World Academy of Science, Engineering and Technology
International Journal of Marine and Environmental Sciences
Vol:18, No:07, 2024

Hydrodynamic Characterisation of a Hydraulic Flume with Sheared Flow

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Abstract : The University of Oxford's recirculating water flume is a combined wave and current test tank with a 1 m depth, 1.1 m width, and 10 m long working section, and is capable of flow speeds up to 1 ms^{-1} . This study documents the hydrodynamic characteristics of the facility in preparation for experimental testing of horizontal axis tidal stream turbine models. The turbine to be tested has a rotor diameter of 0.6 m and is a modified version of one of two model-scale turbines tested in previous experimental campaigns. An Acoustic Doppler Velocimeter (ADV) was used to measure the flow at high temporal resolution at various locations throughout the flume, enabling the spatial uniformity and turbulence flow parameters to be investigated. The mean velocity profiles exhibited high levels of spatial uniformity at the design speed of the flume, 0.6 ms^{-1} , with variations in the three-dimensional velocity components on the order of ±1% at the 95% confidence level, along with a modest streamwise acceleration through the measurement domain, a target 5 m working section of the flume. A high degree of uniformity was also apparent for the turbulence intensity, with values ranging between 1-2% across the intended swept area of the turbine rotor. The integral scales of turbulence exhibited a far higher degree of variation throughout the water column, particularly in the streamwise and vertical scales. This behaviour is believed to be due to the high signal noise content leading to decorrelation in the sampling records. To achieve more realistic levels of vertical velocity shear in the flume, a simple procedure to practically generate target vertical shear profiles in open-channel flows is described. Here, the authors arranged a series of non-uniformly spaced parallel bars placed across the width of the flume and normal to the onset flow. By adjusting the resistance grading across the height of the working section, the downstream profiles could be modified accordingly, characterised by changes in the velocity profile power law exponent, 1/n. Considering the significant temporal variation in a tidal channel, the choice of the exponent denominator, n = 6 and n = 9, effectively provides an achievable range around the much-cited value of n = 7 observed at many tidal sites. The resulting flow profiles, which we intend to use in future turbine tests, have been characterised in detail. The results indicate non-uniform vertical shear across the survey area and reveal substantial corner flows, arising from the differential shear between the target vertical and cross-stream shear profiles throughout the measurement domain. In vertically sheared flow, the rotor-equivalent turbulence intensity ranges between 3.0-3.8% throughout the measurement domain for both bar arrangements, while the streamwise integral length scale grows from a characteristic dimension on the order of the bar width, similar to the flow downstream of a turbulence-generating grid. The experimental tests are well-defined and repeatable and serve as a reference for other researchers who wish to undertake similar investigations.

Keywords : acoustic doppler Velocimeter, experimental hydrodynamics, open-channel flow, shear profiles, tidal stream turbines
Conference Title : ICMHFM 2024 : International Conference on Marine Hydrodynamics and Fluid Mechanics
Conference Location : Stockholm, Sweden
Conference Dates : July 15-16, 2024