Development and characterization of horizontal axis wind turbine apparatus for wind gust studies

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Wind energy deployment continues to expand rapidly as part of the world-wide renewable energy transition effort. For utility scale wind farms, wind gusts are detrimental as they can generate significant structural overloads and generator spikes [1], [2]. For small-to-medium scale turbines, these concerns still apply, yet the effects remain relatively unexplored. This work presents the design and development of a model-scale wind turbine for gust experiments in the water tow tank at Queen's University. The tow tank is 15-meters long and can achieve a maximum diameter-based Reynolds number of 410,000 with a 0.31 m diameter rotor model. An in-house BEM code is used to guide turbine scaling, inform geometric design, and predict performance in the test facility. The new turbine design, based on the established MoWiTO 0.6 [5], is introduced along with its expected thrust and power characteristics for tip-speed ratios between 1 and 9. The rotor geometry and key dimensions are shown in Fig. 1 below and the rotor will be resin 3D printed using Formlabs *Rigid 10K resin.* Additionally, a turbine apparatus, used to measure generated torque and rotation speed, is experimentally characterized in terms of its transmission efficiency. The characterization is performed at conditions matched to operation in the towing tank, providing an efficiency map between input and output rotational speed, torque, and power parameters based on the transmission efficiency. Together, the turbine design and apparatus validation establish the foundation for a future experimental campaign investigating the relationship between gust strength and turbine power output across tip-speed ratios and Reynolds numbers relevant to field operation of small-to-medium scale wind turbines.

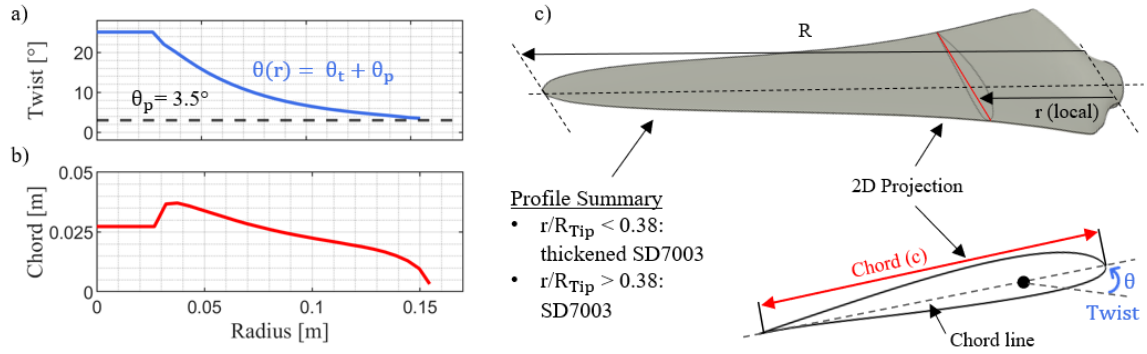

Figure 1. 1a) and 1b): Twist angle and chord length as a function of radial position. 1c), CAD rendering of reference wind turbine blade, with profile summary and 2D projection for illustration of key dimensions.

References

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