Abstract

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Investigation and Improvement of Wells Turbine Performance- Fluid Analysis & 2nd Law of Thermodynamics Study

There have been several attempts to establish efficient methods to convert the energy of marine waves into electrical power. Wells turbine, with an Oscillating Water Column (OWC), is one of such methods. Wells turbine is the most common type of self-rectifying air turbine employed by OWC wave energy devices due to its technical simplicity, reliability, and design robustness. Because Wells turbine is subject to early stall, which negatively limits its performance, there were many endeavours to improve the energy extraction performance of Wells turbine within the stall regime. However, those endeavours were based only on the first law of thermodynamics analysis, without relying on the second law analysis. Since the second law of thermodynamics is concerned with the generation rate of entropy and accordingly the useful work, it is important to take the entropy generation rate into account while improve the performance of Wells turbine. The main objective of this thesis is to analyse and improve the performance of Wells turbine under sinusoidal wave based on the entropy generation minimization method for various passive flow control technique parameters. To achieve this purpose, two-dimensional numerical models for Wells turbine aerofoils under sinusoidal wave flow conditions were built and used to investigate the single and multi-slots as passive flow control means. Different operating conditions with various design parameters were investigated. Furthermore, the turbine blade with optimum slots number, location and angle were investigated using the oscillating water system based on the real data from the northern coast of Egypt. Firstly, in addition to the commonly used first law analysis, the present study utilized an entropy generation minimization method to examine the impact of the flow control method on the entropy generation characteristics around the turbine blade. The obtained results indicate that the global entropy generation rate has a different value according to the aerofoil design. It was determined that a certain aerofoil geometry always gives a global entropy generation rate less than that of other aerofoil geometries under sinusoidal inlet velocity. Furthermore, the angle of attack radically affects the second law efficiency. Subsequently, a comprehensive investigation was carried out on the passive flow control effect on the entropy generation as well as the torque coefficient. It was found that with the use of passive flow control, the entropy generation around the aerofoil section increases. On the other hand, torque coefficient of aerofoil increases before the stall happens and continues to increase within the stall regime. A significantly delayed stall is also observed with the use of the passive flow control. Moreover, aerofoils with two, three and four slots were investigated to improve the performance of Wells turbine in the stall regime. The optimum slots number and locations were determined based on minimizing the global entropy generation rate in addition to increasing the torque coefficient. Furthermore, the optimum angle for single slot aerofoil was confirmed to provide a lower global entropy generation rate as well as a higher torque coefficient than the zero angle slot before and after the stall. Finally, from the modelling results, it can be concluded that the operating conditions based on real data for the northern coast of Egypt are very suitable for the oscillating water column system with Wells turbine as a wave energy converter. Moreover, by adopting the optimum slots number, location, and angle, the performance of Wells turbine can be significantly improved for a wide range of operating conditions.