Experimental Investigations of Hydrokinetic Turbines at Full Dynamic Similarity

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Abstract
Tidal power is one of the renewable energy sources with the greatest potential for large scale integration. Large underwater turbines capture the kinetic energy of ebbing and surging ocean tides, converting them to electrical power. However, there are several aspects of their design, operation, performance and structural loading that needs to be better understood before hydrokinetic power can reach its true potential. A major challenge when designing and operating hydrokinetic turbines is that the hydrodynamic conditions make it impossible to numerically predict the flow around them, and, until this research project, laboratory studies were infeasible (even referred to as impossible). A world-unique test facility has been designed and manufactured. The new facility, located in the Princeton University Gas Dynamics Lab on the Forrestal Campus, allows tests at full dynamic similarity, which implies that the hydrodynamics of a full-scale turbine can be produced with a model-scale turbine. This is accomplished by exposing the miniature turbine to air at very high pressure (up to 220 atm). Under these conditions, the air has a density up to a fifth that of water, which increases the Reynolds number by more than two orders of magnitude at only 10 m/s. Furthermore, using pressure to increase the Reynolds number, the tip speed ratio can be matched simultaneously. Resolved structural forces and power output have been studied with both Reynolds numbers and tip speed ratios matched to what a full scale turbine experiences in the ocean. Fluid mechanically, the conditions under which tidal turbines operate, are very similar to those that large scale wind turbines operate in, and thus the new facility can also address interesting questions related to wind engineering.