Abstract

The present work provides a systematic and comprehensive analytical and computational study for understanding the flow through co-rotating discs, and, for predicting and optimizing the performance of a Tesla turbine. The analytical model can predict torque, power output and efficiency, and compares well with experimental results. A work equivalence principle has been enunciated, which establishes the equality between the magnitudes of work transfer determined rigorously from two different approaches—one based on the shear stress acting on the disc surfaces and the other based on the change in angular momentum of the fluid. The results of CFD simulations (in presence of shroud wall and discrete multiple nozzles at the rotor's periphery) show that an axisymmetric inflow condition is desirable in order to obtain a high value of efficiency. Several subtle flow physics and fluid dynamic behaviours have been elucidated for axisymmetric inflow conditions. As an example, it is shown that a Tesla turbine may generate net torque and power even when the tangential fluid speed at the disc periphery is less than the local tangential speed of the disc. The subtle role of the Coriolis acceleration in establishing such flow conditions, which involve flow reversal and complex pathlines, has been explained. The dual role of fluid friction and the variations in the four fundamental components ($\Delta\hat{p}_{io,inertia}$, $\Delta\hat{p}_{io,centrifugal}$, $\Delta\hat{p}_{io,Coriolis}$ and $\Delta\hat{p}_{io,viscous}$) of the overall radial pressure difference $\Delta\hat{p}_{io}$ are critically explained. It has been demonstrated that $\Delta\hat{p}_{io,viscous}$ depends predominately on dynamic similarity number Ds; $\Delta\hat{p}_{io,centrifugal}$ depends predominately on tangential speed ratio at inlet γ; and, $\Delta\hat{p}_{io,inertia}$ and $\Delta\hat{p}_{io,Coriolis}$ depend on both Ds and γ. It is shown that the magnitude of $\Delta\hat{p}_{io}$ decreases monotonically as γ increases, and the centrifugal force is dominant at low γ. $\Delta\hat{p}_{io}$ exhibits a minima when Ds is varied, viscous effects dominating at low Ds while Coriolis force and inertia dominating at large Ds. The thesis presents a performance optimization study which is carried out in terms of carefully formulated non-dimensional numbers – five input parameters: radius ratio $\hat{r}_o$, aspect ratio $\hat{b}$, tangential speed ratio at inlet γ, flow angle at inlet α, dynamic similarity number Ds and three output parameters: power coefficient $\hat{\dot{W}}$, pressure difference coefficient $\Delta\hat{p}_{io}$, efficiency η. It is found that Ds, γ and α have major influence on the efficiency, and, $\hat{r}_o$ and $\hat{b}$ play minor role. A systematic design methodology is established for the optimum selection of input parameters for a Tesla turbine that would satisfy practical constraints and deliver high value of power and efficiency. It is shown that a further substantial increase in power output is possible with an appropriate use of nanofluids.