Aerodynamic performance prediction of SG6043 airfoil for a horizontal-axis small wind turbine

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Abstract. In order to design a small wind turbine, the performance of SG604x airfoil and previously existing 15 airfoils was reviewed at a Reynolds number of 300,000, which suggests the maximum lift-to-drag ratio of the airfoils, corresponding lift coefficient, and the maximum lift coefficient for both free and fixed transition. The SG6043 airfoil provides enhanced lift-to-drag ratio performance as compared with previously existing airfoils at a Reynolds number of 300,000. Only a SG6043 airfoil for small wind turbine performance prediction is applied along the length of the blades. This is why a blade constructed using airfoils of different performance may not exhibit the expected performance. A code based on BEMT(Blade Element/Momentum Theory) was used for performance predictions of small horizontal axis wind turbine. As important input parameter of BEMT, distributions of chord and twist was derived by the optimization method using genetic algorithm. The power performance prediction of airfoil data of SG6043 using BEMT is presented over a wide range of wind speeds. The results of BEMT using SG6043 show that the rated wind speed can be reduced to 10 m/s for a rotor radius of 7.25m and a rating of 32kW. The reduced rated wind speed would increases the annual capacity factor as compared the existing airfoils.

1. Introduction
The entire length along the blades of small HAWT(Horizontal Axis Wind Turbine)s typically operate at low Reynolds numbers where laminar separation effects can degrade the performance of airfoils [1]. Besides, the fast rotational speeds of small HAWTs provide centrifugal stiffening that reduces the blade bending loads and allows for the use of thinner airfoils in comparing with those designed for larger wind turbines. Reduction in laminar separation effects and in airfoil thickness provide an increase in aerodynamic performance, which produces better energy capture. Therefore, due to low Reynolds number aerodynamics and centrifugal stiffening effects, wind turbine airfoils designed for medium and large blades are not especially suitable for smaller blades.

The low Reynolds number can be defined as that for which laminar separation dominates the drag. Low Reynolds numbers mean low lift to drag ratios and hence lower blade efficiencies. Even though there is no fixed Reynolds number range that bounds the low Reynolds number, the low Reynolds number has also come to mean the flow regime where the Reynolds number is below about 500,000. This is why small HAWTs are said to usually operate at low Reynolds. Accordingly, low Reynolds number airfoils are good candidates for small HAWTs to enhance aerodynamic blade performance.
A conventional airfoils such as the NACA airfoils, were designed to operate at high Reynolds numbers since they were mainly intended for full-scale aircraft. At high Reynolds numbers, boundary layers takes place before laminar separation with avoiding the peculiarities of low Reynolds number aerodynamics. In contrast, the behavior of the boundary layer is much different at low Reynolds where laminar separation is predominant. The airfoils generally result in poor performance at low Reynolds because of laminar separation effects. Therefore, optimum aerodynamic performance of small HAWTs can be found by the use of airfoils designed for low Reynolds number airfoils.

In existing studies [1, 2], a few low Reynolds number airfoils had been designed for small HAWTs. In order to the blade design process of small wind turbines, The studies provided the database of low Reynolds number airfoil data under clean and rough conditions on the basis of the wind tunnel facility.

2. The airfoils for small wind turbine

From a large variety of airfoils, 15 airfoils were considered as candidates for the design of small wind turbines in present study. These airfoils were based on the wind-tunnel test data, which was facilitated by the Low-Speed Airfoil Test program at the University of Illinois at Urbana-Champaign[3,4]. These airfoils are described in Figure 1 with their respective relative thickness. With the exception of the Clark-Y and NACA 2414 and the Go417a, all other airfoils were specifically designed for low Reynolds number applications. Furthermore, the BW-3 airfoil and the NREL S822/S823 thick airfoils were developed specifically for small blades while the others have been mainly used for unmanned aerial vehicle applications. For the NREL S822 and S823 airfoils, the S822 is for the tip and the S823 is for the root of the blade. The S822 and S823, which at 16% and 21% thick are the two thickest airfoils. The important structural advantages provided by a high relative airfoil thickness come with poor aerodynamic performance at low Reynolds. BW-3 airfoil were developed by Bergey Wind Power and are used in 7m rotor diameter Excel wind turbine systems with a maximum output of 10kW.

![Figure 1. Airfoils considered[2].](image)

The performances of the 15 airfoils considered at a Reynolds number of 300,000 are summarized in Table 1, which suggests the maximum lift-to-drag ratio($C_l/C_d$)$_{\text{max}}$ of the airfoils and corresponding lift coefficient($C_l$), and the maximum lift coefficient($C_{l,max}$) for both free and fixed transition. A free transition is for clean-blade conditions. A fixed transition is to simulate leading-edge roughness caused by blade erosion, accumulation of insect. As an indication of the sensitivity of each airfoil to leading-edge roughness on the maximum lift-to-drag ratio and maximum lift coefficient, the percentage difference between the results for free and fixed transition is also indicated.
The airfoil requirements for small stall-regulated HAWTs are the same as those for variable-speed HAWTs. However, there is one additional requirement for wind turbines that have their blades stall to regulate power. The airfoils used on stall-regulated wind turbines should be $C_{l,\text{max}}$ insensitive to roughness in order to minimize the loss in peak power due to roughness effects. In Table 1, the percentage difference of $C_{l,\text{max}}$ of A18, BW-3, S822, S823 and S7037 airfoils are below $\pm 3.8$. Thus, $C_{l,\text{max}}$ of these airfoils are not particularly sensitive to roughness. Therefore, the A18, BW-3, S822, S823 and S7037 are applicable to stall regulated HAWTs. The largest percentage difference is SD 7062. The fixed transition cases used to simulate dirty-blade conditions decreased $C_{l,\text{max}}$ from 1.66 to 0.96. The ability of a wind turbine using the SD7062 to capture wind energy may be significantly degraded under dirty-blade conditions. Thus, it seems that SD7062 is not suitable for stall regulated wind turbines.

### Table 1. Performance parameters for the airfoils considered for free and fixed transition at $Re=300,000$.  

| Airfoil  | Free transition | Fixed transition | Percentage Difference |
|----------|-----------------|------------------|-----------------------|
|          | $(C_l/C_d)_{\text{max}}$ | $C_l$ | $C_{l,\text{max}}$ | $(C_l/C_d)_{\text{max}}$ | $C_l$ | $C_{l,\text{max}}$ | $(C_l/C_d)_{\text{max}}$ | $C_l$ | $C_{l,\text{max}}$ |
| A18      | 79.6            | 0.8            | 1.23             | 41.2            | 1.03            | 1.22            | 48.2            | 0.7            |
| BW-3     | 69.6            | 1.05           | 1.44             | 39.6            | 0.89            | 1.41            | 43.1            | 1.9            |
| Clark-Y  | 77.2            | 0.85           | 1.35             | 39.1            | 0.83            | 1.13            | 49.4            | 16.5           |
| E387     | 81.7            | 0.93           | 1.29             | -               | -               | -               | -               | -              |
| Go471a   | 82.3            | 1.08           | 1.40             | -               | -               | -               | -               | -              |
| NACA2414 | 66.6            | 0.90           | 1.23             | -               | -               | -               | -               | -              |
| RG15     | 69.0            | 0.66           | 1.14             | -               | -               | -               | -               | -              |
| S822     | 69.4            | 0.88           | 1.22             | 32.9            | 0.68            | 1.18            | 52.6            | 3.8            |
| S823     | 62.7            | 1.05           | 1.18             | 30.2            | 0.78            | 1.14            | 51.8            | 3.0            |
| S6062    | 73.1            | 0.65           | 1.11             | -               | -               | -               | -               | -              |
| S7012    | 72.1            | 0.71           | 1.14             | 40.4            | 0.94            | 1.15            | 44.0            | -0.7           |
| SD6060   | 73.5            | 0.72           | 1.11             | -               | -               | -               | -               | -              |
| SD7032   | 83.4            | 1.00           | 1.39             | -               | -               | -               | -               | -              |
| SD7037   | 76.3            | 0.84           | 1.28             | 44.1            | 0.99            | 1.32            | 42.2            | -3.1           |
| SD7062   | 77.5            | 1.23           | 1.66             | 45.1            | 0.96            | 1.23            | 41.8            | 25.8           |

3. The SG604x airfoils

![Figure 2. SG604x profile](image)
### Table 2. Performance summary for the SG6040 airfoil

|       |       | Free transition |       | Fixed transition |       |
|-------|-------|-----------------|-------|------------------|-------|
|       |       | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ |
| Re    |       |                 |       |                   |       |       |                   |
| 100,000 | 1.29 | 1.16            | 460   | 1.08              | -     | -     |                  |
| 150,000 | 1.33 | 1.21            | 570   | 1.09              | 0.7   | 33.1  |                  |
| 200,000 | 1.35 | 1.17            | 663   | 1.09              | -     | -     |                  |
| 300,000 | 1.39 | 1.11            | 765   | 1.11              | 0.64  | 34.7  |                  |
| 400,000 | 1.42 | 1.13            | 83.5  | 1.13              | -     | -     |                  |
| 500,000 | 1.42 | 1.13            | 86.6  | 1.14              | 0.76  | 36.7  |                  |

### Table 3. Performance summary for the SG6041 airfoil.

|       |       | Free transition |       | Fixed transition |       |
|-------|-------|-----------------|-------|------------------|-------|
|       |       | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ |
| Re    |       |                 |       |                   |       |       |                   |
| 100,000 | 1.15 | 0.86            | 51.5  | 1.06              | -     | -     |                  |
| 150,000 | 1.58 | 0.67            | 57.5  | 1.09              | 0.8   | 33.3  |                  |
| 200,000 | 1.59 | 0.70            | 64.1  | 1.14              | -     | -     |                  |
| 300,000 | 1.65 | 0.85            | 72.2  | 1.16              | 0.87  | 36.7  |                  |
| 400,000 | 1.68 | 0.60            | 80.0  | 1.19              | -     | -     |                  |
| 500,000 | 1.70 | 0.61            | 84.4  | 1.20              | 0.77  | 39.4  |                  |

### Table 4. Performance summary for the SG6042 airfoil.

|       |       | Free transition |       | Fixed transition |       |
|-------|-------|-----------------|-------|------------------|-------|
|       |       | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ |
| Re    |       |                 |       |                   |       |       |                   |
| 100,000 | 1.35 | 1.10            | 55.6  | 1.26              | -     | -     |                  |
| 150,000 | 1.29 | 0.89            | 59.7  | 1.27              | 0.83  | 38.7  |                  |
| 200,000 | 1.41 | 1.01            | 77.8  | 1.28              | -     | -     |                  |
| 300,000 | 1.47 | 0.92            | 90.3  | 1.32              | 0.86  | 41.5  |                  |
| 400,000 | 1.50 | 0.93            | 101.0 | 1.33              | -     | -     |                  |
| 500,000 | 1.52 | 0.84            | 105.9 | 1.34              | 0.90  | 45.7  |                  |

### Table 5. Performance summary for the SG6043 airfoil.

|       |       | Free transition |       | Fixed transition |       |
|-------|-------|-----------------|-------|------------------|-------|
|       |       | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ | $C_{\text{max}}$ | $C_l$ | $(C_l/C_d)_{\text{max}}$ |
| Re    |       |                 |       |                   |       |       |                   |
| 100,000 | 1.52 | 1.37            | 59.4  | 1.36              | -     | -     |                  |
| 150,000 | 1.58 | 1.31            | 74.2  | 1.38              | 1.10  | 42.0  |                  |
| 200,000 | 1.59 | 1.33            | 88.3  | 1.40              | -     | -     |                  |
| 300,000 | 1.65 | 1.16            | 105.3 | 1.42              | 0.93  | 45.2  |                  |
| 400,000 | 1.68 | 1.17            | 118.0 | 1.44              | -     | -     |                  |
| 500,000 | 1.627 | 1.10-1.20 | 125.1 | 1.43              | 0.98  | 48.4  |                  |
The SG6043 and SG6041, SG6042, SG6043 are described in figure 2. SG6040 is suitable for root airfoil and SG6041, SG6042 and SG6043 are suitable for primary airfoil[5]. With the root airfoil over the inboard 30 percent of the blade, the primary airfoils are recommended for use over the last 25 percent of the blade (from the 75 percent station to the tip), with blending between 30 percent and 75 percent of the blade span. Three airfoils as the primary airfoils were designed to provide optimum performance over a broad range of operating conditions. In consideration of the low operating Reynolds numbers and beneficial centrifugal stiffening effects of small HAWTs, the airfoil thickness for the primary airfoils was fixed at 10%. A 16% root airfoil was also designed to withstand possible large root bending moment and to accommodate large blade-stiffness requirements.

Table 2-5 show the maximum lift coefficient, maximum lift-to-drag ratio and the corresponding lift coefficient for both the free and fixed transition cases of the SG604x airfoil family. In range of Reynolds number 100,000-500,000, the maximum lift-drag ratios with fixed transition of the airfoil having the highest design lift coefficient (SG6043) remain the largest of all the airfoils. In addition, the lift-to-drag ratio characteristics of the airfoils with fixed transition are for the most part independent of the Reynolds number. Consequently, blades using the SG6043 airfoil are likely to yield the best energy capture in the presence of leading-edge roughness elements. In present study, a SG6043 airfoil to maximize power of small wind turbine is applied along the length of the blades.

The value of $C_{l,\text{max}}$ in the free transition in Table 2-5 have quite a few loss in the fixed transition as compared to the values in A18, BW-3, S822, S823 and S7037, which are less sensitive to the roughness. In case of SG6040, the $C_{l,\text{max}}$ was reduced from 1.39 to 1.11, and for SG6043, the $C_{l,\text{max}}$ was reduced from 1.65 to 1.42 at Reynolds number 300,000. Based on this loss of $C_{l,\text{max}}$, the use of SG604x family should not be extended to small stall-regulated.

Figure 3 indicates the maximum lift-to-drag ratio and corresponding lift coefficient under clean conditions of the SG604x airfoil family and other low Reynolds number airfoils applicable to small HA WTs. The results are shown for a Reynolds number of 300,000, which is representative of the data for other Reynolds numbers. Note that all the data shown in Fig. 3 is based on wind tunnel experiments. As indicated in Fig. 3, the SG604x airfoils provide better lift-to-drag ratios than those of previously existing low Reynolds airfoils over a wide range of design lift coefficients. Therefore, small variable-speed HAWTs are likely to benefit from enhanced energy capture from the use of the SG604x airfoils. The data shown in Fig. 3 are indicative of the potential of the SG604x airfoils for small variable-speed wind turbines.
Figure 3. Maximum lift-to-drag ratio versus the corresponding lift coefficient of various airfoils for small HAWTs (Re = 300,000)

Figure 4. Lift coefficient for the SG6043

Figure 5. Drag coefficient for the SG6043
Figure 6. Lift: Drag ratio for the SG6043

Figure 7. Drag polars and corresponding lift curves for the SG6043

Figure 4-7 shows the performance of SG6043 in case of free transition. Graphs of Cl, Cd, Cl/Cd and drag polar according to angles of attack -5° to 13° were presented. In Figure 5, what is noteworthy about the results of Cd of the SG6043 airfoil is the local maximum value shown in cd at Re 10^5 curve. Similarly, in Figure 7, the curve of Re 10^5 completely loses its basket shape as the cd value increases. The increase in Cd values in Figure 5 and Figure 7 is generally the result of the laminar separation bubble[7]. Figure 3 indicates that the lift coefficient for maximum lift-to-drag ratio of the SG6043 airfoil at Re 3.0 × 10^5 is 1.16. The lift curves for the SG6043 airfoil presented in figure 4 indicates that these lift coefficient correspond to an angle of attack of 4°.

4. Airfoil selection

From the airfoil data presented in the previous section, it is possible to establish specific guidelines for the selection of appropriate airfoils for the design of small HAWTs[2]. The first step in the airfoil selection process is the purpose of estimating the Reynolds number range which the blades will operate. This step can be applied to small or medium size of HAWT, but is particularly important for small wind turbines owing to the wide variation in drag according to lift and angle of attack at low Reynolds numbers. The expression for the Reynolds number on a wind turbine blade is given by equation (1).

\[ \text{Re} = \frac{c \sqrt{V_\infty [1 - a]^2 + [\Omega r]^2}}{\nu} \]  

(1)

For the case of a variable-speed wind turbine, the rotational component \( \Omega r \) is more greater than the freestream velocity(\( V_\infty \)), thus the Reynolds number can be approximated by equation (2).

\[ \text{Re} = \frac{V_\infty \text{TSR}(r / R)c}{\nu} \]  

(2)

Where TSR is the tip-speed ratio(\( \lambda \)). Regarding stall-regulated (constant speed) wind turbines, the general expression (1) can’t be simplified to (2). Once the operational Reynolds number range is known for a particular rotor, the basket shape of the drag polars at the Reynolds numbers is a key element in the classification of airfoils for the different types of wind turbines. Drag polar characteristics, such as the maximum lift-to-drag ratio and corresponding lift coefficient, and the size of drag bucket are important features in evaluating the potential of an airfoil for wind turbine applications. For wind
turbines that operate up to and beyond stall, the maximum lift coefficient is another important parameter to consider. Roughness effects increase the drag and can give negative affection of the lift characteristics. Therefore, aerodynamic performance with simulated leading-edge roughness is likely to be useful in the airfoil selecting process.

5. Airfoils of variable-speed HAWTs
Under normal conditions, variable-speed HAWTs ideally operate at constant TSR, and each segment of blade operates at a constant angle of attack. The lift coefficient at each segment of blade is then constant and accordingly, the blade can be set to operate at the angle of attack or lift coefficient that maximizes the lift-to-drag ratio at that segment. Consequently, the airfoil selection process for variable-speed HAWTs can be almost based on maximum lift-to-drag ratio characteristics.

There is usually a trade-off between the size of the drag bucket and the maximum lift-to-drag ratio of an airfoil. Higher lift-to-drag ratios can be achieved at the cost of a narrower drag bucket. For variable-speed operations, that is acceptable since the operating lift coefficient is ideally constant, practically, however, one must also account for off-design conditions caused by fluctuations in the TSR owing to atmospheric turbulence. Off-design conditions can also be caused by roughness effects from erosion and accumulation of airborne contaminates such as insects, but for variable-speed HAWTs these effects are not as significant as for particularly stall regulated HAWTs [2]. Airfoils with a narrow drag bucket will generally maximize performance under the design conditions while those with a wider drag bucket will be less affected by off-design conditions. Besides, the selection of the airfoils should consider the ability of the power electronics to keep the TSR constant.

6. Input parameter
Angle of attack Cl, and Cd such as airfoil table using Airfoilprep program [8] were extended from the usual limited angle of attack to the entire ±180° range required by BEMT. The equations and algorithms on BEMT were referenced to Hansen's literature [6]. The algorithm uses Glauert correction for the trust coefficient(Cr) versus the high axial structure factor(a). The SG6043 Airfoil developed for small wind turbine was applied along the blade to predict the performance, and the performance of the blade by a code based on BEMT was predicted. It is assumed that it is variable speed wind turbine and maximum rotational speed is 6.49 rad/s. Other given parameters which are used in the BEM code are that rotor radius is 7.25 m, density of air is 1.24 kg/m³, number of blades are 3. Reynolds number of blade root and tip is $1.78 \times 10^6$, $4.59 \times 10^5$ respectively. The small wind turbine covered in this study has the following blade-characteristics in table 6.

| Element number | r   | c(chord) | β(twist) | Airfoil data |
|----------------|-----|----------|----------|--------------|
| 1              | 1.25| 0.675    | 12.97    | SG6043       |
| 2              | 3.16| 0.481    | 8.60     | SG6043       |
| 3              | 5.13| 0.315    | 4.16     | SG6043       |
| 4              | 6.69| 0.201    | 1.21     | SG6043       |
| 5              | 7.25| 0.174    | 0.02     | SG6043       |

In the present study, optimisation methods using a genetic algorithm was used to generate the optimum chord and twist distribution for maximum annual energy production at specified average speed of 7.5 m/s. As two objective function, the power coefficient and staring was calculated to be optimized. The maximum $C_p$ and minimum $T_s$ are determined from the current population [5, 8]. These optimization methods search to mimic the process of natural selection to arrive at an “optimum” solution by “evolving” a population over a sufficient number of generations. They start with a randomly-generated initial population, breed new members, determine the fitness of existing and new members, and then
decide which members live and which ones die. The genes are the twist and chord of each segment of blade. In table 6, values of chord and twist was produced by optimisation methods of the genetic algorithm.

7. Blade element/Momentum theory

In figure 8, the relative velocity $V_{rel}$ seen by a section of the blade is a combination of the axial velocity $(1 - a)V_{\infty}$ and the tangential velocity $(1 + a')\omega r$ at the rotor plane. $\theta$ is the local pitch of the blade, in other words, the local angle between the chord and the plane of rotation. The local pitch is a combination of the pitch angle, $\theta_p$, and the twist of the blade, $\beta$, as $\theta = \theta_p + \beta$, where the pitch angle is the angle between the tip chord and the rotor plane and the twist is measured relative to the tip chord. $\phi$ is the angle between the plane of rotation and the relative velocity($V_{rel}$)[6].

The algorithm of BEMT can be summarized as the 8 steps below.

Step (1) Initialize the axial (a) and the tangential (a') induction factors, typically $a=a'=0$

Step (2) Compute the flow angle of $\phi$ in figure 8, as

$$\tan \phi = \frac{(1-a)V_{\infty}}{(1+a')\omega r} \quad (3)$$

Step (3) compute the local angle of attack using equation (4)

$$\alpha = \phi - \theta \quad (4)$$

Step (4) read off $C_l (\alpha)$ and $C_d (\alpha)$ from coefficient of lift and drag force of airfoil of SG6043

Step (5) compute $C_n$ and $C_t$ from equations (5) and (6). Here, $C_n, C_d$ are coefficient of Lift and Drag force.

$$C_n = C_l \cos \phi + C_d \sin \phi \quad (5)$$

$$C_t = C_l \cos \phi - C_d \cos \phi \quad (6)$$

Step (6) Calculate values of a, a' from equations (7) and (8).

$$a = \frac{1}{\frac{4 \sin^2 \phi}{\sigma C_n} + 1} \quad (7)$$

And,

$$a' = \frac{1}{\frac{4 \sin \phi \cos \phi}{\sigma C_t} - 1} \quad (8)$$
Step (7) If the difference between the new values of \([a, a']\) and \([a_{\text{new}}, a'_{\text{new}}]\) has changed more than a certain tolerance, go back to step (2). Else, go to step (8).

Step (8) Compute the local loads on the segment of the blades.

![Figure 9. Velocities at the rotor plane](image)

By applying the BEM algorithm to the segment along length of the blade, the tangential and normal load distribution is known. And then, the mechanical power, thrust, torque and root bending moments can be computed. Newton Rapson method is applied together with a relaxation factor of 10% to find the roots of \(a, a'\) employing an initial guess of \(a, a' = 0\). Newton Rapson method plods along for over several iterations until converging on the roots \(a, a'\) with adequate accuracy.

8. Results

The value of power coefficient \((C_p)\) was calculated by BEMT method. \(C_p\) is dimensionless and the ratio of the actual power produced to the power in the wind that would otherwise pass the blade disk. A graph of \(C_p\) is presented in the figure 10, 11. The value of \(C_p\) is a function of the lambda \((\lambda)\) and blade pitch angle \((\theta)\) as input parameter. When the lambda is 7.53 and the blade pitch angle is -0.5°, the peak of \(C_p\) is 0.4665. The value of \(C_p\) exceeds 0.4 in the range with a tip speed ratio of 5 ~10 and the blade fixed pitch angle of -2.5° ~ 2°. The maximum rotational speed of the blade reaches 6.45 rad/s at wind speeds of 6.12 m/s. When the wind speed is 3.6 m/s, the blade begin to rotate, and the initial rotation speed of the blade has a value of 3.63 rad/s. The power varies from 33-41 kW in the range of -2.5° ~ 0° of the blade fixed pitch angle. The value of power remains relatively constant in the range of 11 ~ 16 m/s of wind speed.

![Figure 10. Optimum \(C_p(\lambda)\)](image)

![Figure 11. Optimum \(C_p(\theta)\)](image)
9. Conclusion
Performance database of 15 airfoils can be used in wind turbine performance and design of small HAWTs. SG604x airfoil family on the basis of wind tunnel test provides data sets that can be used in the design of variable speed HAWTs. Blade using the SG6043 airfoil are likely to yield the best energy capture in presence of free and fixed condition. The calculation of BEMT using SG6043 airfoil reduces the rated wind speed to 10 m/s for a rotor radius of 7.25 m and a rating of 32kW. The reduced rated wind speed would increases the annual capacity factor.

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