Effect of Blade Sweep Angle with Blade Pitch Angle on the Performance of Wells Turbine

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Abstract: The Wells turbine for wave energy conversions has been computed numerically. Wells turbine is a part for the effective experimental wave energy transmitter the Oscillating water column (OWC). The effect of pitch and sweep angles of blade for standard profile NACA0025 airfoil have been considered to improve the aerodynamically overall efficiency of Wells turbine. Optimum design proposed to increase overall efficiency, peak torque coefficient, difference of pressure and mass flow coefficient with velocities. This research aims to analyze the result of pitch angle and sweep angle taking place the overall performance for Wells turbine. The torque coefficient and the consistent efficiency are the basic independent parts, which are take full advantage of mechanical devices depend on on renewable energy. Oscillating axial force and tangential force are basic feature that even by the cyclic airflow.

Keywords: *Wells Turbine, Pitch Angle, Sweep Angle, Simulation, Airfoil Design*

1. Introduction

SEVERAL decades in the previous expenditure of energy are productively increased, and conventional fossil fuel is not enough to meet the demands and their price is increasing day by day, the alternative source of energy becomes unavoidable. Scientists and Engineers are hooked to meet the current requirements of energy for available resources. Generally, a shortage of energy is greater in the developing countries because of their capital as well as operating cost of the plants is difficult to afford. For this solution, some attempts are going to made to create such sources of energy that have the least capital cost as well as the operating cast [1].

Oscillating water column (OWC) principle make used by definite wave energy devices. Perhaps, OWC is the best wave energy converter device, it has been the most fruitful used for wave energy converting, and OWC is forming reciprocal airflow [2]. The reciprocal fluid flow produced by open surfaces inside the chamber due to the changeover of the surface for the water. That exchange produces a tangential and axial flow force, an air turbine is operating on this fluid flow. This helps to produce a reciprocating flow, which turns round in solo direction for the reciprocating flow [3-5].

[4]; The other application of the axial flow turbine is the implement of this rotary device in the flow of the wastewater, there is the large quantity of wastewater in the urban areas and small cities everywhere, the larger the quantity of water the larger power can be extracted from it, this power can be collected at one center and it may become a ride to escape from the energy crisis specially the load-shedding which is a major problem of our nation, it can' be a primary way to decrease load-shedding but this system will be helpful for this cries.

The detached of this research is to investigate the effect of blade sweep and blade pitch angle on the enactment of the Wells turbine, as the optimum blade shape for the Standard airfoil NACA0025.

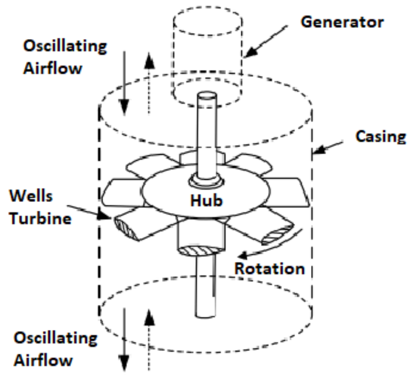

Figure.1 sketch of wells turbine

2. Related Work

[4] Rotor type blades are the sweetest able to be increasing the efficiency of the turbine. [3]. Guide vanes increase the performance by fixing very near to hub on rotor the extension of stall can be obtained. [1] It is finalized that the optimization of the turbine blade angle known as pitch angle essentially vanquishes problems of wells turbine, by using CFD simulation, in regards to accurate CFD results. [6] Simulation of the swept blade has positive effects on overall efficiency, by using the CFD simulation the peak-torque coefficient and the corresponding efficiency are assessed due to blade sweep for wells turbine. [7] Inlet guide vanes are sufficient for overall efficiency, it is suggested to install inlet guide vanes with self-pitch blade controlled wells turbine. [1] The optimal blade pitch angle designed for NACA 0021 is between +0.3° & +0.6°. These results show the optimal blade angle depends on airfoil structures. [8] Due to optimization (numerically) the effects of blade pitch angle. The blade geometry has a normal NACA 0021 airfoil at the blade pitch angle equals zero. [9] With the sweep ratio of 0.35°, airfoil NACA0020 gives sufficient overall enactment of wells turbine. [10] Wells turbine requires the proper opinion of irreversibility flow around the turbine

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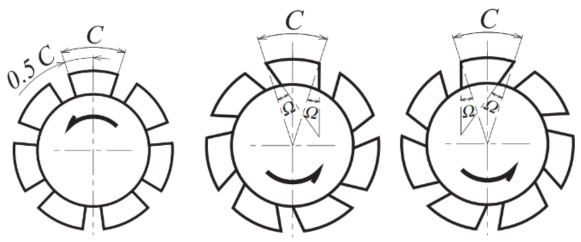
blades is second law analysis. [11] Well modified blade profile gives sufficient torque for the hydrokinetic turbine, for the transformation of rotor torque a magnetic coupling is used and anglicized in the 3D CFD method for a hydrokinetic turbine, obtained by the focusing on blade profile modification.

3. Methodology

The methodology about optimization for the optimal sweep and pitch angles of the blade numerically [1, 4]. The current numerical to extend the enactment. Presents the optimization practice. At first, a standard airfoil (NACA0025) blade profile was engaged, the transposition computing process area was calculated in the first designed and connected data existing in the literature for the enactment of parameters. An algorithmic program finds the feasible points in surrogate models and is used in drawing the graph evaluated by the CFD programmer [6].

3.1 Current Profile of Blade with Applying Sweep Angle Ω = 18°

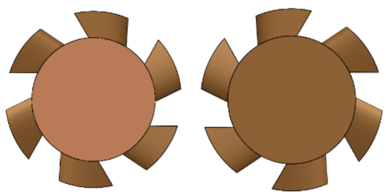
The following are three different proposed designs of rotor Blade profiles.



(a) Normal (b) Forward Swept (c) Back swept

Figure.2 (a) to (c) Shows a 2D model of normal, forward, and backswept.

3.2 3D Models of forwarding and Back Swept



(a) Forward swept. (b) Back Swept

Figure.3 (a) and (b) shows 3D view of Ω = 18° forward and backswept.

What are the different proposed designs of Rotor type Blades profiles? Correspondingly the Sweep angle is 18° degrees designed for the swept forward and swept backward blades. The rotary device with Fan-Shaped blades is capable to acquire the high efficiency for the best performance. These have additional performance as equal to the existing design of rotor blades profiles used [4].

3.3 Current Profile of Rotor Blades with Applied Pitch angle γ = 2°.

Wells turbines enactment under physical operating conditions magnifies a modest, operative, and practical mechanism plan that can be Pitch angle control of wells turbine. Forces investigation for a Wells turbine blade, and scenery the blades at their optimal pitch angle is anticipated appreciably improve wells turbine efficiency.

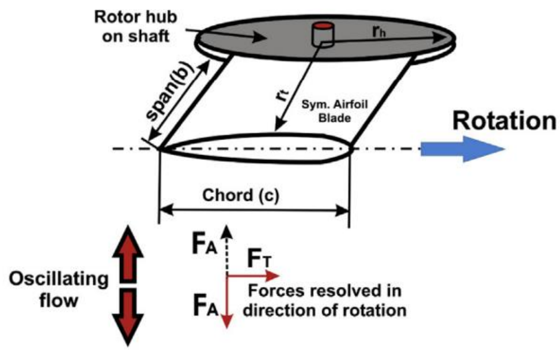


Figure.4 Forces analysis for applying pitch angle

Figure.4: Shows the Schematic explanation and main dimensions for forces study for a Wells turbine blade Pitch angle. Since numerous studies have been conducted on wells turbine, nevertheless, a diligent effort has not been completed up till now, that regarding the optimal pitch angle with optimal sweep angle designed for maximizing the overall efficiency of Wells turbine [1].

3.4 Blade Design γ = 2° Pitch angle with Ω = 18° Sweep Angle.

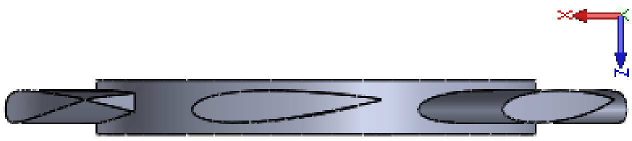


Figure.5 Top view of Blade design

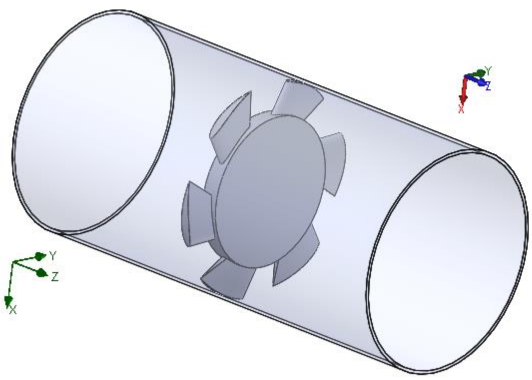


Figure.6 cylindrical view of wells turbine

Figure.5 & 6. Shows the Wells turbine using new types of blades is modeled. Change in Sweep Angle and Pitch Angle modification is focused, and Solidworks generated the coarse type mesh using the tool. It is also perceived as the highly turbulent fluid flow inside the Wells turbine.

3.5 Boundary Conditions of Blade at γ = 02° pitch angle with Ω = 18° Sweep angle

Table 1.1: The model dimension of Wells Turbine

Specification	Dimensions
Mean radius, r	127.5 mm
Aspect ratio	0.5
Number of blades, z	6
Casing diameter, D	300 mm
Hub to Tip ratio, v	0.7
Tip clearance	1 mm
Cylinder length, L	1700 mm
Tip diameter	299 mm
Solidity at mean radius, σ	0.67
The Chord length, l	90 mm
Width of the flow passage, h	45 mm
Applied Sweep Angle,	18°
Applied Pitch Angle,	02°

3.6 Mathematical Equations

(a) $m = \rho v A$

(b) $T = 1/2 \rho A C t V^2$

(c) $Cp = T\omega / 0.5 \rho A V^3$

4. Results and Discussion

Fresh models' effects are matched with present models. Additionally, simulated models also distinct graphically depiction. Similarly, flow trajectory altered models and pressure coefficient for standard NACA0025 at the optimal design of the blade pitch angle designed for diverse values of the flow coefficient at a different point. Further, parametric studies and tables of simulated productivity mandatory results created by the software are recognized. Using these Graphs diverse requisite output physical parameters are calculated. These parameters are defined in diverse charts so that results can effortlessly be understood.

4.1 Flow Trajectory of wells turbine with γ = 2° pitch angle & Ω = 18° sweep angle for standard NACA0025 airfoil

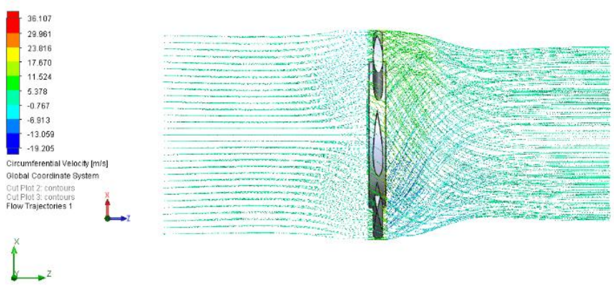


Figure.7 Circumferential velocity flow trajectory of wells turbine with γ = 02° pitch angle & Ω = 18° sweep angle for standard NACA0025 airfoil Blades.

The flow trajectory of the design of Wells turbine in a new design of this study shown in fig 7 having both zigzag and helical direction flow trajectory and outlet circumferential velocity is maximum as equated to previous circumferential velocity flow trajectory that increases the overall performance.

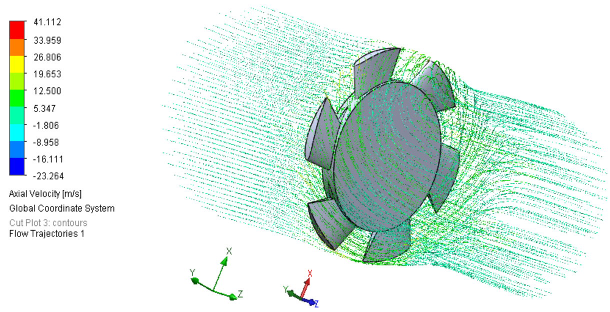


Figure.8 Axial velocity flow trajectory of wells turbine with γ = 2° pitch angle & Ω = 18° sweep angle for standard NACA0025 airfoil Blades.

Figure 8 shows Wells turbine with axial velocity flow trajectory, it can be observed in this flow trajectory that the fluid course the path is helical and decrease and increase in performance with affect drop in pressure has very few dead zones. This outlet axial velocity is maximum as an associated previous axial velocity flow trajectory that increases the overall performance. It is initiate that it has additional performance as equal to an existing design

4.2 Pressure Drop Simulated cut plot of wells turbine with γ = 2° pitch angle & Ω = 18° sweep angle for standard NACA0025 airfoil

Pressure drops openly distresses the enactment, efficiency, and functioning cost of Wells turbine. The further the pressure drops more the power consumed by blades and reduces the overall efficiency.

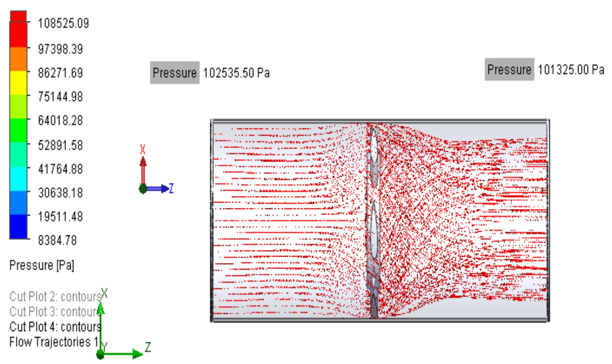


Figure.9 Cut Plot of Pressure Drops Occurs Inside Of Wells Turbine With γ = 2° Pitch Angle And Ω = 18° Sweep Angle.

Figure.9 Shows cut plot for the drop of pressure inside of Wells turbine, it is practical that the turbine inlet pressure is 102535.50 Pa and the turbine outlet pressure is 101325.00 Pa, So the pressure drop is 1210 Pa.

4.3 CFD Parametric Studies of Wells Turbine Blade Model of Airfoil NACA0025 with Pitch Angle γ = 2° at Sweep Angle Of Ω = 18°.

Efficiency, mass flow rate, axial force coefficient, tangential force coefficient, flow coefficient and power charts for NACA0025 airfoil with Pitch angle γ=2° at Sweep angle is Ω=18° of blade used in Wells turbine

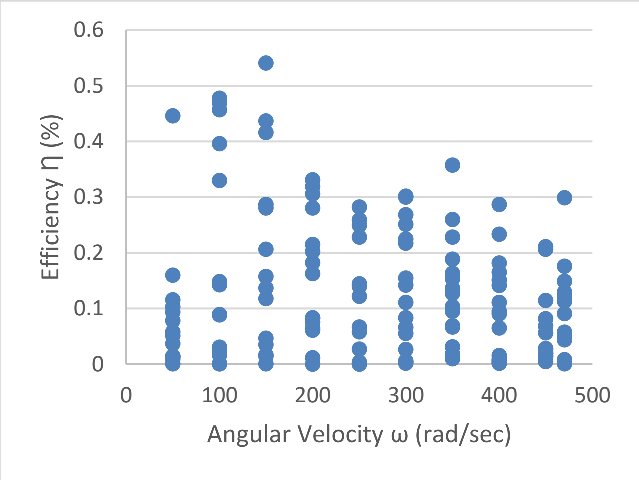


Figure 10. The efficiency of the NACA0025 Blade Variation for Angular Velocity at Optimum Blade Pitch Angle

Figure 10. Presents the efficiency of the standard NACA0025 at different Angular velocities. Wells turbine with optimal blade pitch and sweep angle has advanced efficiency at (150 rad/s) angular velocity, the Efficiency is (0.54η) maximum for Wells turbine.

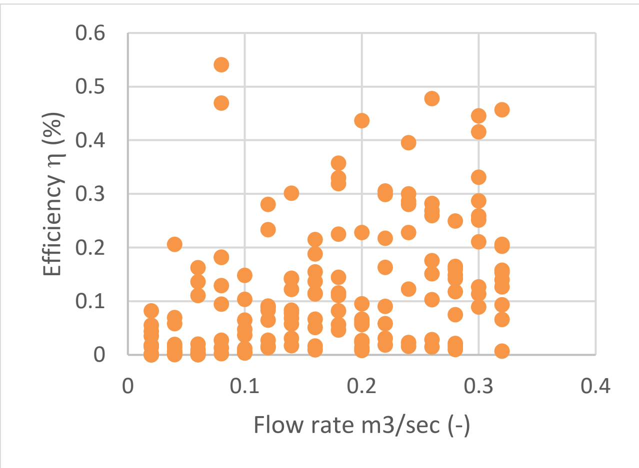


Figure 11. Variations of Efficiency for mass flow rate.

Figure 11. Depicts the result of the Flow rate on the efficiency of the turbine blade. At 0.08 m3/s flow rate, the efficiency is a maximum of 0.54η.

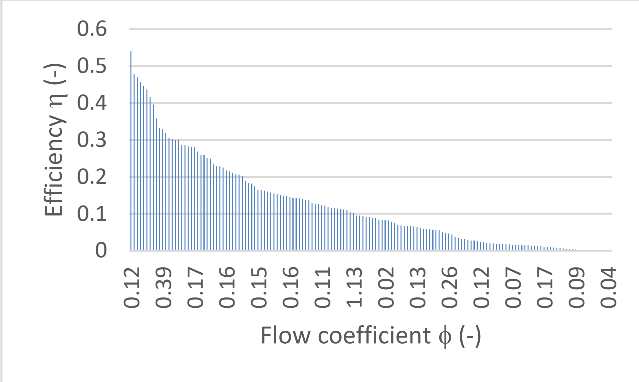


Figure 12. Variations of Efficiency to the Flow coefficient occurs in Wells turbine.

Figure 12. Shows the effect of the mass flow coefficient on the efficiency of the turbine. At 0.116 mass flow coefficient, efficiency is a maximum of 0.54η for the standard NACA0025.

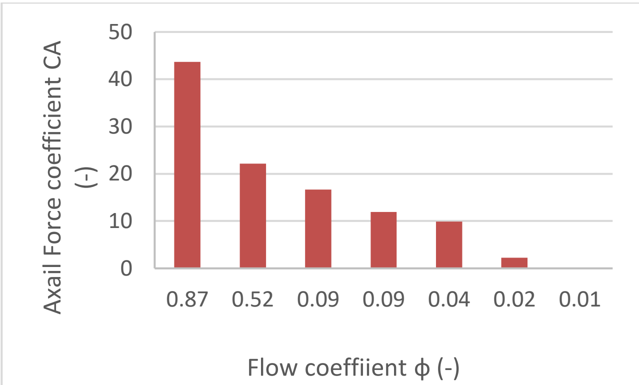


Figure 13. Result of Flow coefficient on Axial force Coefficient.

Figure 13. Displays the consequence of the mass flow coefficient upon the axial force coefficient. At the 0.87 mass flow coefficient, the axial force coefficient is a maximum of 43.64.

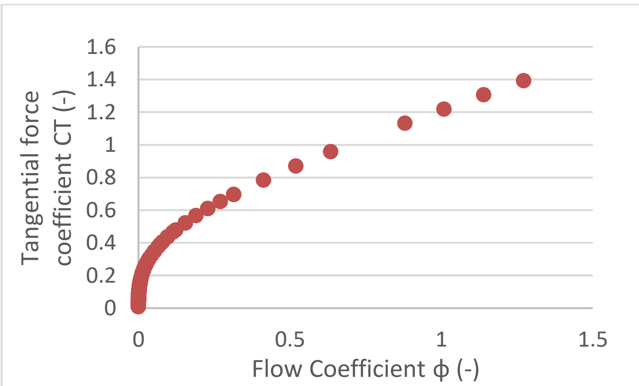


Figure 14. Tangential force coefficient VS Flow coefficient.

Figure 14 displays the effect of the flow coefficient with the tangential force coefficient. At the 1.393 flow coefficient, the tangential force coefficient is a maximum 1.27 for the standard NACA0025 blade airfoil with optimum blade pitch and sweep angle. The blade sweeps angle and pitch angle for enhancing flow coefficient are perceived as those angle optimizations also results in a reduction of left-over fluid flow.

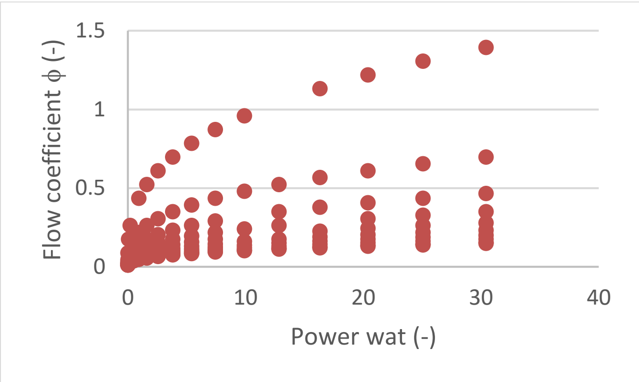


Figure 15. Optimum power for maximum efficiency for the standard NACA0025 at an optimum blade pitch angle.

Figure 15. Shows the variation of power on the variation of flow coefficient. Considered the maximum Power for NACA0025 to be about 30.4wat during Flow coefficient is 1.272 respectively.

New proposed design of blade including γ = 2° Pitch angle with Ω = 18° sweep angle blade of standard NACA0025 airfoil, is analyzed and the result demonstrations in the graph that this newly projected type of blade have high Efficiency Comparatively previous available blades while increasing overall efficiency and that assistances the overall performance of wells turbine. Therefore, it is recommended that at required mass flow rate novel types of the blade γ = 2° Blade pitch with Ω = 18° sweep angle blade to be used for receiving maximum performance. For the low turbulence inflow, this fresh novel designed of the blade has greatly better results and this design is not used afore. Hence, these blades reduce the operating cost save energy with an increase in overall performance.

5. Conclusion

In this research, a CFD model is generated to compare and compute the results of blades' designs on the enactment of the Wells turbine to maximize its overall efficiency numerically. Its beneficial for those countries friendly come across at oceans or seas from them Wave energy can intensify the renewable energy part.

This blade γ = 02° optimum pitch angle with Ω = 18° optimum blade sweep angle blade was simulated to realize the effects of blades' design on the overall velocities, pressure drop, torque with co-efficient in XYZ direction and Efficiencies. Efficiency swell effects if the pitch and sweep angle of blades' is improved. Therefore, altering the blades' design with optimizing the blade pitch and sweep angle of the standard NACA0025 airfoil profile, it is recommended that γ = 2° optimum pitch angle with Ω = 18° optimum blade sweep angle blade maximize the overall efficiency of Wells' turbine.

It was also concluded without a pitch and sweep angle blade occurs whereas low tangential and axial torque grosses place. This matter is resolute by using new blades' design. New optimum design as associated with the previously used design of blades can lower the efficiency drop and improved the overall efficiency of the Wells turbine.

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