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Review on Performance and Working of Wells Turbine for Wave Power Conversion

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Abstract— The one of the method of wave energy conversion utilizes an oscillating water column (OWC) like Wells turbine. The OWC changes wave energy into low-pressure pneumatic energy as bidirectional airflow. Wells turbine with its zero blade pitch setting has been utilized to change this pneumatic force into unidirectional mechanical shaft power. But a Wells turbine has somewhat disadvantages like lower effectiveness and poorer beginning attributes. To improve the starting and running characteristics of wells turbine, many experimental and numerical studies have been done based on different parameters like Providing Guide vanes, Changing the hub/tip ratio, Providing End plate to the blade Section, Giving guide vanes on either side of the rotor could be standout of the most effective ways of improving its performance. This paper includes parameters controlling the performance of the wells turbine.

Key words: Oscillating Water Column, Wells Turbine, Wave Energy Conversion

I. INTRODUCTION

A Turbine Is A Rotary Mechanical Device That Extracts Energy From A Fluid Flow And Converts It Into Useful Work. A Turbine Is A Turbo-Machine Consisting Moving Part Called A Rotor Assembly, Which Is A Shaft Or Drum With Blades Attached. Renewable energy is generally defined as energy that comes from natural resources which are recharged on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy replaces traditional fuels in four distinct areas: electricity generation, air and water heating/cooling, motor fuels, and rural (off-grid) energy services. The five renewable sources used most often are: Biomass (including wood and wood waste, municipal solid waste, landfill gas, biogas, ethanol, and biodiesel), Hydropower (including tidal, water potential and ocean wave energy), Geothermal, and Wind & Solar energy. India is the fourth largest energy consumer in the world after the United States, China, and Russia. In recent years, India's energy consumption has been expanding at a relatively fast rate due to population growth and economic development. The worldwide energy demand is continuously growing and, according to the forecasts of the International Energy Agency, it is expected to rise by approx. 50% until 2030.Currently, over 80% of the primary energy demand is covered by fossil fuels.[1]

Wave power is the transport of energy by ocean surface waves, and the capture of that energy to do useful work – for example, electricity generation, water desalination, or the pumping of water (into reservoirs). A machine able to exploit wave power is generally known as a wave energy converter (WEC). There is a large amount of ongoing work on wave energy due to a broad availability which cannot be done justice in a brief overview. For ease of presentation, the activities will be divided between the technologies suitable for deployment on the shoreline, near the shore and offshore.[2]

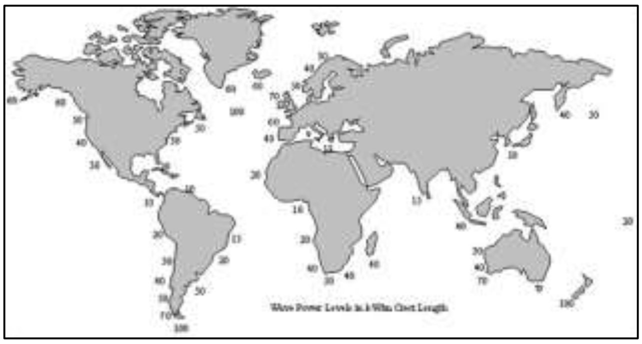

Fig. 1: Global Distribution of Deep Water Wave Power Resources [2]

An OWC consists of a chamber with an opening to the sea below the waterline. As waves approach the device, water is forced into the chamber, applying pressure on the air within the chamber. This air escapes to atmosphere through a turbine. As the water retreats, air is then drawn in through the turbine. A low-pressure Wells turbine is often used in this application as it rotates in the same direction irrespective of the flow direction, removing the need to rectify the airflow.[3]

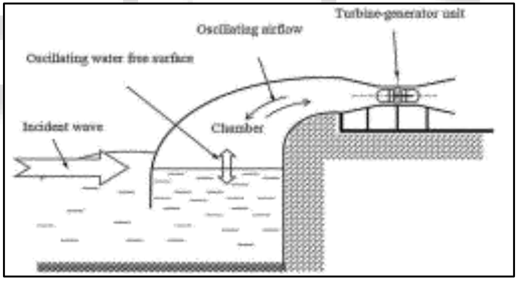

Fig. 2: Oscillating Water Column [3]

Dr. A.A. Wells, a former Assistant Professor of civil engineering at Queen's University, Belfast, proposed in 1976 a form of self-rectifying axial flow air turbine as a device suitable for wave energy conversion using the oscillating water column. In its simplest form the air turbine rotor consists of several symmetrical airfoil blades positioned around a hub.

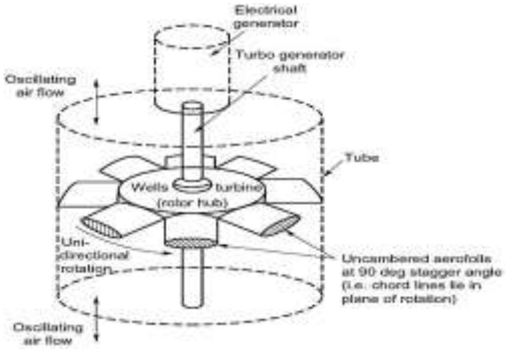

Fig. 3: Wells Turbine[4]

The principle of operation of Wells turbine is based on the classical airfoil theory. According to the classical airfoil theory, an airfoil which is set at an angle of incidence α in a fluid flow generates a lift force L normal to the free stream. The airfoil also experiences a drag force D in the direction of the free stream (relative velocity). These lift and drag forces can be resolved into tangential (in the plane of rotation) and axial (normal to the plane of rotation) components F_T and F_A respectively.

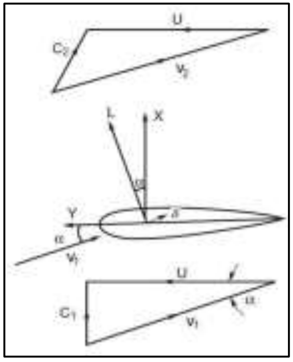

Fig. 4: Velocity and force vectors acting on aerofoil [4]

$$F_A = L \cos \alpha + D \sin \alpha$$

$$F_T = L \sin \alpha - D \cos \alpha$$

II. LITERATURE REVIEW

Toshiaki Setoguchi et al.[5] did research and the objective of study was to compare the Performances of bi-directional turbines under irregular wave condition, which could be used for wave power conversion in the near future. The overall performances in connection with the behaviour of oscillating water columns have been evaluated numerically. The types of different turbines were included for study and in the study, the experimental investigations were carried out to check the performance under steady flow condition and then the numerical simulation was used for predicting the performance of the turbine under irregular wave condition, which typically occurs in the sea. As a result, it is found that the running and starting characteristics of the impulse type turbines could be best to that of the Wells turbine under irregular wave condition.

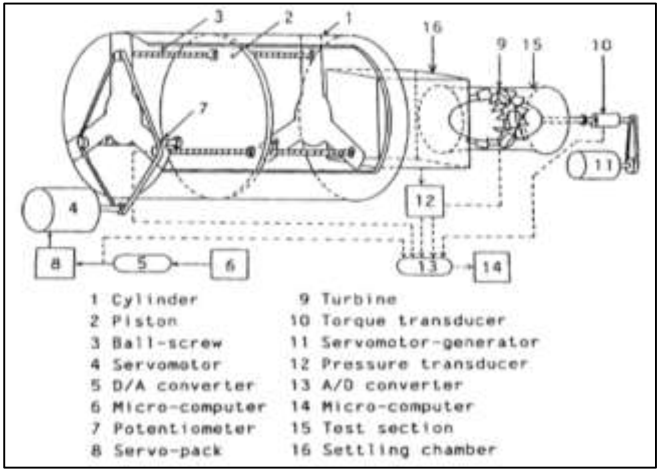

Fig. 5: Test Rig

Taeho Kim et al.[6], study shows the effect of blade geometry with the hub-to-tip and aspect ratios of rotor on the turbine performance was investigated with a numerical technique. Practically, it is recommend that the optimum geometry for the Wells turbine due to the complex interrelation among essential parameters, the solidity, hub-to-tip ratio, aspect ratio, blade sweep of rotor, and so on. So author carried out numerical investigation taking blade profile NACA 0020 with blade sweep ratio = 0.35, solidity at mean radius = 0.67. Effect of hub to tip ratio and aspect ratio were studied by varying them and keeping other parameters constant.

As a result, the optimum blade geometry is as follows: the hub-to-tip ratio is about 0.7, and the aspect ratio about 0.5 under other constant important parameters, NACA0020 blade with blade sweep ratio of 0.35, and solidity of about 0.67, which have been concluded as optimum design for blade geometry.

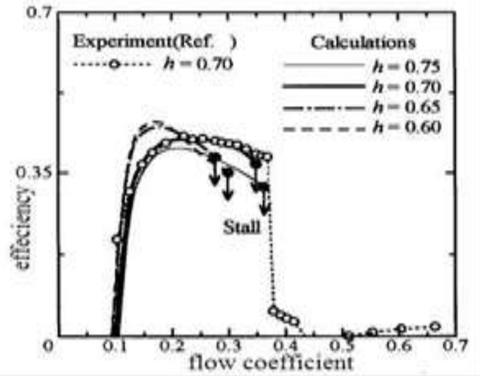

Fig. 5.1: Effect of hub to tip ratio

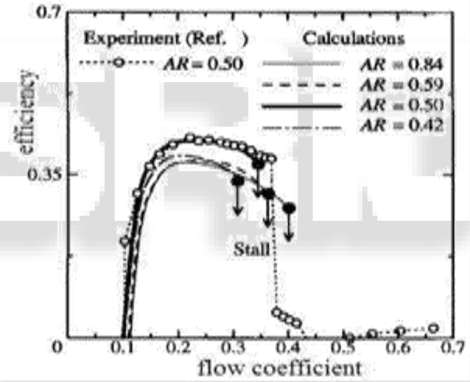

Fig. 5.2: Effect of Aspect Ratio

K. Kaneko et al.[7] investigates the performance of the Wells turbine, an axial flow air turbine used for wave power conversion. The Wells turbine has the benefit of not requiring rectifying air valves and can extract power at low airflow rate, when other turbines would be inefficient. But the Wells turbine is also suffered from the limitations of a relatively narrow operating range, poorer starting characteristics and higher noise level in comparison to the conventional turbines. In this paper, an attempt is made to enhance the performance of the Wells turbine by attaching a very thin endplate (approximately air foil shaped) with a relatively larger chord length at the tip with an aim to reduce the tip leakage flow resulting in the improvement of the performance. Both experimental test and numerical investigations are made and it is found that the endplate for sure add to the change of the Wells turbine execution.

M.H. Mohamed et al.[8] carried out Multi-objective optimization of the air foil shape of Wells turbine. All the hypothetical and experimental investigations recorded in the past area only consider the performance of Wells turbines utilizing standard symmetric air foils of type NACA 00XX And some reference researches demonstrated that NACA

0021 air foil profiles lead to the best performance. Author concentrated on the optimization of a symmetric air foil shape, leading to the best possible performance of a Wells turbine using optimum shape other than standard aerofoil. This optimization procedure was able to recognize a extensively better configuration than the standard design relying on NACA 0021. A relative increase of the tangential force coefficient exceeding 8.8% (as a mean, 11.3%) is obtained for the full operating range. At the same time, the efficiency improved also by at least 0.2% and up to 3.2%.

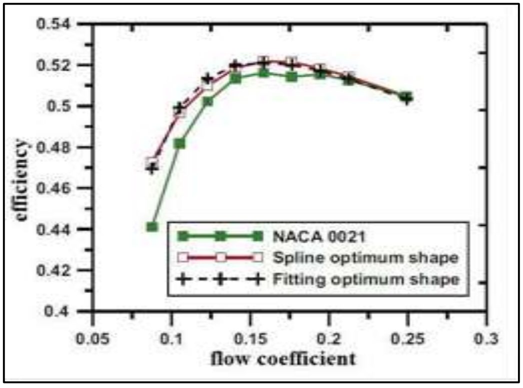

Fig. 6: Performance of optimum shaped blade

T. Setoguchi et al.[9] found that the axial airflow velocity during exhalation is higher than that during inhalation. As per creator the stream rate is not symmetric as for bearing and doubtlessly adjusting a Wells turbine with a non-zero rotor edge setting edge may have better execution contrasted with the Wells turbine. T To clear up the execution of the Wells turbine utilizing edges with setting edges tests done utilizing a test rig having 300mm width test area. Piston-cylinder mechanism was used to produce waves. Tests were performed with turbine shaft precise speeds up to 471 rad/s and the stream rates up to 0.320 m^3 /s. Tests were performed with various setting edges - 4,- 2, 0, 2, 4 degree likewise the running attributes of turbine was measured with and without guide vanes. The values of V i /V o ware 0.6, 0.8 and 1.0 used for calculation. From various results and quasi steady analysis it was found that the new turbine utilizing rotor sharp edges with an altered setting edge was better than the Wells turbine, and that the ideal setting edge is 2° in both with guide vanes and without guide vanes configurations.

S. Shaaban et al.[10] further studied the effect of duct geometry on the performance of wells turbine. The basic governing equations were solved in the absolute frame and discretised by the finite volume technique using the CFD code ‘‘Fluent’’. The author studied the effect of mesh size on efficiency. The grid size was expanded in five slow strides from 735,540 cells to 1,131,540 cells. This test demonstrated that the most extreme rate variety in torque coefficient is ±1.32%, in productivity ±1.19% and in weight drop ±1.22%. Further he indicated correlations between Gato trial results and numerical results given by various models, Torresi et al. used Spalart turbulence model and the two-equation SST k–x turbulence model with two different mesh sizes and The present simulation using realizable k–e model and non-equilibrium wall function. Deviation of numerical results from experimental results under stall and deep stall conditions are clearly depicted as was expected because steady RANS models fail to model turbine performance under complex stall conditions. Therefore, many authors simulate the turbine performance up to stall point when proposing new Wells turbine design modification. Finally, author studied numerically the effect of duct on turbine performance by changing the duct inlet area to duct throat area (Aspect Ratio) and diffuser angle. The numerical examination uncovers that channel territory proportion AR = 1.5 is viewed as the ideal zone proportion for the explored turbine as a most extreme estimation of 10% expansion of the turbine force is accomplished. Expanding the conduit edge to an ideal estimation of 7° at this ideal AR guarantees detachment free stream in the downstream diffuser and up to 14% change in turbine control and up to 9% expansion of the turbine efficiency.

Zahari Taha et al.[11] found that non-uniform tip clearance gives better performance against uniform tip clearance. So Zahari Taha examined the execution of wells turbine with different non-uniform tip clearances with the utilization of CFD. The examination was performed on numerical models of a NACA0020 edge profile under steady flow conditions. The computational results of this study were compared with the values obtained by experiments. To obtain non-uniform tip clearance the gap increased gradually from leading edge to trailing edge, average size of the gap was taken from 0.63 to 1.13. From the studies it was found that a turbine with a bigger tip clearance would have a more operational scope of flow without slowing down. Moreover, the peak efficiency of the turbine decreases and movement towards a higher value of the flow coefficient as the tip clearance increases.

Devendra Patel et al.[12] analysed the effect of flow co-efficient on the performance of wells turbine by using computational fluid dynamics software. In this paper they worked on different flow coeffient for 0.15 to 1.5 with varying turbine rotor speed ranging from 1000 rpm to 1500 rpm. As a result, they found the Torque on blades and efficiency for different flow coefficient with varying different speed generated by wells turbine. By using Simulation , they found that as flow coefficient increases with respect to increasing the turbine speed , Efficiency of the turbine also increases upto certain value , after which it decreases. Abrupt changes in efficiency represents stalling effect. Maximum efficiency of Wells turbine is achieved at 1500 rpm at flow coefficient 0.2.

III. CONCLUSIONS

- The solidity of the turbine, is a measure of blockage to airflow within the turbine. For a wave vitality gadget with a vast accessible weight drop a high solidity turbine with a diminishment in productivity can be utilized. A low solidity turbine, in any case, does not be able to self-begin. For ideal execution the estimation of solidity is kept somewhere around 0.6 and 0.8.
- The hub-to-tip proportion affects: (1) the wind current occurrence at the hub (2); the spillage misfortunes at the tip; and (3) the relative impedance impacts at the hub. For a turbine working at a certain speed, the rate at the hub is bigger than the occurrence at the tip and increments with a diminish in hub-to-tip proportion. In this manner, it ought not out of the ordinary that a diminishing in the hub-to-tip proportion ought to advance a prior turbine slow down and prompt a decline in the streamlined proficiency.

- Validation research concluded that CFD can be successfully applied to wells turbine study. From the comparative results of CFD analysis of wells turbine without guide vanes and wells turbine with guide vanes, it is concluded that Guide vanes have greater impact on performance of wells turbine. Research also says that Efficiency of wells turbine can be increased by providing guide vanes.
- Wells turbine is very sensitive to the tip clearance. Decrease in Tip clearance increases cyclic efficiency as a result of decreased leakage losses. On the other hand, a turbine with a relatively large tip clearance could operate over a much wider range of flow rate without stalling.
- Curves of bidirectional flow and single directional flow are having almost same nature, so it can be said that characteristics of wells turbine can be also studied by doing one dimensional steady state flow analysis on wells turbine.
- Providing Uniform and Non-uniform tip clearance on blade rotor may also vary the Wells Turbine performance.
- Using Simulation, It is found that as Flow coefficient increases, Torque also increases. the flow co-efficient φ increases with respect to speed of wells turbine, efficiency of turbine η is increase up to certain value, after which it decreases. So it is also concluded that sudden drop in efficiency shows the stalling effect. And obtain the efficiency from range 4.79% to 43.39%.

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REFERENCES

[1] US Energy Information, India full report, 26 June 2014.
[2] Thesis- Mohamed Hassan Ahmed Mohamed, Design Optimization of Savonius and Wells Turbines, Otto Von Guericke University, 2011.
[3] T. V. Heath, “A review of oscillating water columns.” Phil. Trans. R. Soc. A, 370, 235–245, 2012.
[4] S. L. Dixon, Fluid Mechanics and Thermodynamics of Turbo machinery, 5th Edition.
[5] Tae-Ho Kim, Manabu Takao, Toshiaki Setoguchi, Kenji Kaneko, Masahiro Inoue,” Performance comparison of turbines for wave power conversion”, Int. J. Therm. Science,40, 681–689,2001.
[6] Taeho Kim ,Toshiaki Setoguchi ,Yoichi Kinoue , Kenji Kaneko , Effects of Blade Geometry on Performance of Wells Turbine for Wave Power Conversion, Journal of Thermal Science, Vol. 10, No.4, 293-300, 2001.
[7] M. Mohammad, Y. Kinoue, T. Setoguchi, K. Kanekoand A.K.M.S. Islam, Improvement of the Performance of the Wells Turbine By Using A Very Thin Elongated Endplate At The Blade Tip, Proceedings of the 3 rd BSME-ASME International Conference on Thermal Engineering, 20-22, Dec 2006.
[8] M.H. Mohamed, G. Janiga, E. Pap, D. Thévenin, Multi-objective optimization of the airfoil shape of Wells turbine used for wave energy conversion, Energy 36, 438-446, 2011.
[9] T. Setoguchi, S. Santhakumar, M. Takao, T.H. Kim, K. Kaneko, “A modified Wells turbine for wave Energy conversion”, Renewable Energy, 28, 79–91, 2003.
[10] S. Shaaban, A. Abdel Hafiz, “Effect of duct geometry on Wells turbine performance”, Energy Conversion and Management, 61, 51–58, 2012.
[11] Zahari Taha, Sugiyono, T.M.Y.S. Tuan Ya, Tatsuo Sawada, “Numerical investigation on the performance of Wells turbine with non-uniform tip clearance for wave energy conversion”, Applied Ocean Research, 33, 321–331, 2011.
[12] H. R. Sapramer, Devendra A. Patel, “Effect of Change in Flow Co-Efficient with Different Speed on the Performance of Wells Turbine”, Afro - Asian International Conference on Science, Engineering & Technology, 131-134,2015.