Power optimization of wind mill turbine blade for different cross section

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Abstract

The aim of this paper was to attain best optimization for twist angle and the chord of wind mill blade by using CFD code with Schmitz, Betz and .Lift to drag twist optimization along with Genetic Algorithm method. The technical point of view to change the cross section of the blade by using symmetry airfoil (NACA-0012), unsymmetrical airfoil (NACA-4412) and supercritical airfoil (Eppler-417). The best optimization Method was Schmitz chord optimization and lift to drag for twist optimization which increase the Cp 10.3% for Eppler 417 , 9.5% for NACA 4412 and 16% for NACA 0012. All results were plotted and tabulated for all optimization results.

Keywords: Optimal Design, Algorithms, Betz Schmitz Lift/Drag optimization, Wind Power, Computational Fluid Dynamics, Aerodynamic.

الخلاصة

الهدف من هذا البحث هو الحصول على زاويه التواء والوتر الامثل لريشه التوربين الهوائي باستخدام برنامج السوائل الحسابيه الديناميكيه (CFG) والمتضمن نظريه (Schmitz) ونظريه (Betz) وطريقه الرفع الى الكبح (Lift To Drag) باستخدام طريقه (Genetic Algorithm) .

من وجه النظر الفنيه هو هو تغير المقطع العرضي للريشه باستخدام المطيار المتناظر (Symmetrical) والغير متناظر (Unsymmetrical) ومطيار ابلر(Eppler-417) في الطرق اعلاه حيث تبين ان نظريه (Schmitz) للوتر الامثل وطريقه الرفع الى الكبح (Lift To Drag) لزاويه الالتواء المثلي هي احسن الطرق لرفع معامل القدره الكهربائيه 10.3% لمطيار ابلر (Eppler-417) و9.5% للمطيار الغير متناظر(Unsymmetrical) و16% للمطيار الغير متناظر(Symmetrical) . جميع النتائج مثبته بالاشكال والجداول المرفقه .

الكلمات المفتاحية :- التصميم الامثل ، اللوغارتمية ، طاقة الرياح ، ديناميك الهواء , Betz Schmitz Lift /Drage optimization، حساب الديناميك المانع

List of Symbols

Symbol	Definition	Units
ω	angular speed	Rad/sec
n	rotational speed	1/sec
X	tip speed ration	---------
α_D	Angle of Attack	deg
r	Rotor Local radius	m
C_L	coefficient of lift	
C(r)	*Chord length*	m
B(r)	Pitch Angle	deg
W	wind Speed	m/sec
Cx	Coefficient of Axial Force	-----
Cy	Coefficient of Normal Force	---------
P	Power	watts
M	Torque	N/m
v	Axial Speed	m/sec
u	Normal Speed	m/sec
a'	Tangential Interference	--------------
CL	Coefficient of Drag	--------
T	Thrust	N

Φ(r)	Setting Angle	deg
γ(r)	Wind Angle	deg
R	Blade Length	m
B	No of blade	------
F_L	Lift Force	N
F_D	Drag Force	N
V_{tip}	Velocity at tip of Blade	m/sec
V_1	Stream Velocity	m/sec

Introduction

1. Betz optimization

Figure (1) shows the velocities and the angles in a given distance, r, from the rotor axis. The rotor shown on the figure is with two blades, i.e. B = 2. To design the rotor we have to define the pitch angle β and the chord length c. Both of them depend on the given radius, that we are looking at therefore we sometimes write β(r) and c(r).

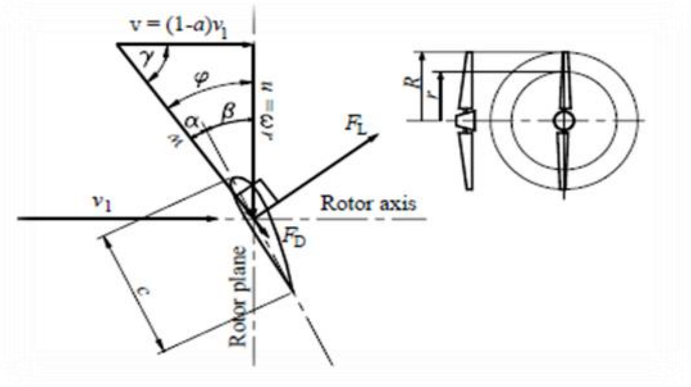


Figure (1). Velocities and Angles

The blade, as shown on the figure is moving up wards, thus the wind speed, seen from the blade, is moving down wards with a speed of u. We have

$$W^2 = V^2 + u^2 \qquad (1)$$

Betz does not include rotation of the wind, i.e. $a' = 0$

Therefore $u = \omega r$ (2)

Here ω is the angular speed of the roto given by

$\omega = 2\pi n$

Where n is the rotational speed of the rotor in and per second.

Now we define the "tip speed ration" i.e.

$$X = \frac{V_{tip}}{V_1} = \frac{\omega R}{V_1} \qquad (3)$$

Combining these equations we get

$$\gamma(r) = \arctan\frac{3r\,X}{2\,R} \qquad (4)$$

Or

$$\phi(r) = \arctan\frac{2\,R}{3r\,X} \qquad (5)$$

And then the pitch angle

$$\beta\,(r\,)\text{Betz} \;=\; \arctan\frac{2\,R}{3r\;X} \;-\; \alpha\,\text{D} \tag{6}$$

Where α_D is the angle of attack, used for the design of the blade. Most often the angle is chosen to be close to the angle, that gives maximum glide ration, see figure 2 that means in the range from 5 to 10°, but near the tip of the blade the angle is sometimes reduced.

Chord length, c(r):

If we look at one blade element in the distance r from the rotor axis with the thickness dr the lift force is $\mathrm{d}F_\mathrm{L} = \frac{1}{2}\rho\, w^2\, c\, \mathrm{d}r\, C_\mathrm{L}$ (7)

The drag force $\mathrm{d}F_\mathrm{D} = \frac{1}{2}\rho\, w^2\, c\, \mathrm{d}r\, C_\mathrm{D}$ (8)

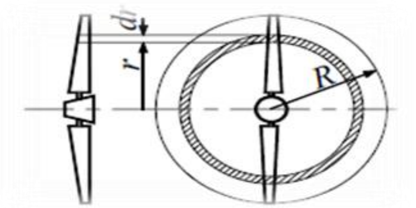
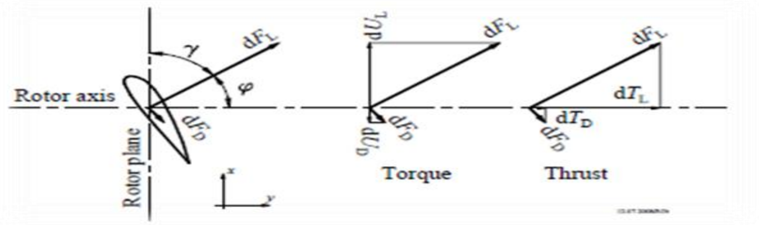


Figure (3) Blade Section



Figure(4) Forces on the Blade Element

For the rotor plane (torque) we have

$$\mathrm{d}U \;= \frac{1}{2}\;\rho\; w2\; c\; \mathrm{d}r\; Cx \tag{9}$$

$$Cx \;=\; CL\sin(\phi\,)\;-\;CD\cos(\phi\,) \tag{10}$$

For the rotor axis (thrust) we have

$$\mathrm{d}T \;= \frac{1}{2}\;\rho\; w2\; c\; \mathrm{d}r\; Cy \tag{11}$$

$$Cy \;=\; CL\sin(\phi\,)+\;CD\cos(\phi\,) \tag{12}$$

Now, in the design situation, we have $C_L >> C_D$, then (9) and (10) becomes

$$\mathrm{d}U \;= \frac{1}{2}\;\rho\; w2\; c\; \mathrm{d}r\; CL\cos(\gamma\,) \tag{13}$$

And then the power produced

$$\mathrm{d}P \;=\; \mathrm{d}U\; r\omega \tag{14}$$

If we have B blades, (3.16) including (3.17) gives

$$\mathrm{d}P \;=\; B\;\frac{1}{2}\rho\; w2\; c\; \mathrm{d}\; r\; CL\cos(\gamma\,)r\;\omega \tag{15}$$

According to Betz, the blade element would also give

$$\mathrm{d}P \;=\; \frac{16}{27}\frac{1}{2}\;\rho V_1^2(2\pi\; r\; \mathrm{d}r) \tag{16}$$

Using $v_1 = 3/2\; w \cos(\gamma)$ and $u = w \sin(\gamma)$, then (15) and (16) gives

$$c(r\,)\text{Betz} \;=\; \frac{16\pi\;R}{9B\;CL,D}\;\frac{1}{X\;\sqrt{X^2(\frac{r}{R})^2+\frac{4}{9}}} \tag{17}$$

Where $C_{L,}$ is the coefficient of lift at the chosen design angle of attack, $\alpha_{A,\,D.}$

2. Schmitz optimization

Schmitz has developed a little more detailed and sophisticated model of the flow in the rotor plane. The torque M in the rotor shaft can only be established because of the rotation of the wake, cf. Appendix A which is a result of the conservation law for angular momentum

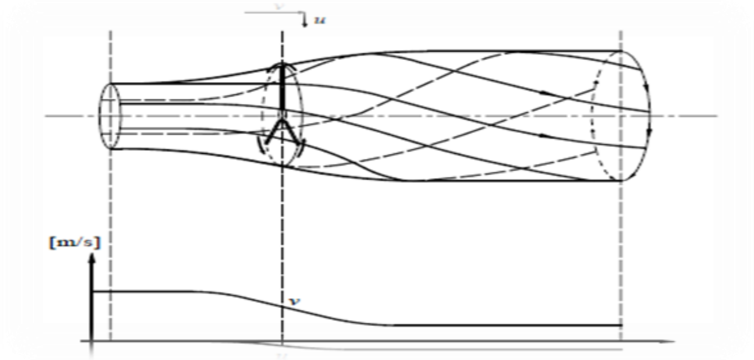


Figure (6) Downstream Rotation of the Wake

The power can be calculated as $P = M\,\omega$ (18)

Where M is the torque in the rotor shaft and ω is the angular speed. According to the conservation rule of angular momentum, the torque in the rotor shaft can only be established because of a swirl induced in the slipstream in the flow downstream of the rotor. As for the axial speed v it can be shown theoretically that the change in the tangential speed in the rotor plane is half of the total change, i.e. we have in the rotor plane

$u = r\,\omega + ½\,\Delta u$ Or (19)

$u = r\,\omega(1 + a')$ (20)

The factor a' is tangential interference

As mentioned previously index 1 is used for the upstream situation, index 2 and 3 for rotor plane and downstream respectively. In the following index 2 is sometimes omitted – for simplicity.

Now look at the flow in the rotor plane, what is important here is the relation

$\overrightarrow{\mathrm{W}} = \overrightarrow{W_1} + {}^1\!/_2\,\overrightarrow{\Delta \mathrm{W}}$ (21)

The change in w_1 is because of the airfoil effect. If we assume that the drag is very low (compared to lift, i.e. $CD << CL => CD \approx 0$) then the Δw vector is parallel to the lift force vector dFL (because of the conservation law of momentum) and we – per definition of the direction of lift force – also have that the Δw vector is perpendicular to w Based on these considerations we have the following geometrical relations

$w = w1\cos(\phi1 - \phi)$ (22)

$v = w\sin(\phi)$ (23)

Combining (25) and (26) we get

$v = w1\cos(\phi1 - \phi)\sin(\phi)$ (24)

$$\Delta w = 2w1\sin(\phi 1 - \phi) \tag{25}$$

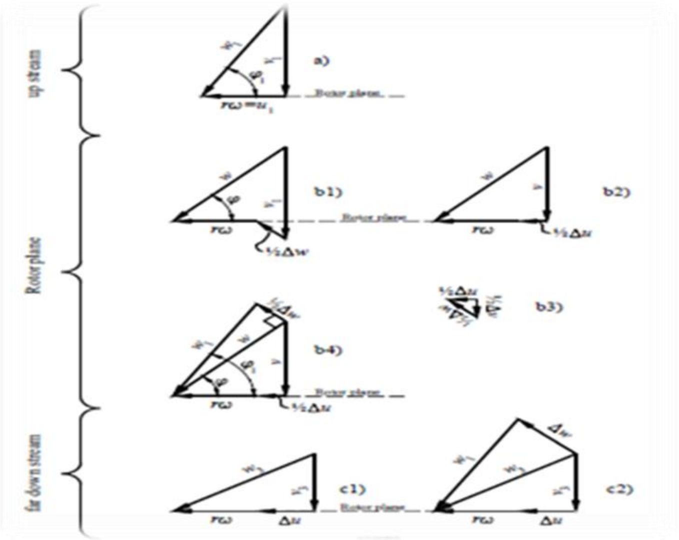


Figure 7. Speed in the rotor plane a) far upstream; b) in the rotor plane and; c) far down stream

Now, let us look at the power! From the conservation of momentum we have

$$dFL = \Delta w dq \tag{26}$$

Where d*q* is the mass flow through the ring element in the radius *r* with the width d*r*, i.e.

$$dq = 2\rho\,\pi\,r\,dr\,v \tag{27}$$

Power equals "torque multiplied by angular velocity" and (neglecting drag) then

$$dP = dM\,\omega \tag{28}$$

In the bottom transaction above we have used the relation sin(x) cos(x) = sin (2x). We have now a relation for the power of the ring element as a function of the angle φ but we do not know this angle? The trick is now to solve the equation d (dP)/dφ = 0 to find the angle that gives maximum power. Doing this for (28) we get

$$\frac{d(dP)}{d\phi} == (r\,2\omega\,\rho\,2\pi\,dr\,w12)2\sin\phi\{\sin(2\phi 1 - 3\phi)\} \tag{29}$$

From d (dP)/dφ = 0, it follows

$$\phi\max = \frac{2}{3}\phi_1 \quad \text{Or} \tag{30}$$

$$\phi\max = \frac{2}{3}\arctan\frac{v1}{\omega\,r} \tag{31}$$

$$\beta\,(r\,)\text{Schmitz} = \frac{2}{3}\arctan\frac{R}{r\,X} - \alpha_D \tag{32}$$

Using the result of (24), (25) and (30) in (26) we get

$$dF_L = \Delta w\,dq = 2\,w_1^2\,2\rho\pi\,r\,dr\sin^2\left(\frac{\phi 1}{3}\right)cos^2\left(\frac{\phi 1}{3}\right) \tag{33}$$

Where we again use sin (2x) = 2 sin(x) cos (x).
From the air foil theory we have

$$dF_L = ½\rho\,w^2\,B\,c\,dr\,C_L$$

$$= \tfrac{1}{2}\rho\, w^2\, B\, c\, \mathrm{d}r\, C_L \cos\left(\frac{\phi 1}{3}\right) \tag{34}$$

Where we have used (22) and $\varphi = 2/3\varphi_1$.
Combining (34) and (33) we get

$$c(r)\mathrm{Schmitz} = \frac{1}{B}\frac{16\pi\, r}{C_L}\sin^2\left(\frac{\phi 1}{3}\right) \tag{35}$$

Results and Discussions

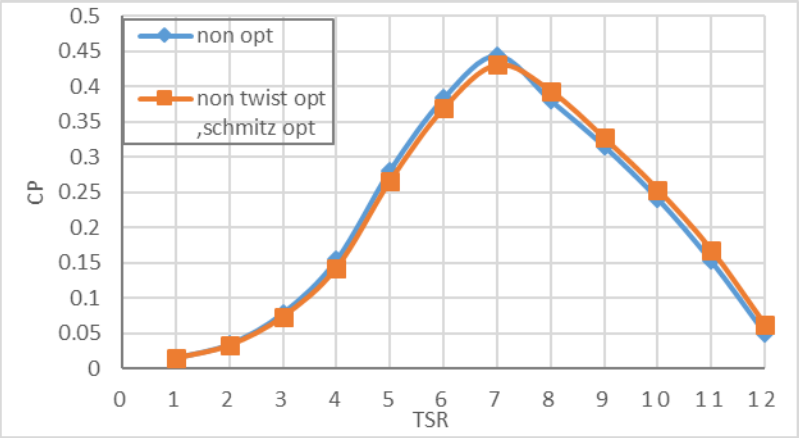


Fig. (8) Power coefficient and tip speed ratio (TSR) at none twist opt, Schmitz opt for eppler417 airfoil.

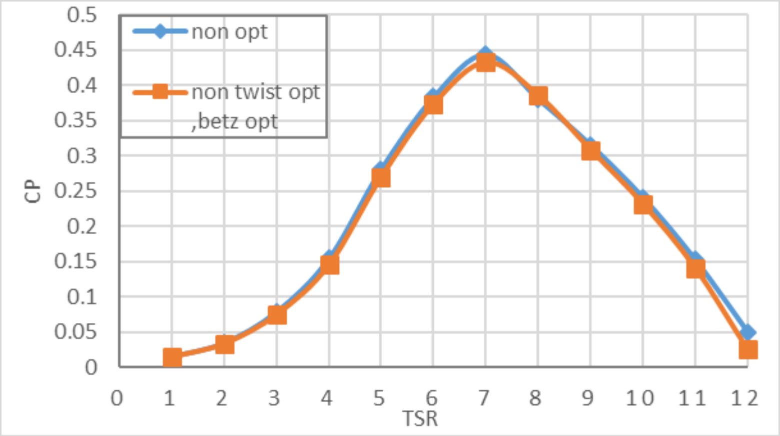


Fig. (9) Power coefficient and tip speed ratio (TSR) at none twist opt, betz opt for eppler417 airfoil.

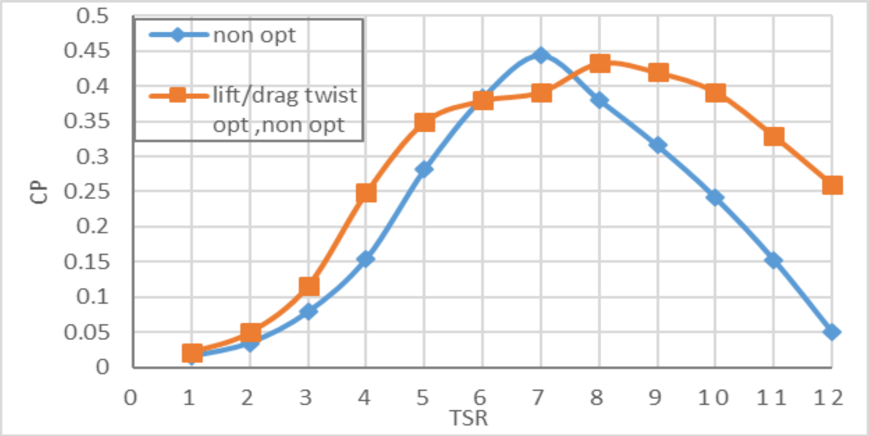


Fig. (10) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, none Chord opt for eppler417 airfoil.

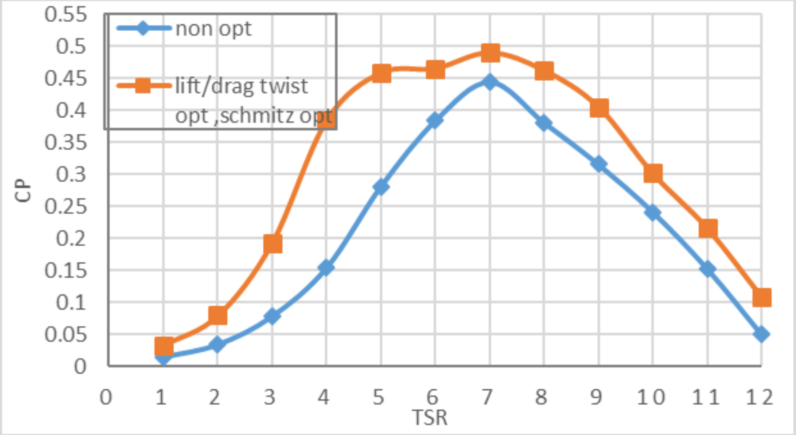


Fig. (11) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, Schmitz opt for eppler417 airfoil.

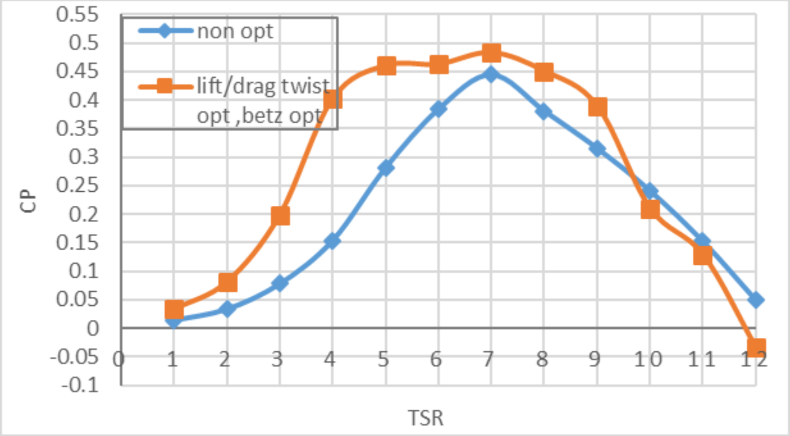


Fig. (12) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, betz opt for eppler417 airfoil.

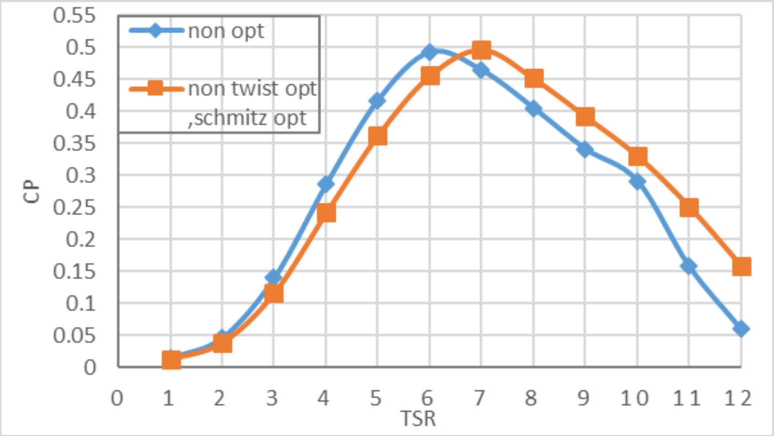


Fig. (13) Power coefficient and tip speed ratio (TSR) at none twist opt, Schmitz opt for NACA 4412 airfoil.

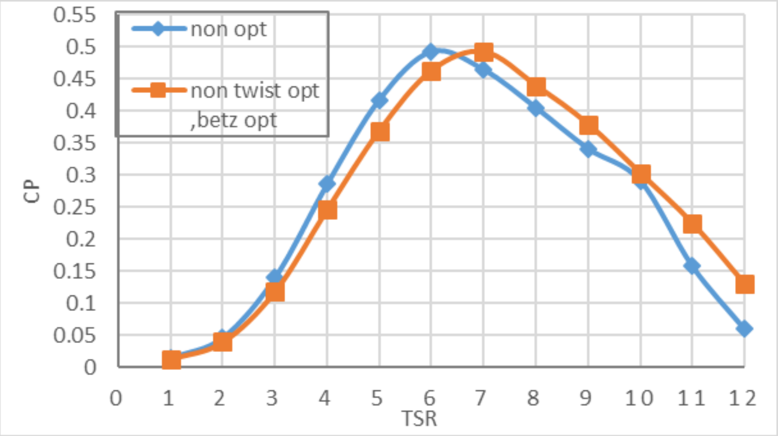


Fig. (14) Power coefficient and tip speed ratio (TSR) at none twist opt, betz opt for NACA 4412 airfoil.

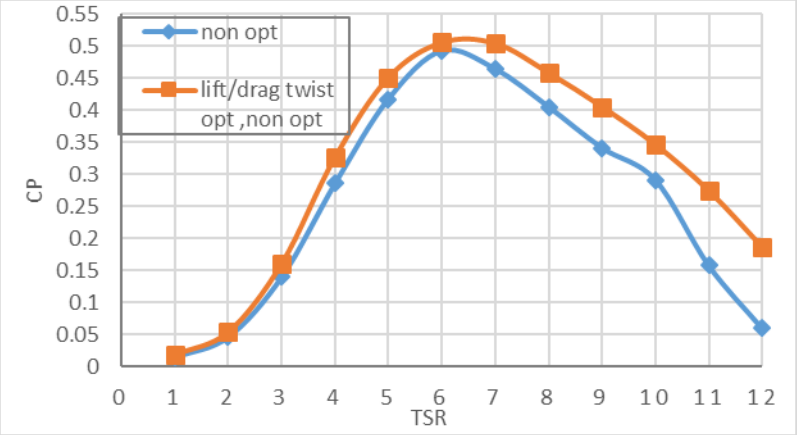


Fig. (15) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, none Chord opt for NACA 4412 airfoil.

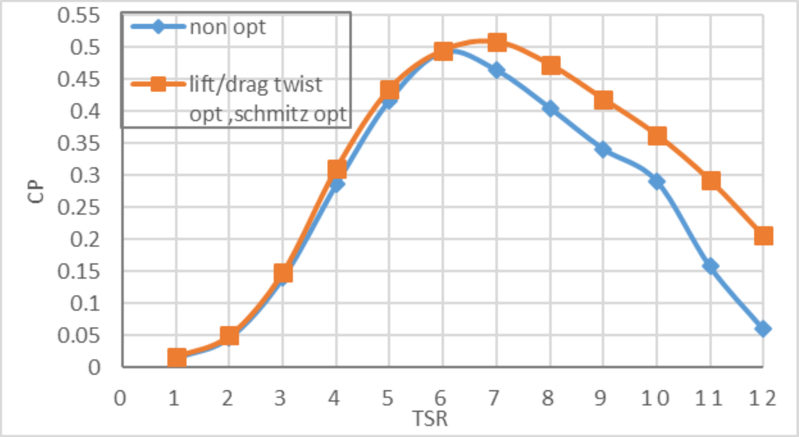


Fig. (16) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, Schmitz opt for NACA 4412 airfoil.

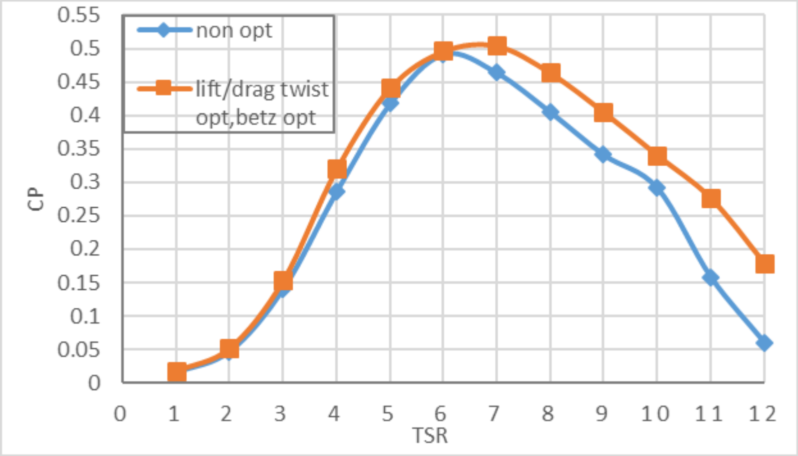


Fig. (17) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, betz opt for NACA 4412 airfoil.

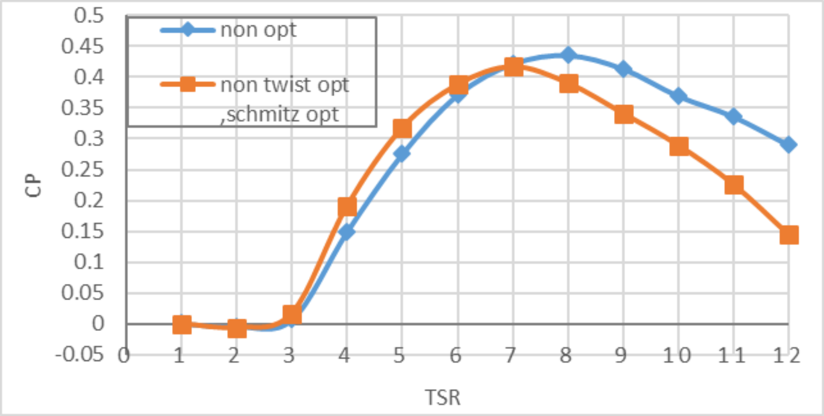


Fig. (18) Power coefficient and tip speed ratio (TSR) at none twist opt, Schmitz opt for NACA 0012 airfoil.

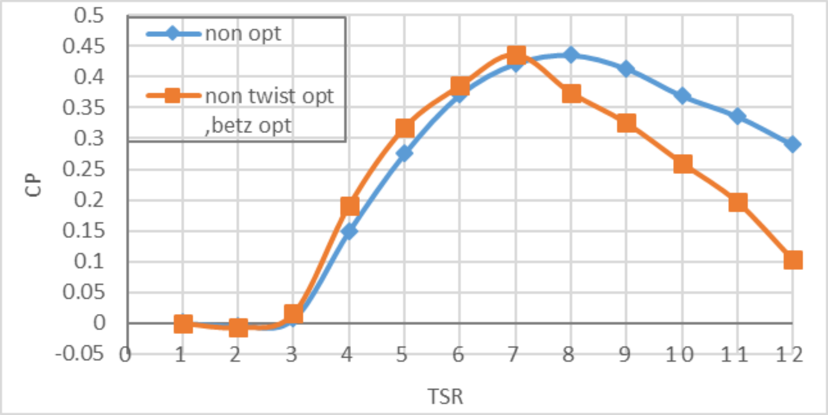


Fig. (19) Power coefficient and tip speed ratio (TSR) at none twist opt, betz opt for NACA 0012 airfoil.

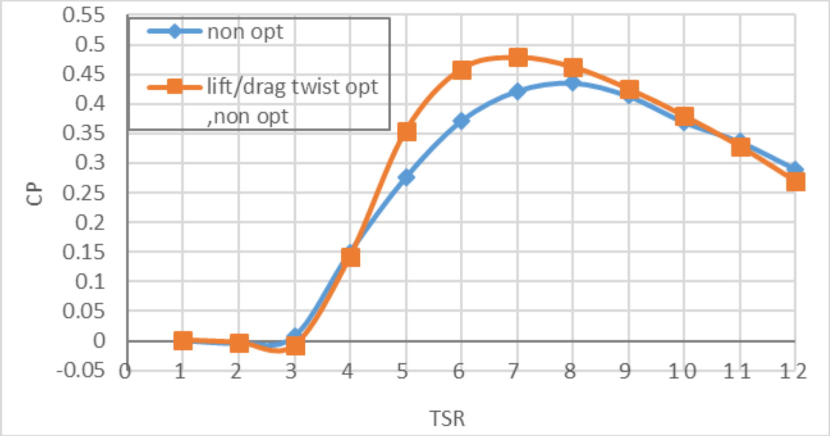


Fig. (20) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, none Chord opt for NACA 0012 airfoil.

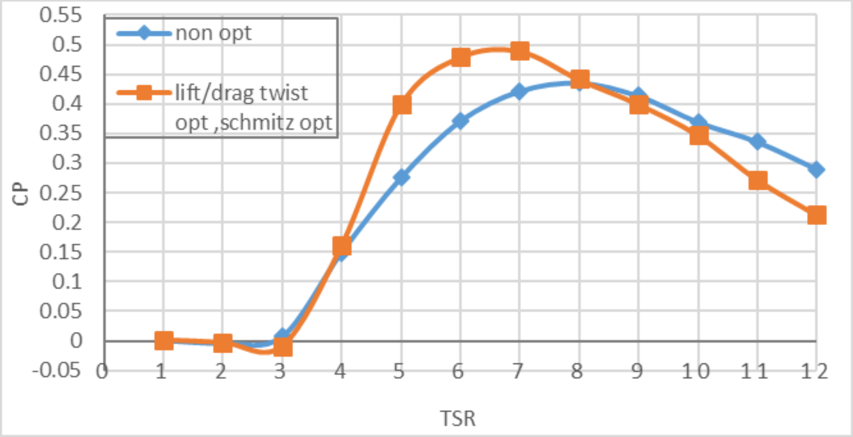


Fig. (32) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, Schmitz opt for NACA 0012 airfoil.

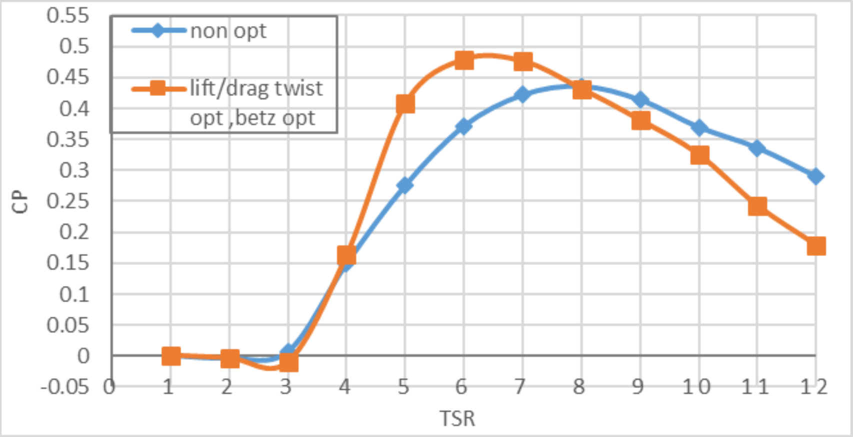


Fig. (21) Power coefficient and tip speed ratio (TSR) at lift/drag twist opt, betz opt for NACA 0012 airfoil.

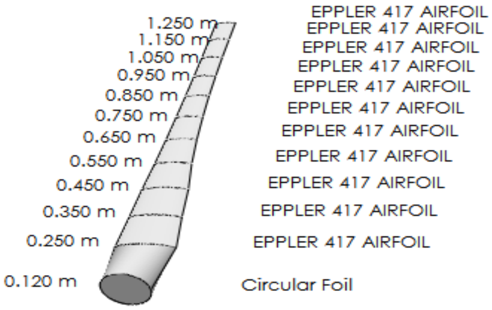


Fig. (22) Combination between None twist and none chord opt.

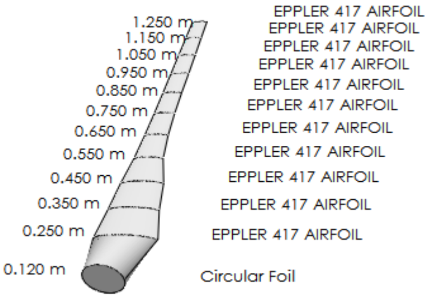


Fig. (23) Combination between none opt twist opt and Schmitz chord opt.

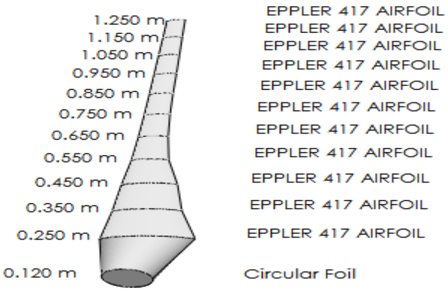
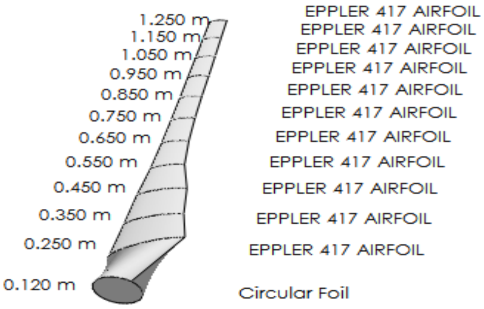


Fig. (24) Combination between non Twist opt and betz chord opt.



Figs (25) combination between lift/drag Twist opt and none chord opt.

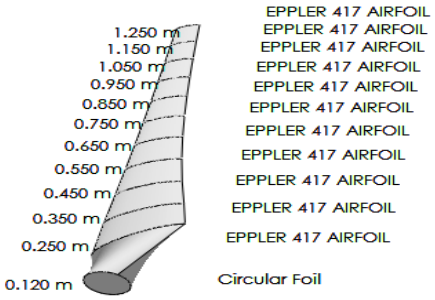
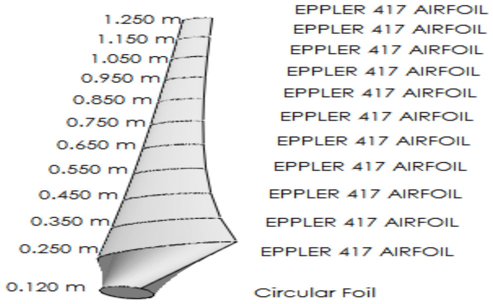


Fig. (26) Combination between lift/drag twist opt and Schmitz chord opt.



Figs (27) combination between lift/drag twist opt and Betz chord opt.

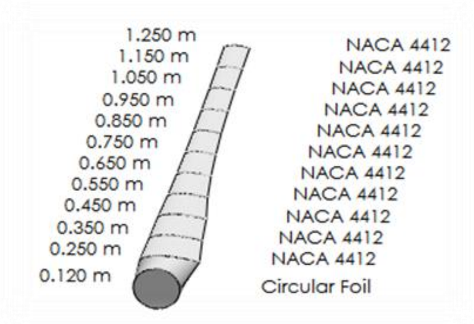


Fig. (28) Combination between None twist and none chord opt.

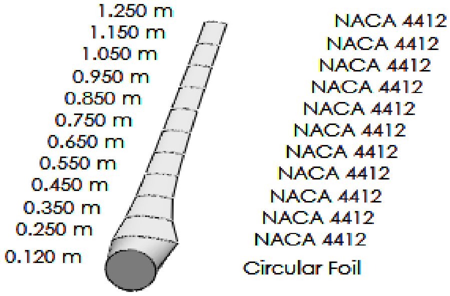


Fig. (29) Combination between none Opt Twist opt and Schmitz chord opt.

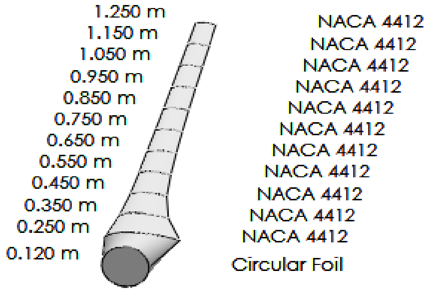
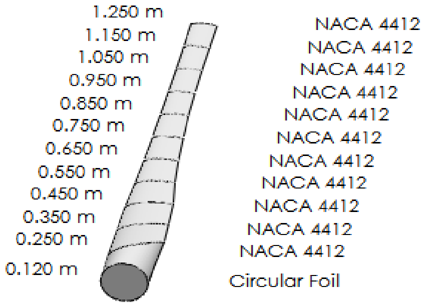


Fig. (30) Combination between non Twist opt and betz chord opt.



Figs (31) combination between lift/drag Twist opt and none chord opt.

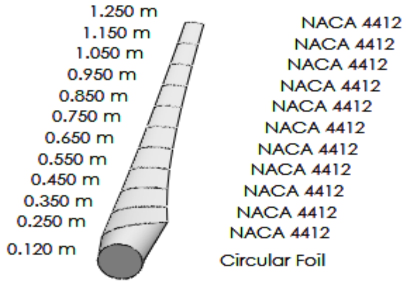
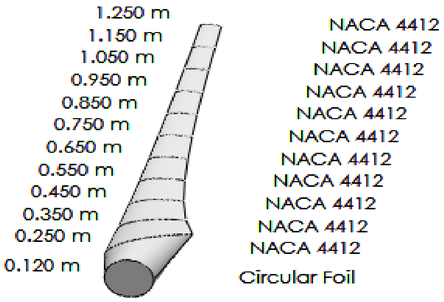


Fig. (32) Combination between lift/drag Twist opt and Schmitz chord opt.



Figs (33) combination between lift/drag Twist opt and betz chord opt.

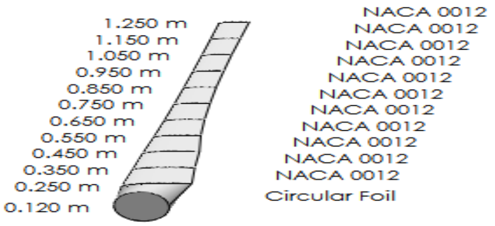


Fig. (34) Combination between None twist and none chord opt.

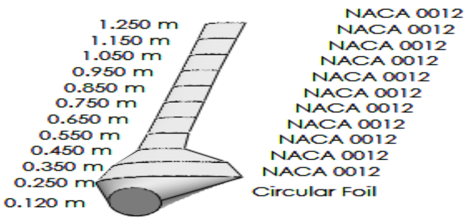


Fig.(35) Combination between none Twist opt and Schmitz chord opt.

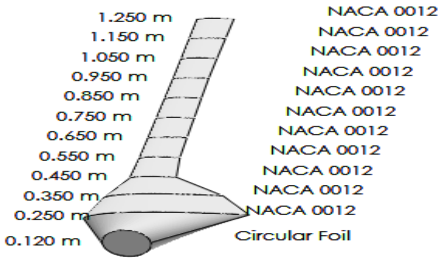
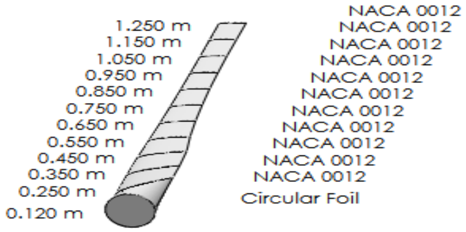


Fig. (36) Combination between non Twist opt and betz chord opt.



Figs (37) combination between lift/drag Twist opt and none chord opt.

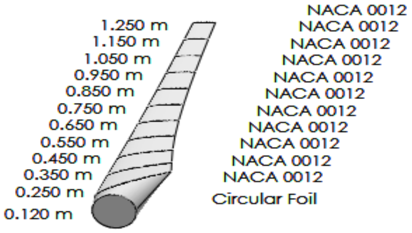
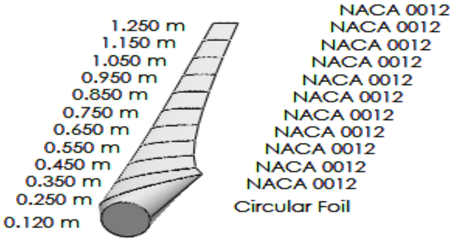


Fig. (38) Combination between lift/drag Twist opt and Schmitz chord opt.



Figs (39) combination between lift/drag Twist opt and betz chord opt.

Table (1) combination between None twist optimize and none chord optimize for Eppler 417 airfoil.

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt Cp	Optimized Cp
1	0	0.1	0	0	0	0.014887	0
2	0.13	0.128	0	0	0	0.0346	0
3	0.23	0.114	0	0	0	0.078642	0
4	0.33	0.104	0	0	0	0.154333	0
5	0.43	0.086	0	0	0	0.281359	0
6	0.53	0.074	0	0	0	0.383703	0
7	0.63	0.066	0	0	0	0.444314	0
8	0.73	0.060	0	0	0	0.38085	0
9	0.83	0.057	0	0	0	0.315684	0
10	0.93	0.055	0	0	0	0.24123	0
11	1.03	0.055	0	0	0	0.152779	0
12	1.13	0.055	0	0	0	0.050189	0

Table (2) combination between non twist optimize and Schmitz chord optimize for Eppler 417 airfoil.

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt Cp	Optimized cp
1	0	0.1	0.1	0	0	0.01488	0.014214
2	0.13	0.128	0.1608	0	0	0.0346	0.03282
3	0.23	0.114	0.1318	0	0	0.07864	0.073582
4	0.33	0.104	0.1143	0	0	0.15433	0.142813
5	0.43	0.086	0.0803	0	0	0.28135	0.266172
6	0.53	0.074	0.0665	0	0	0.38370	0.369098
7	0.63	0.066	0.0597	0	0	0.44431	0.431021
8	0.73	0.060	0.0565	0	0	0.38085	0.394001
9	0.83	0.057	0.0551	0	0	0.31568	0.327272
10	0.93	0.055	0.0529	0	0	0.24123	0.253994
11	1.03	0.055	0.0503	0	0	0.15277	0.16843
12	1.13	0.055	0.0484	0	0	0.05018	0.062451

Table (3) combination between none twist optimize and Betz chord optimize for eppler417 airfoil.

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt Cp	Optimized cp
1	0	0.1	0.1	0	0	0.014887	0.014618
2	0.13	0.128	0.1953	0	0	0.0346	0.03356
3	0.23	0.114	0.1472	0	0	0.078642	0.074883
4	0.33	0.104	0.1335	0	0	0.154333	0.145248
5	0.43	0.086	0.0841	0	0	0.281359	0.270193
6	0.53	0.074	0.0668	0	0	0.383703	0.373505
7	0.63	0.066	0.0613	0	0	0.444314	0.432677
8	0.73	0.060	0.0576	0	0	0.38085	0.385637
9	0.83	0.057	0.0560	0	0	0.315684	0.30833
10	0.93	0.055	0.0536	0	0	0.24123	0.231625
11	1.03	0.055	0.0509	0	0	0.152779	0.140465
12	1.13	0.055	0.0488	0	0	0.050189	0.024818

Table (4) combination between lift/drag twist optimize and none chord optimize for eppler417 airfoil.

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt Cp	Optimized cp
1	0	0.1	0	0	44.77	0.014887	0.020688
2	0.13	0.128	0	0	24.46	0.0346	0.049394
3	0.23	0.114	0	0	17.78	0.078642	0.115833
4	0.33	0.104	0	0	13.82	0.154333	0.248332
5	0.43	0.086	0	0	11.21	0.281359	0.348924
6	0.53	0.074	0	0	9.38	0.383703	0.379495
7	0.63	0.066	0	0	8.019	0.444314	0.391713
8	0.73	0.060	0	0	6.97	0.38085	0.432725
9	0.83	0.057	0	0	6.14	0.315684	0.41975
10	0.93	0.055	0	0	5.46	0.24123	0.39172
11	1.03	0.055	0	0	4.91	0.152779	0.32935
12	1.13	0.055	0	0	4.44	0.050189	0.260351

Table (5) combination between lift/drag twist optimize and Schmitz chord optimize for eppler417 airfoil.

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt Cp	Optimized cp
1	0	0.1	0.1	0	44.77	0.014887	0.032954
2	0.13	0.128	0.27049	0	24.46	0.0346	0.07942
3	0.23	0.114	0.22041	0	17.78	0.078642	0.192883
4	0.33	0.104	0.18223	0	13.82	0.154333	0.384023
5	0.43	0.086	0.15407	0	11.21	0.281359	0.45869
6	0.53	0.074	0.13294	0	9.38	0.383703	0.465429
7	0.63	0.066	0.11666	0	8.019	0.444314	0.490052
8	0.73	0.060	0.10381	0	6.97	0.38085	0.462652
9	0.83	0.057	0.09344	0	6.14	0.315684	0.405513
10	0.93	0.055	0.08490	0	5.46	0.24123	0.301678
11	1.03	0.055	0.07778	0	4.91	0.152779	0.216395
12	1.13	0.055	0.07175	0	4.44	0.050189	0.109162

Table (6) combination between lift/drag twist and Betz chord optimize for eppler417

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt cp	Optimized cp
1	0	0.1	0.1	0	44.77	0.014887	0.033917
2	0.13	0.128	0.3285	0	24.46	0.0346	0.081512
3	0.23	0.114	0.2460	0	17.78	0.078642	0.198014
4	0.33	0.104	0.1954	0	13.82	0.154333	0.401821
5	0.43	0.086	0.1616	0	11.21	0.281359	0.460007
6	0.53	0.074	0.1376	0	9.38	0.383703	0.462543
7	0.63	0.066	0.1198	0	8.019	0.444314	0.482884
8	0.73	0.060	0.1060	0	6.97	0.38085	0.450525
9	0.83	0.057	0.0950	0	6.14	0.315684	0.389835
10	0.93	0.055	0.0861	0	5.46	0.24123	0.210473
11	1.03	0.055	0.0787	0	4.91	0.152779	0.129527
12	1.13	0.055	0.0724	0	4.44	0.050189	-0.03285

Table (7) combination between none twist and none chord optimize for NACA 4412

	Position (m)	Chord(m)	Optimized chord(m)	Twist(deg)	Optimized twist (deg)	Non opt cp	Optimized Cp
1	0	0.1	0	0	0	0.014714	0
2	0.13	0.128	0	0	0	0.046631	0
3	0.23	0.114	0	0	0	0.140096	0
4	0.33	0.104	0	0	0	0.285899	0
5	0.43	0.086	0	0	0	0.417685	0
6	0.53	0.074	0	0	0	0.492292	0
7	0.63	0.066	0	0	0	0.46395	0
8	0.73	0.060	0	0	0	0.404959	0
9	0.83	0.057	0	0	0	0.34101	0
10	0.93	0.055	0	0	0	0.29121	0
11	1.03	0.055	0	0	0	0.157782	0
12	1.13	0.055	0	0	0	0.059998	0

Table (8) combination between none twist and shmitz chord optimize for NACA 4412

	Position (m)	Chord (m)	Optimized chord(m)	Twist(deg)	Optimized twist (deg)	Non opt cp	Optimized cp
1	0	0.1	0.1	0	0	0.014714	0.0121
2	0.13	0.128	0.1608	0	0	0.046631	0.038457
3	0.23	0.114	0.1318	0	0	0.140096	0.116077
4	0.33	0.104	0.1143	0	0	0.285899	0.241517
5	0.43	0.086	0.0803	0	0	0.417685	0.362942
6	0.53	0.074	0.0665	0	0	0.492292	0.456121
7	0.63	0.066	0.0597	0	0	0.46395	0.496897
8	0.73	0.060	0.0565	0	0	0.404959	0.451815
9	0.83	0.057	0.0551	0	0	0.34101	0.392289
10	0.93	0.055	0.0529	0	0	0.29121	0.330744
11	1.03	0.055	0.0503	0	0	0.157782	0.251474
12	1.13	0.055	0.0484	0	0	0.059998	0.159009

Table (9) combination between none twist and Betz chord optimize for NACA 4412

	Position	Chord	Optimized chord(m)	Twist	Opt twist (deg)	Nonopt cp	Optimized
1	0	0.1	0.1	0	0	0.014714	0.012436
2	0.13	0.128	0.1953	0	0	0.046631	0.03931
3	0.23	0.114	0.1472	0	0	0.140096	0.118296
4	0.33	0.104	0.1335	0	0	0.285899	0.246012
5	0.43	0.086	0.0841	0	0	0.417685	0.369488
6	0.53	0.074	0.0668	0	0	0.492292	0.462925
7	0.63	0.066	0.6131	0	0	0.46395	0.49202
8	0.73	0.060	0.0576	0	0	0.404959	0.439679
9	0.83	0.057	0.0560	0	0	0.34101	0.379403
10	0.93	0.055	0.0536	0	0	0.29121	0.303125
11	1.03	0.055	0.0509	0	0	0.157782	0.224856

Table (10) combination between lift/drag twist and none chord optimize for NACA 4412

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt cp	Optimized cp
1	0	0.1	0	0	44.77	0.014714	0.017668
2	0.13	0.128	0	0	24.46	0.046631	0.053726
3	0.23	0.114	0	0	17.78	0.140096	0.160656
4	0.33	0.104	0	0	13.82	0.285899	0.327199
5	0.43	0.086	0	0	11.21	0.417685	0.451364
6	0.53	0.074	0	0	9.38	0.492292	0.505915
7	0.63	0.066	0	0	8.019	0.46395	0.504498
8	0.73	0.060	0	0	6.97	0.404959	0.458572
9	0.83	0.057	0	0	6.14	0.34101	0.40566
10	0.93	0.055	0	0	5.46	0.29121	0.346607
11	1.03	0.055	0	0	4.91	0.157782	0.274614
12	1.13	0.055	0	0	4.44	0.059998	0.186755

Table (11) combination between lift/drag twist and Schmitz chord optimize NACA 4412

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt cp	Optimized cp
1	0	0.1	0.1	0	44.77	0.014714	0.017108
2	0.13	0.128	0.27049	0	24.46	0.046631	0.050579
3	0.23	0.114	0.22041	0	17.78	0.140096	0.149095
4	0.33	0.104	0.18223	0	13.82	0.285899	0.311193
5	0.43	0.086	0.15407	0	11.21	0.417685	0.435322
6	0.53	0.074	0.13294	0	9.38	0.492292	0.495229
7	0.63	0.066	0.11666	0	8.019	0.46395	0.508197
8	0.73	0.060	0.10381	0	6.97	0.404959	0.473028
9	0.83	0.057	0.09344	0	6.14	0.34101	0.419267
10	0.93	0.055	0.08490	0	5.46	0.29121	0.36353
11	1.03	0.055	0.07778	0	4.91	0.157782	0.292848
12	1.13	0.055	0.07175	0	4.44	0.059998	0.206172

Table (12) combination between lift/drag twist and Betz chord optimize for NACA 4412

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Non opt cp	Optimized cp
1	0	0.1	0.1	0	44.77	0.014714	0.017729
2	0.13	0.128	03285	0	24.46	0.046631	0.052127
3	0.23	0.114	0.2460	0	17.78	0.140096	0.153206
4	0.33	0.104	0.1954	0	13.82	0.285899	0.31984
5	0.43	0.086	0.1616	0	11.21	0.417685	0.441032
6	0.53	0.074	0.1376	0	9.38	0.492292	0.496225
7	0.63	0.066	0.1198	0	8.019	0.46395	0.503986
8	0.73	0.060	0.1060	0	6.97	0.404959	0.463603
9	0.83	0.057	0.0950	0	6.14	0.34101	0.404833
10	0.93	0.055	0.0861	0	5.46	0.29121	0.3406
11	1.03	0.055	0.0787	0	4.91	0.157782	0.276464

Table (13) combination between none twist and none chord optimize for NACA 0012

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Not opt cp	Optimized cp
1	0	0.1	0	0	0	0.000174	0
2	0.13	0.128	0	0	0	-0.00408	0
3	0.23	0.114	0	0	0	0.006821	0
4	0.33	0.104	0	0	0	0.149255	0
5	0.43	0.086	0	0	0	0.275467	0
6	0.53	0.074	0	0	0	0.371223	0
7	0.63	0.066	0	0	0	0.421798	0
8	0.73	0.060	0	0	0	0.435749	0
9	0.83	0.057	0	0	0	0.413793	0
10	0.93	0.055	0	0	0	0.36963	0
11	1.03	0.055	0	0	0	0.336319	0
12	1.13	0.055	0	0	0	0.290134	0

Table (14) combination between none twist and Schmitz chord optimize for NACA 0012

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Not opt cp	Optimized cp
1	0	0.1	0.1	0	0	0.000174	-0.00045
2	0.13	0.128	0.2808	0	0	-0.00408	-0.00657
3	0.23	0.114	0.2210	0	0	0.006821	0.016584
4	0.33	0.104	0.0899	0	0	0.149255	0.191419
5	0.43	0.086	0.0799	0	0	0.275467	0.318112
6	0.53	0.074	0.0782	0	0	0.371223	0.388399
7	0.63	0.066	0.0766	0	0	0.421798	0.417243
8	0.73	0.060	0.0746	0	0	0.435749	0.390651
9	0.83	0.057	0.0737	0	0	0.413793	0.341254
10	0.93	0.055	0.0733	0	0	0.36963	0.289406
11	1.03	0.055	0.0745	0	0	0.336319	0.225732
12	1.13	0.055	0.0758	0	0	0.290134	0.143907

Table (15) combination between none twist and Betz chord optimize for NACA 0012

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Not opt cp	Optimized cp
1	0	0.1	0.1	0	0	0.000174	-0.00071
2	0.13	0.128	0.3411	0	0	-0.00408	-0.00738
3	0.23	0.114	0.2467	0	0	0.006821	0.015674
4	0.33	0.104	0.0965	0	0	0.149255	0.191311
5	0.43	0.086	0.0838	0	0	0.275467	0.317766
6	0.53	0.074	0.0809	0	0	0.371223	0.38558
7	0.63	0.066	0.0786	0	0	0.421798	0.436423
8	0.73	0.060	0.061	0	0	0.435749	0.374287
9	0.83	0.057	0.0739	0	0	0.413793	0.325118
10	0.93	0.055	0.0743	0	0	0.36963	0.260124
11	1.03	0.055	0.0754	0	0	0.336319	0.196855

Table (16) combination between lift/drag twist and none chord optimize for NACA 0012

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Not opt cp	Optimized cp
1	0	0.1	0	0	0	0.000174	0.001161
2	0.13	0.128	0	0	17.46	-0.00408	-0.00258
3	0.23	0.114	0	0	10.78	0.006821	-0.008
4	0.33	0.104	0	0	6.82	0.149255	0.14141
5	0.43	0.086	0	0	4.21	0.275467	0.353794
6	0.53	0.074	0	0	2.38	0.371223	0.458744
7	0.63	0.066	0	0	1.019	0.421798	0.478665
8	0.73	0.060	0	0	-0.027	0.435749	0.462643
9	0.83	0.057	0	0	-0.86	0.413793	0.42578
10	0.93	0.055	0	0	-1.53	0.36963	0.380246
11	1.03	0.055	0	0	-2.09	0.336319	0.328655
12	1.13	0.055	0	0	-2.56	0.290134	0.269691

Table (17) combination between lift/drag twist and Schmitz chord optimize NACA 0012

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Not opt cp	Optimized cp
1	0	0.1	0.1	0	0	0.000174	0.001493
2	0.13	0.128	0.1939	0	17.46	-0.00408	-0.0026
3	0.23	0.114	0.1580	0	10.78	0.006821	-0.00862
4	0.33	0.104	0.1306	0	6.82	0.149255	0.161339
5	0.43	0.086	0.1105	0	4.21	0.275467	0.398831
6	0.53	0.074	0.0953	0	2.38	0.371223	0.479487
7	0.63	0.066	0.0836	0	1.019	0.421798	0.489343
8	0.73	0.060	0.0744	0	-0.027	0.435749	0.441659
9	0.83	0.057	0.0670	0	-0.86	0.413793	0.399568
10	0.93	0.055	0.0608	0	-1.53	0.36963	0.347289
11	1.03	0.055	0.0557	0	-2.09	0.336319	0.272019
12	1.13	0.055	0.0514	0	-2.56	0.290134	0.212296

Table (18) combination between lift/drag twist and Betz chord optimize NACA 0012

	Position (m)	Chord (m)	Optimized chord(m)	Twist (deg)	Optimized twist (deg)	Not opt cp	Optimized cp
1	0	0.1	0.1	0	0	0.000174	0.001512
2	0.13	0.128	0.2355	0	17.46	-0.00408	-0.00276
3	0.23	0.114	0.1764	0	10.78	0.006821	-0.00911
4	0.33	0.104	0.1401	0	6.82	0.149255	0.163139
5	0.43	0.086	0.1159	0	4.21	0.275467	0.407402
6	0.53	0.074	0.0987	0	2.38	0.371223	0.478764
7	0.63	0.066	0.0858	0	1.019	0.421798	0.475984
8	0.73	0.060	0.0760	0	-0.027	0.435749	0.431522
9	0.83	0.057	0.0681	0	-0.86	0.413793	0.381167
10	0.93	0.055	0.0617	0	-1.53	0.36963	0.325524
11	1.03	0.055	0.0564	0	-2.09	0.336319	0.243131

Table (19). The optimization results showed with the following tables for Eppler 417

	Non optimized cp	Optimized cp	Optimization method	Percentage of optimization (%)
1	0.4443	0.4310	Non twist opt , Schmitz chord opt	-3
2	0.4443	0.4327	Non twist opt , Betz chord opt	-2.6
3	0.4443	0.3917	Lift/drag twist opt , non-chord opt	-11.8
4	0.4443	0.4901	Lift/drag twist opt , Schmitz chord opt	10.3
5	0.4443	0.4829	Lift/drag twist opt , betz chord opt	8.7

Table (20) For NACA 4412 airfoil

	Non optimized cp	Optimized cp	Optimization method	Percentage of optimization (%)
1	0.464	0.4969	Non twist opt , Schmitz	7
2	0.464	0.492	Non twist opt , betz chord	6
3	0.464	0.5045	Lift/drag twist opt , non-	8.7
4	0.464	0.5082	Lift/drag twist opt , Schmitz	9.5
5	0.464	0.504	Lift/drag twist opt , betz	8.6

Table (21) For NACA 0012 airfoil

	Non optimized cp	Optimized cp	Optimization method	Percentage of optimization (%)
1	0.4218	0.4172	Non twist opt , Schmitz	-1
2	0.4218	0.4364	Non twist opt , betz chord	3.5
3	0.4218	0.4787	Lift/drag twist opt , non-	13.5
4	0.4218	0.4893	Lift/drag twist opt ,	16
5	0.4218	0.4760	Lift/drag twist opt , betz	13

Discussion

The aerodynamic design point of view for all wind turbine blade is the airfoil section which is the more sophisticate aerodynamic principles to capture the winds energy more effectively .L/D ratio is the technical point of selecting the airfoil and doesn’t matter what type of airfoil select except some side view point which also important and its related to L/D ratio like amount of angle at each section of wind mill blade for giving high L/D ratio, so the significant point to select the maximum L/D ratio range from the working area of the airfoil section and the amount of angle at that range that gives quieter and capable of generating more power from less wind speed, so it gives higher TSR many factor to e consider for chord optimization one of these factor tangential interference because the rotation of the wind does exist, number of blade which present the frontal area facing the wind, also the blade length which is manger parameter to be consider for chord optimization.

Betz consider the tangential interference á equal to zero and Schmiz consider the coefficient of equal to zero that was the reason Schmitz method gives largest chord than the Betz method .Lift/drag take the best L/D angles operate the airfoil section only with that angle by that technical this method was the best for twist angle optimization.

Twist angle which based on L/D ratio is the significant parameter to calculate for chord optimization. Also the curvature of airfoil section is much important for optimization that why the proper one (symmetry) gives the highest value and Eppler 417 gives less value due to its complicated curvature

All these parameter, optimization method betz, Schmitz lift/drag twist optimization and genetic algorithm have been built to gather to get best result for highest coefficient of power.

Conclusion

- Best windmill blade airfoil selection should be at high L/D and low angle of attack.
- Highest CP can be attained if optimization done for twist angle and for chord length together
- Highest CP optimization value always occur at mid length of blade(approximately 55% of blade length
- Optimization increase the CP value about 10-16%
- Optimum methods increase the root chord approximately 100% at the root and 30% at the tip

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