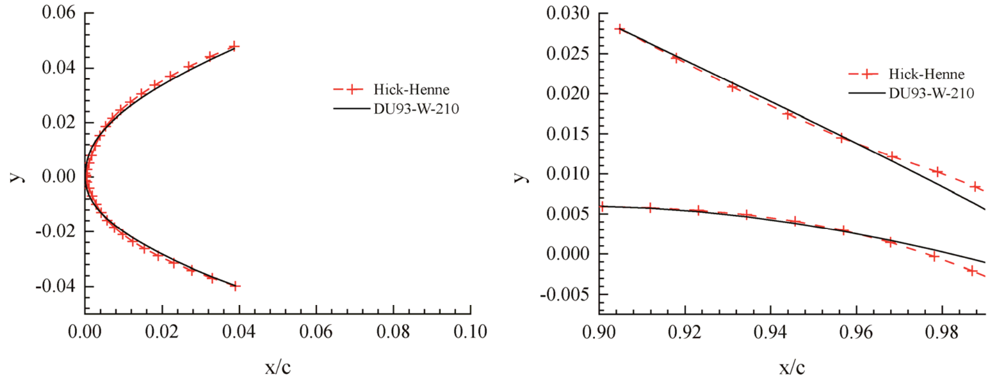
As shown in Tab.1, due to the lack of completeness, the fitting precision of Hicks-Henne method is obvious less than that of other parametric methods. Although PARSEC method has good controllability, the fitting precision for most airfoils in this method is lower than B-spline method and new Bezier method due to the lack of completeness. B-spline method has good completeness but lack of control ability, which causes its fitting precision less than that of the new Bezier method. The new Bezier method has better fitting precision than the other three methods for NACA63-215, FFA-W2-301 and DU93-W-210, but for the S809 airfoil, the fitting precision of new Bezier method is less than PARSEC and B-spline method. It reflects the new Bezier method has relative wide universality in representation of the airfoil shape of wind turbine but still has its disadvantage in some particular airfoils. It also shows the new Bezier method has better expression on the airfoil completeness and better controllability compared to B-spline method.

To further validate the airfoil shape representation capacity of the new Bezier method, especially at the leading edge and trailing edge of the airfoil, the DU93-W-210 is chosen as a standard sample to validate fitting precision in four different parametric representation methods. The leading edge and trailing edge of airfoil area are enlarged partially to clearly present the fitting characteristics, shown in Fig.5~Fig.8. As can be seen from those figures, the new Bezier method is better than the other



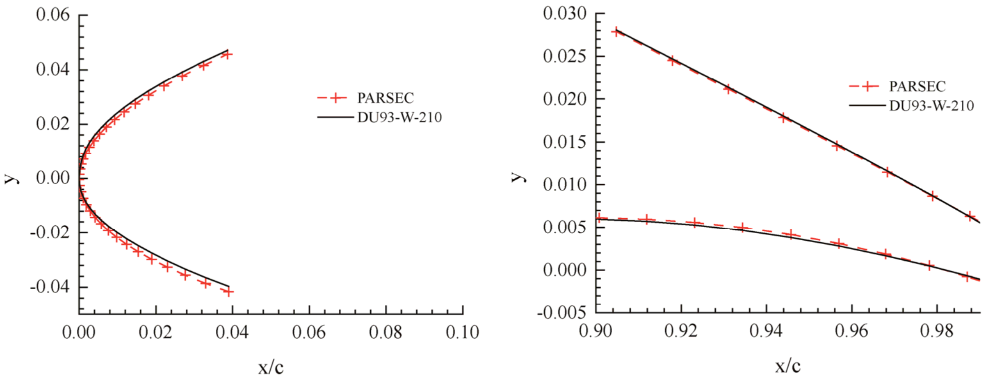
(a) Leading edge (b) Trailing edge

Fig. 5 Fitting geometry in B-spline method



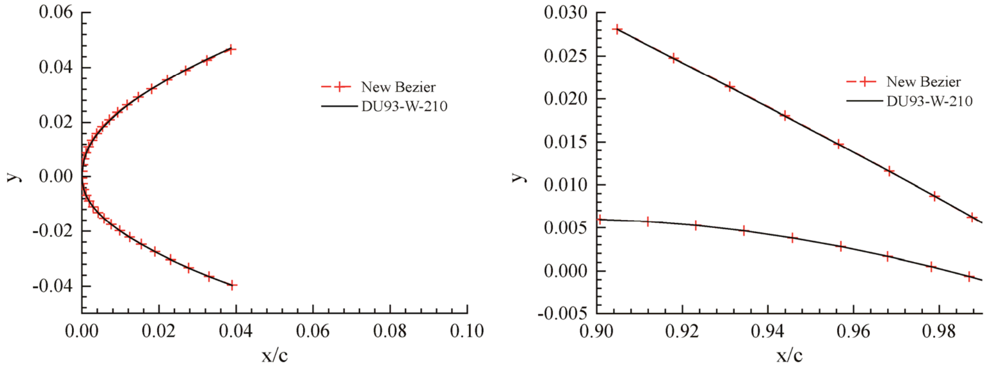
(a) Leading edge (b) Trailing edge

Fig. 6 Fitting geometry in Hick-Henne method



(a) Leading edge (b) Trailing edge

Fig. 7 Fitting geometry in PARSEC method



(a) Leading edge (b) Trailing edge

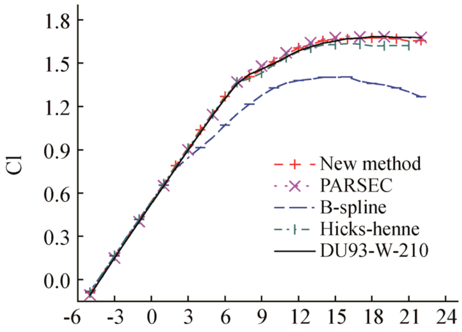
Fig. 8 Fitting geometry in New Bezier method

methods in the approaching degree of the original airfoil shape, especially at the leading edge and the trailing edge. It almost completely coincides with the original airfoil shape, while the other three methods present insufficient approach to original airfoil shape at the leading edge and the trailing edge in some degrees. This mainly because that the new method both has good completeness and favorable controllability. It is more accurate to approximate to the original airfoil.

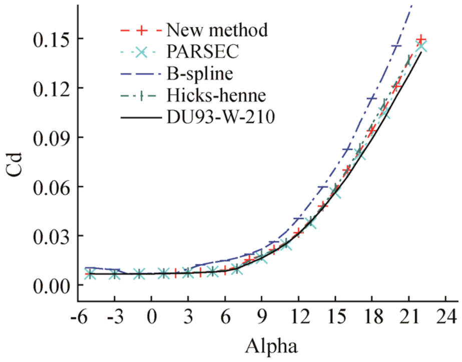
Aerodynamic Performance of Fitting Airfoils

Tiny difference in airfoil shape will lead to significant variation in aerodynamic characteristics. To evaluate the aerodynamic performance of the fitting airfoil, the DU93-W-210 airfoil is selected as the standard numerical example, and the aerodynamic characteristics of the fitting airfoil in the four parametric methods are compared and analyzed, including the lift, drag and lift-drag characteristic, as shown in Fig.9. It can be seen from Fig.9, due to the serious fitting deficiency of the B-spline method and Hicks-Henne method at the leading edge and trailing edge, the aerodynamic performance of the airfoil in those two method deviate from that of the original airfoil obviously, especially for the B-spline method, significant fluctuation appears at the trailing edge region. For the PARSEC method, it shows good aerodynamic performance in lift and draw characteristics, but its lift-drag curve also obviously deviate from original airfoil. Since the new Bezier method has good capability to fit the original airfoil, which avoids the fitting deficiencies at the leading edge and trailing edge of the airfoil, therefore, the aerodynamic performance of the fitting airfoil is coincident with original airfoil well.

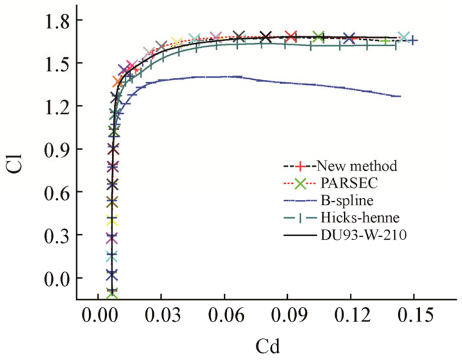
Compared with the fitting insufficiencies at the leading and the trailing edge of airfoil in general parametric methods, the new Bezier curve method has good completeness. Meanwhile, the new Bezier method directly chooses the feature geometry at the leading edge and the trailing edge of the airfoil as the control parameter, adopts the target constraint at the middle section of the



(a) Cl



(b) Cd



(c) Cl-Cd

Fig. 9 Airfoil aerodynamic performance comparisons in different methods airfoil, and introduces a flexible shape parameter, which enhances the control ability of the geometry shape of the airfoil. Therefore, the new Bezier method presents a comprehensive and detailed representation for the airfoil shape. Especially, at the leading edge and trailing edge of the airfoil, the expression of airfoil representation is very accurate and the aerodynamic characteristics are consistent with the original airfoil well, which proves the effectiveness of the new method in airfoil parametric representation.

Airfoil optimization in New Bezier Method

Geometry Shape

A new wind turbine airfoil is obtained by adjusting the radius of the leading edge and the upper and lower surface of airfoil based on the original DU93-W-210 airfoil. For the DU airfoil family, its upper surface has the aerodynamic performance including high lift-drag ratio, high maximum lift, stable stall characteristics, roughness insensitivity and low noise [26]. The lower surface is appropriate to meet the airfoil surface pressure of the above requirements, and the focus is on geometric and structural compatibility. Compared with the conventional airfoil, the DU airfoil has a limitation on the upper surface of the airfoil thickness (particular for the thick airfoil), and a low sensitivity to roughness and the characteristics of aft-loading. Therefore, to overcome the deficiency of this airfoil, the optimized design of new airfoil is focused on maximum lift-drag ratio, maximum lift coefficient, and the optimization design goal is the maximum lift-drag ratio. The design constraints are the maximum thickness and its location, and the radius of leading edge. The optimized airfoil is shown in Fig.10.

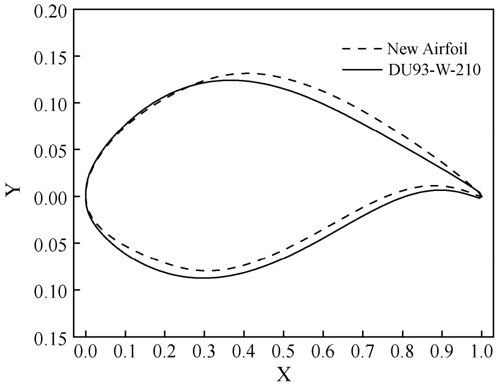
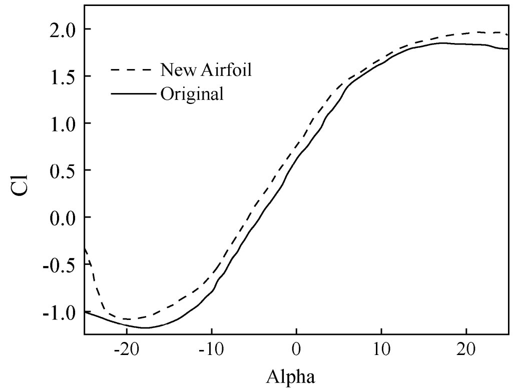


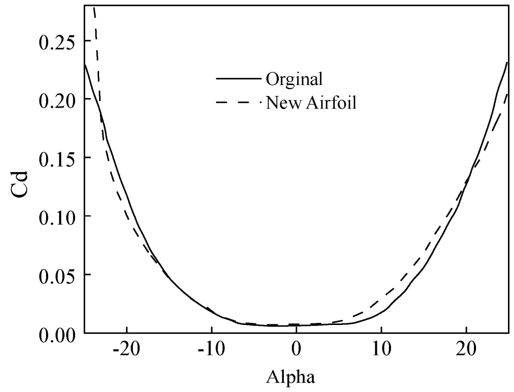
Fig. 10 The optimized airfoil

Aerodynamic Performance

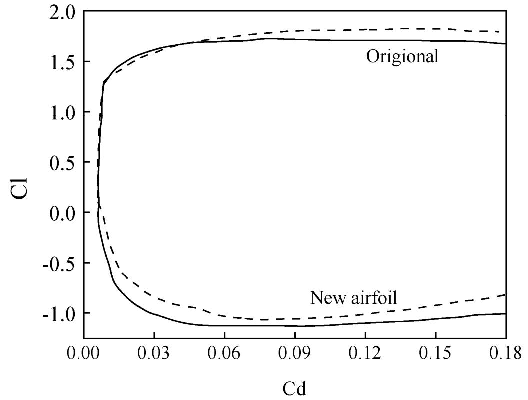
To estimate the aerodynamic performance of optimum airfoil, the original airfoil (DU93-W-210) is chosen for the comparison analysis. In numerical simulation, the same conditions (including computing grid, turbulence model and the boundary condition) are set. The aerodynamic performance of the original airfoil and optimum airfoil are computed by solving the RANS equations. The objective function of lift(Cl) curve, drag(Cd) curve, and the Cl- Cd curve are plotted, as shown in Fig.11. It can be seen that the Cl and Cd of optimum airfoil is obvious favorable than the original airfoil. For the optimum airfoil, the maximum of the lift-drag ratio (Cl/Cd) is 170; the maximum of the lift coefficient (Cl) is 1.82; the stall characteristics degradation is relatively flat.



(a) Cl



(b) Cd

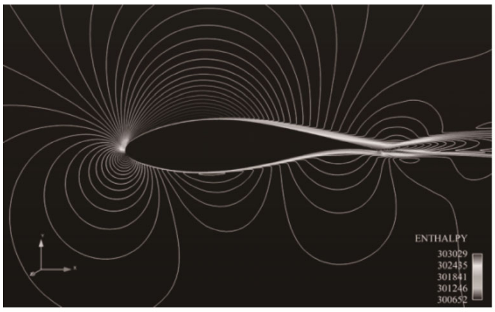


(c) Cl-Cd

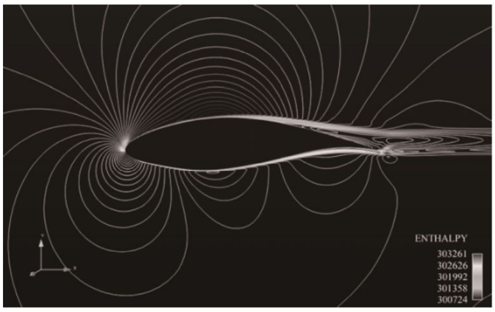
Fig. 11 Cl, Cd and Cl-Cd curves of optimum/original airfoil

For the further analysis of the aerodynamic performance of optimum airfoil, the entropy distributions of optimum/original airfoil are plotted, as shown in Fig.12.

It shows that the aerodynamic performance of optimum airfoil is superior than that of original airfoil in small attack.



(a) optimized airfoil



(b) original airfoil

Fig. 12 Entropy distribution in +5° attack

Conclusions

A new parametric representation method for wind turbine airfoil was presented by extending the Bezier curve to the generalized form with adjustable shape parameters. To verify the availability of the new parameterization method, the fitting characteristics in geometry shape and aerodynamic performance of initial airfoil were compared with other three common parameterization methods. The result shows that the new method is capable of representing the wind turbine airfoil, especially at the leading and trailing edge.

The completeness and controllability as the main parameters should be both satisfied for a superior parameterization method. The lack of completeness easily leads to the solution of the airfoil is insufficiency, even has no solution; while the lack of controllability will cause the divergence of the solution. In the premise of airfoil completeness, a flexible expression of important geometry features will enhance the airfoil controllability effectively. The representation of parameterization method will be improved by selecting appropriate control parameters at the leading and trailing edge.

The new Bezier method was induced to the airfoil shape optimum of wind turbine based on DU93-W-210. A Genetic Algorithm was used as the optimization method to achieve the optimum Cl, Cd and Cl-Cd. The aerodynamic characteristics of the optimum airfoil were obtained by solving the RANS equations in CFD method. This study demonstrates that the application of new method provides enough completeness and controllability in flexible defining the airfoil geometry, thereby resulting in a better shape with favorable aerodynamic performance.

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