*LAUTECH Journal of Engineering and Technology 16 (2) 2022: 72-86*

# MODIFICATION OF BLADE CHORD INFLUENCE ON THE PERFORMANCE AERODYNAMICS OF VERTICAL AXIS WIND TURBINES

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## ABSTRACT

***Performance aerodynamics of VAWTs is given important considerations whenchoosing design parameters for the manufacturing of VAWT to effectively and efficiently perform after installation. Blade chord is amongst the many design parameters that can affect the CP of VAWTs in relation to wind harvest and energy yield. This study examines the influenceblade chord modification can have on the PA of wind turbines. The VAWT blade chord of NACA0022 was modified and two configurations of rotors, one with C = 0.03m and the other of C = 0.04m were tested in a low speed and low turbulent intensitytunnel at several wind speeds. An appropriate performance measuring techniques was used to conduct the tests on the two VAWT configurations. The results showed substantial differences in the measured performance efficiency of the two configurations. The two rotorsreached peak performances at the highest tested freestream speed of 8 m/s. The VAWT configuration of C = 0.04m attained higher performance with peak CP = 0.326 at λ = 3.75 while the C = 0.03m showed lower peak CP = 0.26. Changes in the CPwere seen in relation to changes in the free wind speeds.Also the peakperformanceschanged positively as the wind speed is increased. The curves of plot of the CP - λ is observed to close up at region of the peak performances. The CP, the performance efficiency and aerodynamics of the two rotors and configurations are shown tohave been visibly affected bythe modification of the blade chord.***

***Keywords***: CP; performance; VAWT; blade chord; tip speed ratio

## 1.0 Introduction

Renewable energy is gaining ground everywhere in the world because of non-emission of carbon monoxide that is toxic to the environment from its devices. Water, wind and sun are the major sources which renewable energy could be harnessed. For the healthy and sustainable nature of renewable energy when compared with energy from fossil fuel, researches have been encouraged into producing fuel and cooking gas from organic and waste materials (Eboibi et al., 2018). Wind harvest will not only reduce environmental pollution by minimising carbon emission into the atmosphere but can also provide adequate and affordable energy, which can aid the eradication of poverty thereby raising the living standards.

The growths of renewable energy technology also encourage the creation of jobs through researches into the improvement, developments, operations and maintenance of the wind machines. Wind machines are energy converters which harness the energy from wind, that is, the Kinetic energy through the blade(s) of the rotor rig, the rotor shaft and the generator that converts the harvested mechanical energy to electrical power. Installation of the wind machines is usually preceded by feasibility studies that must include evaluation of wind speed potentials of the area under consideration (Eboibi et al., 2017).

Wind energy isharvested or harnessed by lift-based wind machines, broadly classified as horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT) (Beri, 2011). HAWT are dominant for large scale energy generation because of many decades of research attention they have attracted (Erikson et al., 2008). The VAWT had received little or no attention until 1970 during the oil crisis but has received attention recently with studies showing huge prospects of application ofthe VAWT in urban and offshore environments (Almohammadi et al., 2013; Ismail and Vijayarahaven, 2015; Tiju et al 2015). The adaptability and flexible installation and functioning of the VAWT in cities and the developing suburbs have led to the re-invigoration of research interest in wind technology (VAWT). The use of VAWTs in the urban city brings proximity to centers of demands thereby eliminating loses (Maxwell et al., 2009).

Numerous studies conducted on VAWT have further enumerated the many advantages of the rotor. The VAWT is seen as having higher scalability potentials (Islam et al, 2013) lower production and operation cost and higher robustness because of their faster recovery from wake effect compared to HAWT that their wake recovery is very slow (Tescione et al., 2014). The nature of VAWT simple design is such that the rotor does not need a yaw mechanism (Maeda et al., 2013) and blades are usually straight unlike the twisted and non-uniform blades of their HAWT counterpart (Wekesa et al. 2014).

The performance efficiency of VAWTs have been investigated in relation to tip speed ratio by Templin (1974) at the National Research Council of Canada by implementing the single stream tube model that is based on Glauert's (1948) theory of actuator disc. Templin (1974) observed the VAWT's performance coefficient is influenced by changes in rotor's solidity by modifying the rotor's blade number. Using momentum models and experimental methods at the Sandia National Laboratories of United State of America, Shedhal and Klimas (1980), Worstell (1982), Ashwill (1992) have investigated the aerodynamic of performance of 5m, 17m and 34m diameter VAWTs. They have shown that, VAWT performance varies with tip speed ratios, VAWT diameter and Re. Computational fluid dynamics(CFD) and experimental methods have been used by Howell et al.(2010), Untaroiu et al. (2011), Raciti Castelli (2012), Danao et al.(2013)and Eboibi et. al (2016) in investigation of the VAWT's performance with reference to tip speed ratio in both steady and unsteady wind speed conditions.

Experimentation is ahistorical procedureand one of basic methods explored for investigation of VAWTs characteristics in relation to flow fieldand performance aerodynamics, Peng et al. (2016) used wind tunnel to study VAWT wake aerodynamics and observed a pair of vertical structure that was counter rotating which could beconsidered during installation to affect VAWT performance positively. Inference could be drawn from Peng et al. (2016), to the effect that several designs and design effect factors have influence on the efficient and effective energy conversion of the VAWT.

Visualisation of flow field around a blade of VAWT has also been made possible through experimentation (Eboibi et al., 2015). With the data obtained from visualisations, the aerodynamics of flow field is explained in more details to give understanding to the reason behind the power generated by and aerodynamics of wind turbines. Visualisation of VAWT also help in theverification, validation and authentication of numerical models created for research and demonstrations purposes (Eboibi, 2022)

No study that has investigated the influences of modifyingof blade chord onperformance aerodynamics of VAWTsis known to the author in the available numerous VAWTs studies in literature. This paper aims at bridging this gap through a wind tunnel investigation of two VAWTsconfiguration of $C$ = 0.03m and C = 0.04m at various wind speeds and corresponding tip speed ratios.

## 2.0 Methodology

### 2.1 VAWT models

Two straight three-bladed VAWT rotors were adapted for the experiments. The VAWT geometries have a central shaft of 0.027m that runs across the tunnel test section from the top to the bottom. The central shaft of the rotor is placed 1.8m from upwind and 1.2m downwind of the test section of the tunnel. There are two hubs rigidly fastened to the shaft, with provisions for the attachment of the support arms that connects the blades to the centre shaft. The three straight blades are 0.35m far from the central shaft when affixed to the support arms.

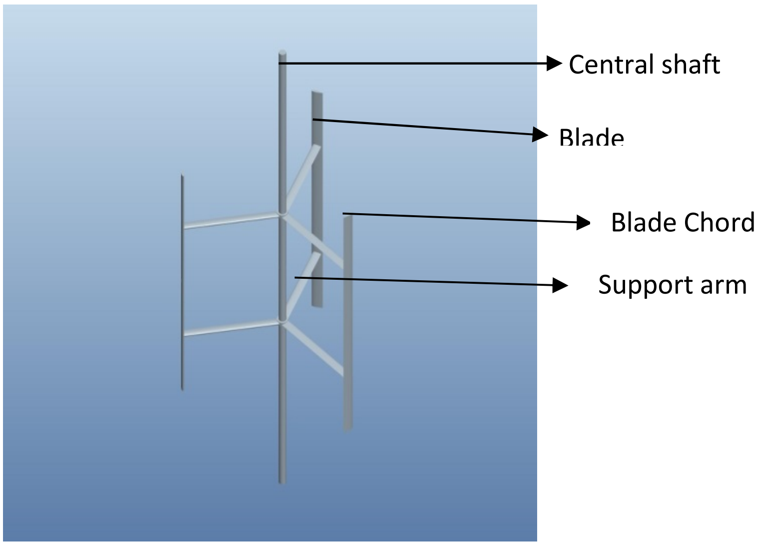



Figure 1. A card model of a typical rotor

Figure 1 shows a card model of a three bladed typical VAWT. The straight blades of the VAWTs are made from aluminium alloy with the blades having a NACA0022 profile, while the support arms are NACA0026. The two sets, one with blade chord of 0.03m with corresponding $\sigma$ = 0.26 and the other with 0.04m, $\sigma$ = 0.34, both of 0.6m span resulting in aspect ratio of 20 and 15 respectively. The straight blades are affixed to the shaft via the two support arms at ¼ and ¾ blade length.

### 2.2 Wind tunnel measurements technique of VAWT performance aerodynamics

All theexperiments were conducted in a low speed; open-circuit and suction tunnel. The wind tunnel was built and commissioned by the Mechanical Engineering Department, University of Sheffield. An axial fan located at the rear of the low turbulence intensity wind tunnel drives the free windflow to a maximum limit of around 25m/s. The working section is 1.2 x 1.2 m$^2$ and 3m long and of turbulence intensity $Tu$ = 1% around the immediately area of the rotor rig and a velocity profile of ≤ 0.01% error which cascaded to ± 1% CP error at $\lambda$ = 4 and at 7m/s wind speed.

Theforces on the rotor blades of the two assembled VAWT configurations were measured by the 'spin down' method, a VAWT performance measuring technique developed by Edwards et al (2012).The method includes the initial spinning down of the VAWT from a maximum / high rotational speed, and through an optical encoder the instantaneous acceleration is computed from the monitored angular velocity by Equation (4).

$$\xi = \frac{\omega_2 - \omega_1}{t_2 - t_1} \quad (4)$$

For every of the test wind speed, the VAWT rotor is spun two times to ascertain the performance efficiency of the VAWT. For the rig's resistive torque to be determined an initial spinning down of therotor was performed. The resistive torque $T_{res}$ is determined by spinning the rotor down without the blades attached to measure the system resistance produced by the mechanical friction, bearings and the support arm's induced drag. Since the VAWTs blades werenot affixed to the rig's rotor when the tests for resistive torque is conducted, brake application was not necessary regardless of the free stream speed the test was being conducted. This is based on the fact that positive torque was not generated. The $T_{res}$is computed after the test by using Equation (5).

$$T_{res} = I_{rig}\xi \quad (5)$$

With the blades attached, a second spinning down test is carried out with a view to ascertain the overall performance coefficient of the VAWT and this is based on the torque of the blade. The brake was applied at 7m/s and 8m/s of the three wind speeds tested. The brake application was needed to prevent the rotor from cutting-in, a situation where positive torque is generated, so the turbine no longer spins down freely. The blade torque $T_B$ was computed by Equation (6), the applied torque, $T_{app}$ = 0 for cases in which brake power was not applied. Other information of the development and verification of the spin down method are found in Danao (2012).

$$T_B = I_{rig}\xi - T_{res} - T_{app} \quad (6)$$

$$\mathrm{CP} = \frac{\mathrm{P_B}}{\mathrm{P_w}}, \mathrm{P_B} = \mathrm{T_B}\omega\mathrm{N}, \ \mathrm{P_w} = 0.5\rho \mathrm{A}\mathrm{V_w^3} \quad (7)$$

The CP of the VAWT was computed by Equation (7) based on the measured torque of the blade after the determination of the$T_B$ from the various spin-down tests. The determined CP of VAWTconfigurations measured at the three respective wind speeds is as presented with discussion in the following section

## 3.0 Results and Discussion

The CPwas determined in respect of the two VAWT models by the "spin down" test procedure detailed in section 2.2. The spin down tests were conducted for eight wind speeds ranging from 5.5m/s to 9m/s at an interval of 0.5m/s. For each test on the rotor rig, the time and revolution per minute were recorded and all other steps as contained in the "spin down" test procedure were followed in obtaining the performance coefficients. The obtained results were analysed thereafter presented and discussed in the succeeding section.

### 3.1 Description of Blade Chord = 0.03m

Figure 2 shows a plot of CP - λ for all the spin down tests for the rotor rig of C = 0.03m.It is clearly obvious that the CP varies considerably in relation to either increase or decrease in the wind speed and λ. Fromthe λ = 1 and λ = 3.8, the VAWT performanceefficiency is negativeat all the wind speed the tested were conducted, implying the turbine is absorbing power rather than generating power. For wind speeds 5.5m/s, 6m/s, 6.5m/s and 7m/s, the rotor performance is completely negative at the tested λ. At 7.5m/s, it is deduced that a peak performance of CP = 0 is achieved by the VAWT at λ = 4.75 whichmay begin to fall below zero beyond λ = 5.

Also the wind speeds above 7.5m/s, the CP – λ performance curves at higher λ is in the region in which positive performance is recorded. The 8m/s CP – λ curve has its positive CParea between λ = 4.3 and 5 and, the 8.5m/s wind speed recorded positive performance between λ = 4.1 and 5, while the 9m/s wind speed performed positively from λ = 3.82 and λ = 5. The VAWT thereafter reached a maximumCP = 0.151 at the λ = 4.75 at the tested maximum 9m/s wind speed.

Figure 3 shows the plot of wind speed versus λ. It is deduce able that there are decreases in the tested wind speeds during the experiments, especially at the beginning of the experiments. This deviation from the set wind speed is ascaused by the blockage effects resulting from the VAWT extracting energy from the wind, while in operation anddue to solid blockage that is caused by solidity characterising the blades in free stream entrance section of the rig rotation. Comparing Figures 2 and 3, it is deduced that the λ with higher CP in Figure 2 is traceable to the λ with a more noticeable decrease in the tested wind speed in Figure 2, and the λ of the lower CP also corresponded to λ with leaser drops in wind speeds. Thus,confirming that energy is being extracted from the freestream wind by the VAWT as one of the reasons for the observed deviation.

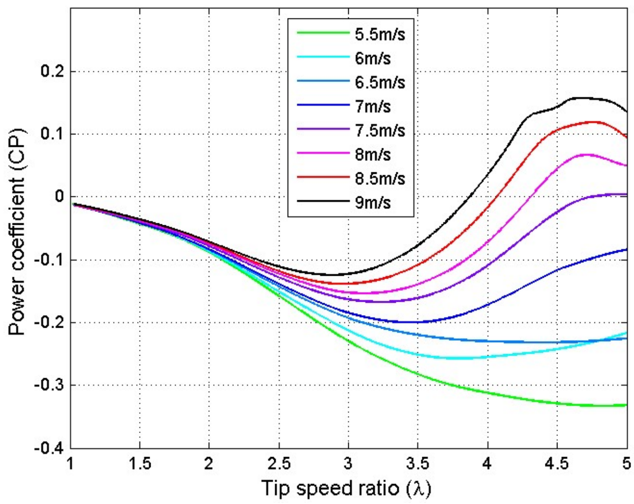



Figure 2. The CP- **λ** for all spin down tests, C = 0.03m, σ = 0.26.

The deviations from the set wind speed can influence the aerodynamics lift and overall CP of the VAWTs, and to compare the experimental data with results computed from numerical simulation (CFD) in a steady wind condition is considered misnomer in the author's opinion. So, these deviations from the set wind speeds were corrected through an interpolation of data obtained from the spin down tests for 5.5m/s – 9m/s to achieve comparable steady performances. The desired wind speeds for this investigation ranged from a lower 6 m/s wind speed to a peak of 8m/s, and despite the drops in the freestream wind speeds, the desired wind speeds are within the resulting data set of all the spin down tests conducted.

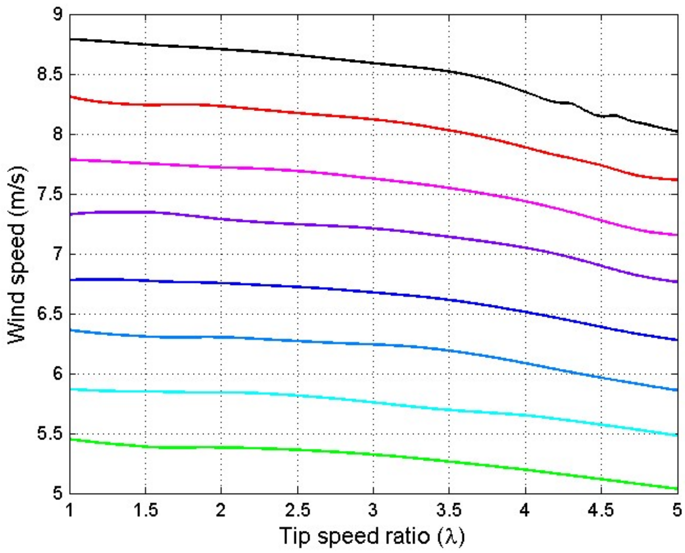



Figure 3. Decreases in wind speed for all the spin down tests, C= 0.03m, σ = 0.26.

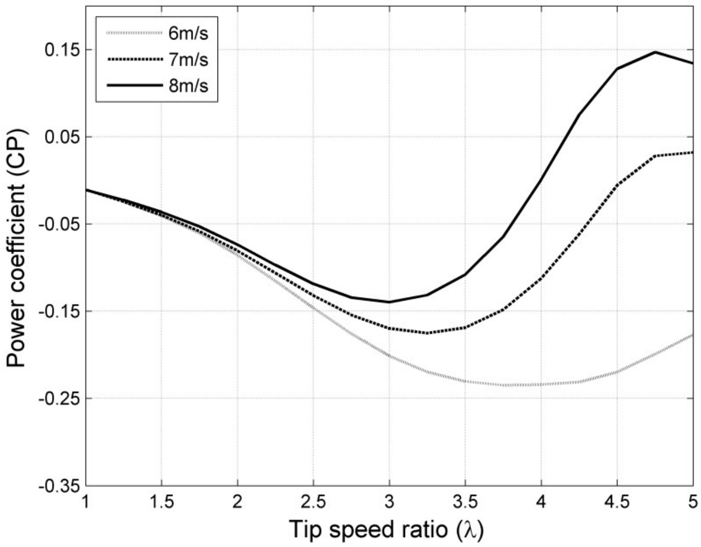


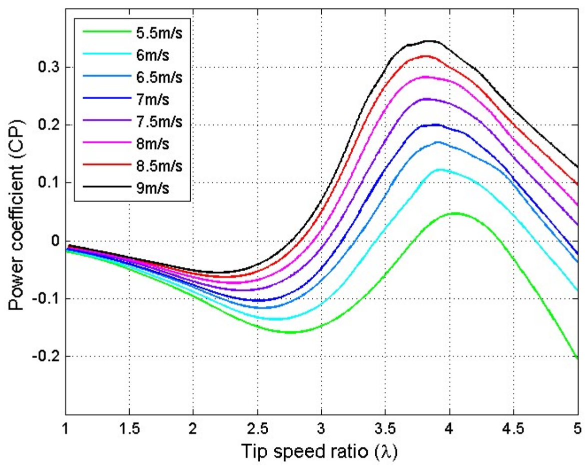

Figure 4. Interpolated CP versus tip speed ratio, C= 0.03m, σ = 0.26.

The interpolated performance curves for the steady performance are shown in Figure 4. Comparison of Figure 4 to the data set in Figure 2, it noticeable that the peak interpolated CP for the 8m/s case is higher at 0.147 than the non-interpolated case. This difference is due, mainly to the non-interpolated case having operated at a lower wind speed of 7.76m/s at the start of the experiment and wind speed of 7.22m/s at the end of the laboratory test. These wind speeds are clearly far below 8m/s set wind speed. Similar differences are also observable between the interpolated and non-interpolated curves of the 7m/s and 6m/s cases. The deviations of the data sets from the set wind speeds are corrected by the interpolation which results in higher CP over the non-interpolated CP, since a steady state performance is assumed for the interpolation.

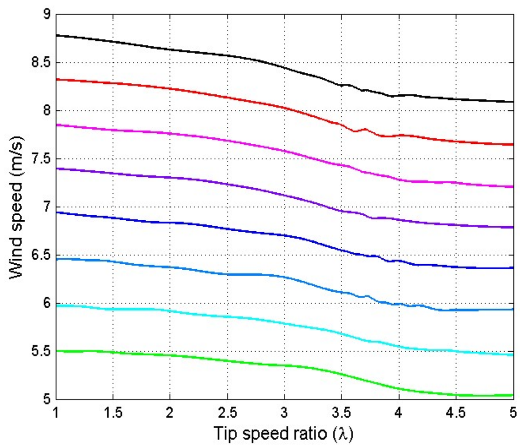
### 3.2 Description of Blade Chord = 0.04m

The spin down tests were also conducted on the VAWT configuration of blade C = 0.04mwith corresponding solidity σ = 0.34 at thefreestreamconditions that the rotor configuration of the smaller C, C = 0.03m was tested. Figure 5 presents the non-interpolated and interpolated plots of the CP - λ, and the decreases in the freestream speed for all the spin down tests. Unlike the observed performance and trend of the configuration with C = 0.03m blade, the region that recorded negative CP is narrower and span from the lowerλ = 1 to high λ = 2.7 for the highest tested wind speed and the VAWT recorded positive CP at λ = 3.75 and λ = 4.4 for all tested wind speeds (Figure 5 (a)). At the lowest wind speed, the VAWT achieved a highest CP = 0.046 atλ = 4.

As the freestream speed is increased at regular interval of 0.5m/s, the peak CP also increased correspondingly until the VAWT reached a maximum of CP = 0.34 at the corresponding λ = 3.75. Convergence of the CP - λ curves at higher tested wind speeds and, a shift of the peak CP towards lower λ with increases of wind speeds is also observed. The observed convergence and shift of the peak CP to lower λ, with further increases in wind speed, thus suggest the VAWT performance can be independent of Re effects if the wind speed were increased further. The influence of Re on the CP is seen more when the VAWT operates at the lower wind speed with corresponding Reynolds number than at a higher wind speed because of the tendency of the Re becoming independent at higher wind speed with the corresponding tip speed ratio.




a

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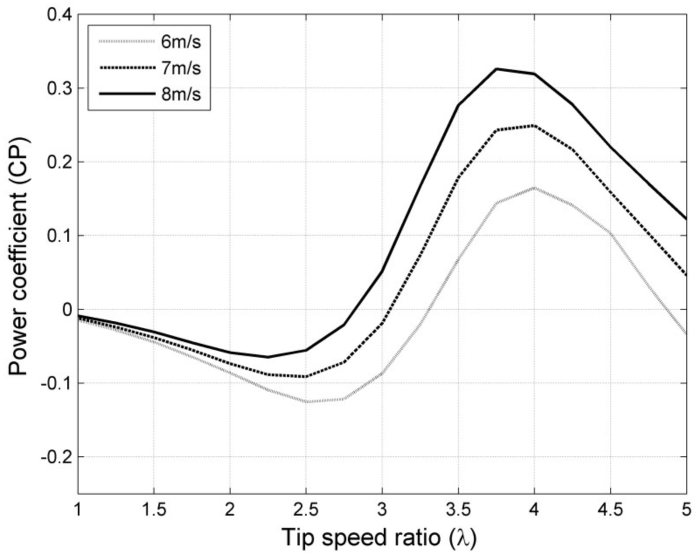


C

Figure 5. Performance of the VAWT of C = 0.04m, σ = 0.034 a) non-interpolated plotsthat shows CP versus λ, b) decreases in the wind speeds for the tests, c) the interpolated plots of CP versus λ.

There is also decreased in the wind speeds during the tests as was previously observed on the rotor with C = 0.03m cases. Figure 6 (b) shows the decreases in wind speeds for all the spin down tests due to blockage. Although the pattern of the decreases in wind speed displayed for the two rotors at the start and end of each test as shown in Figures 3 and 5(b) are similar, there are noticeable differences from λ = 4.5 and up to λ = 2.5 between the drops in wind speeds of the two VAWTs. These observed differences can be attributed to the difference in the blade's chords and solidities of the two VAWTs.

Convergence is also seen in the interpolated CP – λ curves (Figure 4 (c)) as is observed in the data set (Figure 5(b)). Similar to C = 0.03m VAWT, the interpolated CP is higher than the CP of the non-interpolated data set due to the reasons explained earlier. At the highest interpolated wind speed of 8m/s, the VAWT attained a maximum of CP = 0.326 at the corresponding λ = 3.75 whereas the maximum CP = 0.28 is reached by the VAWT at the 8m/ssimilar to the VAWT of bigger Cin the non-interpolated data set at λ = 3.75.

At the negative performance region, a minimum CP = -0.065 for the interpolated 8m/s is recorded as against the minimum CP = -0.08 for the non-interpolated case. However, there are observed similarities seen in the performances characteristics of the two VAWTs under investigation; the effects of Reynolds number are shown clearly in both cases as the CP increase with an increase in wind speed, convergence of the performance curves and shift of the peak CP towards lower λ at higher wind speeds is present in both cases. The negative performance region is also obvious in both cases.

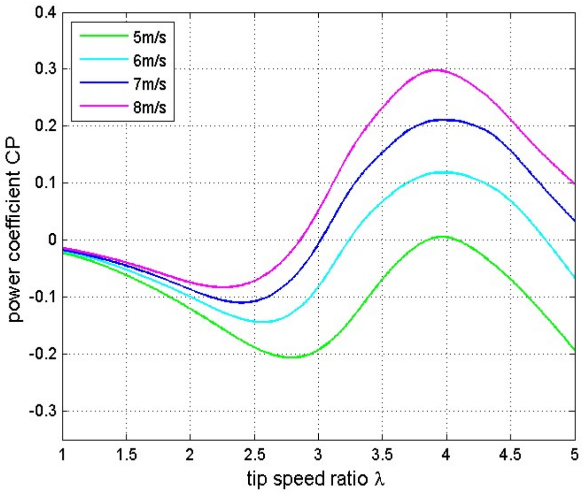


Figure 6. CP –λ curves for spin down test of interpolated CP – λ curves for steady wind speeds (Danao, 2012).

The results are consistent with the works of Danao(2012) and Edwards (2011). They have shown convergence of the CP – λ curves at the higher winds and a negative region (dead band) at the lower λ. The dead band was equally observed by Baker (1982), Kirke (2008) and McIntosh (2009) in their studies. The insignificant difference in the CP observed between Figures 5 (c) and 6) is due to system error arising from replacements of some machine parts. These machine parts that were replaced needed time to break to work full capacity and optimum performance.Despite these differences, the performance trend in the two studies is very similar.

### 3.3 Effectsof blade modification on VAWT performance aerodynamics

The measured and interpolated performances of the configurations of two VAWTs at the different wind speeds are compared in this section. The comparison of the CP of the two VAWTs is based on the 8m/s, 7m/s and 6m/s wind speeds. Figure 7 shows the CP of the two VAWTs at various λ for the 8m/s wind speed. The VAWT of C = 0.03m attained a maximum CP = 0.14 at λ = 4.75 and a minimum CP = -0.14 at λ = 3, also presenting a wider negative power region that runs between λ = 1 and λ = 3.9, while the VAWT of C = 0.04m attained a maximum CP = 0.326 and a minimum CP = -0.065 at the corresponding λ = 3.75 and 2.25, with a smaller negative power region that spans from λ = 1 to 2.75. The differences in the performance of the two VAWTs are due to the differences in the chord lengths resulting in different solidities and Re. At the 8m/s wind speed, the resulting Reynolds number based on C and λ for the C = 0.04m ranges from $Re = 2.2 \times 10^4$ at λ = 1 and $Re = 1.12 \times 10^5$ at λ = 5, that of the C = 0.03m ranges from a minimum of $Re = 1.6 \times 10^4$ at λ = 1 and $Re = 8.4 \times 10^4$ at λ = 5.

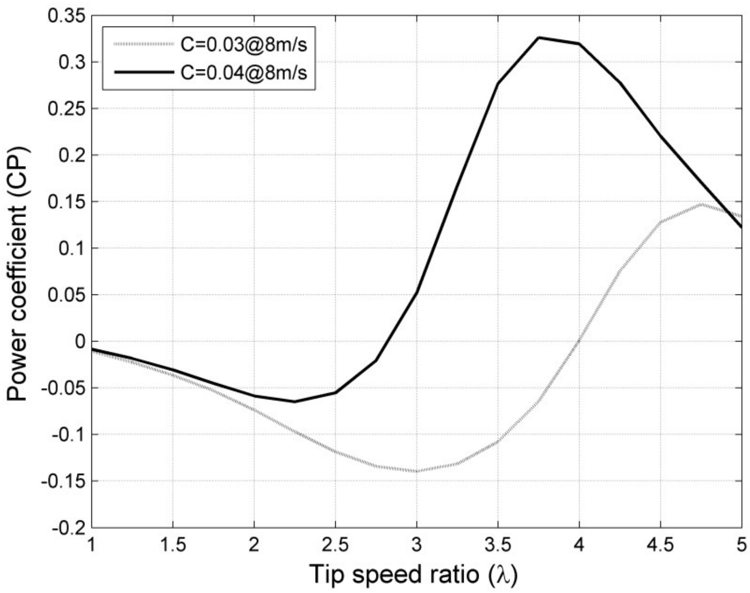


Figure 7. Compares CP versus tip speed ratio of two VAWTs at 8m/s wind speed

For consistency, the performances of the two configurations of VAWT were also investigated at 7m/s and 6m/s wind speeds at similar λ. Tables 1 and 2 show the Re at which the experiments were conducted. Figures 8 and 9 compare the CP versus λ of the two rotor configurations at 7m/s and 6m/s wind speeds. The performance trends of the VAWTs observed in Figure 7 can also be seen in Figures 8 and 9.

Table 1. VAWTs Re at 7m/s for the various λ

| | Reynolds number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **λ** | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| **C = 0.03m (x $10^4$)** | 1.47 | 2.20 | 2.94 | 3.67 | 4.41 | 5.14 | 5.88 | 6.61 | 7.35 |
| **C = 0.04m (x $10^4$)** | 1.96 | 2.94 | 3.92 | 4.90 | 5.88 | 6.86 | 7.84 | 8.82 | 9.80 |

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The VAWT with C = 0.03m presents lower maximum CP values, wider negative power regions, while the VAWT ofC = 0.04m shows higher maximum CP values and narrower negative power regions. It is seen that the power coefficient and efficiency of the two VAWTs configuration are Reynolds number dependent as increases in wind speed had corresponding influences on the CP values at all the λ. From the observed performance of the VAWTs in Figures 7, 8 and 9, it is not only obvious but also evidently shown that the trend of performance of the two configurations is very consistent with changes in wind speeds showing the effects of altering C and Re on VAWT performance.

Table 2. The Reat 6m/s for various λ of the two VAWT configurations.

| | Reynolds number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **λ** | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| **C = 0.03m ($x 10^4$)** | 1.26 | 1.89 | 2.52 | 3.15 | 3.78 | 4.41 | 5.04 | 5.67 | 6.30 |
| **C = 0.04m ($x 10^4$)** | 1.68 | 2.52 | 3.36 | 4.20 | 5.04 | 5.88 | 6.72 | 7.56 | 8.40 |

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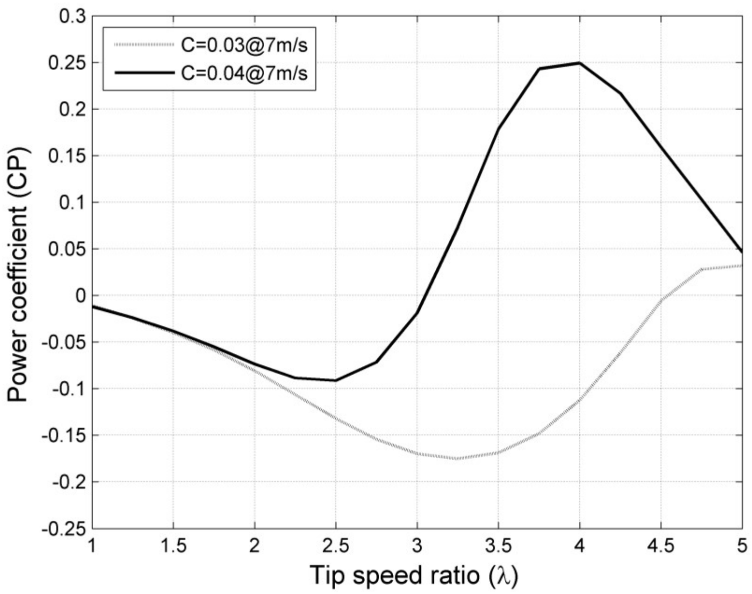


Figure 8. Compares CP and tip speed ratio of two VAWTs at 6m/s wind speed

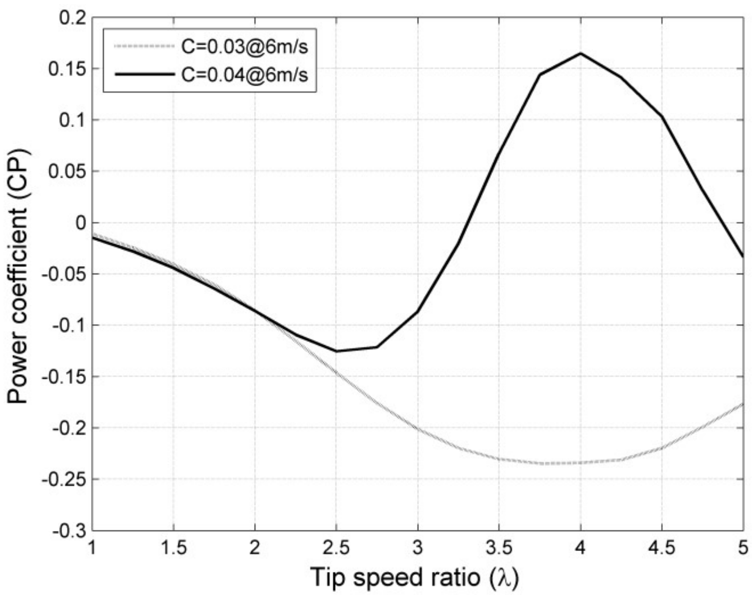


Figure 9. Compares CP and tip speed ratio 6m/s wind speed

### 3.4 VAWTs performance aerodynamics with the same Re

In this section, the CPs at the same Re are examined for the two configurations. The CPs attained at the various λ of the two configurations areshown in the Table 3. The Reynolds number varies from a minimum of 1.68 x $10^4$ to a maximum of 8.4 x$10^4$ at all the λ the experiment were conducted for the C = 0.03m and C = 0.04m VAWTs. The VAWT C and speed were used to calculate the Re.

Table 3. Matching Reynolds number at different λ from 1 – 5 for the two configurations and 8m/s for C= 0.03m and 6m/s for C = 0.4m

| | Reynolds number | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **λ** | 1 | 1.5 | 2 | 2.5 | 3 | 3.5 | 4 | 4.5 | 5 |
| **C = 0.03m (x $10^4$)** | 1.68 | 2.52 | 3.36 | 4.20 | 5.04 | 5.88 | 6.72 | 7.56 | 8.40 |
| **C = 0.04m (x $10^4$)** | 1.68 | 2.52 | 3.36 | 4.20 | 5.04 | 5.88 | 6.72 | 7.56 | 8.40 |

It can be deduced from the Figure 10 thatCP versus the tip speed ratio plot shows differences in the attained CP for the two configurations. The C = 0.03m VAWT present a curve of wider negative performance trough that ranged from λ = 1 to 4. Also the C = 0.03m configuration shows a positive performancetrough that spans between λ = 4 and λ = 5 with corresponding λ = 4.75 and attained a maximum CP = 0.147 and a minimum CP = - 0.14 that corresponds to λ = 3.

In comparison with C = 0.03m VAWT, the C = 0.04m configuration presents a curve of narrower negative performance trough that spans between λ = 1 and λ = 3.3 and a wider positive performance trough that ranged from λ = 3.5 to λ= 4.75. A peak CP = 0.165 and lowest CP = - 0.125 was attained by the C = 0.04m VAWT at the corresponding λ = 4 and λ = 2.5 respectively. The negative performance region shown in the CP - λ curves for the two compared rotor configurations depicts the difficulty in the self-starting ability of the VAWTs. A more difficulty start-up is expected of or characterised the C = 0.03m VAWT as a result ofthe more power needed to overcame the negative power shown in the figure 10. A threshold of an equivalent torques is needed to overcome the negative torque for the rotor to start recording any positive and meaningful performance.

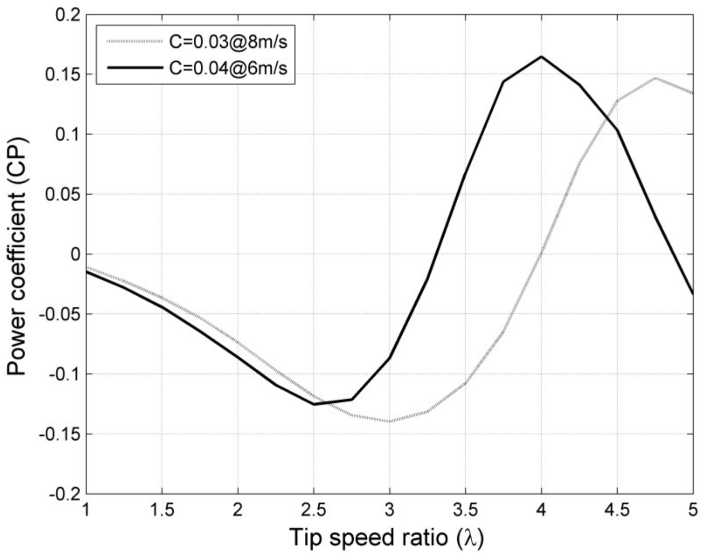


Figure 10. The CP versus λ for the two rotors at the same Re

## 4.0 Conclusion

Blade chord modification effects on VAWTefficiency in performance and aerodynamics have been investigated. The test were conducted in a tunnel with open suction, low speed and turbulent intensity. Two configurations of the VAWT showed significant results which the under listed conclusions could be drawn.

The performance efficiency and aerodynamicsof the investigatedVAWTs is λ and Re dependent especially when the wind machines operate at low or at a transition range of Re. At lower Reand λ a region of negative performance that is wider with decrease in the C is seen. This hinders the self-starting capability of VAWTs. This negative dead band is observed in the trend of theplotted CP - λ graph of the VAWTs configurations with C = 0.03m VAWT having shown wider negative band that resulted from the influence of Clength and directly the solidity. This negative band decreased in both cases as the free stream speedincreased from 5m/s to 9m/s, with significantdifferences in performance efficiencyand the CPof the compared two rotorconfigurations.

VAWT performance has been observed to increase with increases in Cat all the wind speeds compared. Decreases in the C initiate a wider band of negative region, hence a drop in lift and power extraction, while an enlargement in the C causes the narrowing of the band of negative performance aerodynamic region. At the positive section of CP - λ curves and performance region, it is deduced that increased C reduces the peak power region while decreased C increased the peak performance power region of the curve. At the wind speed of 8m/s,the VAWT with C = 0.04m, σ = 0.34 reached a peakCP = 0.326 while C = 0.03m, σ = 0.26 achieved a maximum efficiency CP = 0.146 suggesting a better performance with bigger bladed VAWT.

Optimisation of the blade chord is recommended to ascertain the optimum length required for best aerodynamic performance and overall output of vertical axis wind turbines.

**Acknowledgements**

The author expresses his profound gratitude and thanks to the Tertiary Education Trust Funds (TETFund) of Nigeria for sponsoring the research work at the University of Sheffield, United Kingdom.

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