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FIBER OPTIC SENSORS FOR MONITORING HYDROKINETIC TURBINE STRUCTURAL LOADS

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RESEARCH BACKGROUND

Marine and hydrokinetic (MHK) energy contribute to national energy objectives by providing clean energy to reduce oil dependency and lower carbon emission. In order to become cost-competitive, the US Department of Energy aims to reduce the levelized cost of energy for MHK devices to $0.12-$0.15 per kilowatt-hour by 2030. Reliable load and structural prognostic and health monitoring systems for MHK can significantly reduce operations and maintenance costs and maximize plant revenue, by providing a better servicing schedule, avoiding unnecessary shutdowns, and increasing device availability.

Strain measurements on the rotor blades are key information for assessing blade loads and improving blade design, but obtaining this measurement is challenging because high-frequency signals have to be transmitted off of a high speed rotating platform. There is also a safety concern in using conventional piezoelectric sensors (e.g. coil strain gauges) for this application because powered cables have to be attached into a spinning rotor and submerged in water. Fiber optic sensors, such as the Fiber-Bragg grating (FBG) sensor, do not require electric power at the sensor, and are immune to electromagnetic interference (EMI) and wire-induced noise. These are the main advantages of using fiber optic sensors, especially since MHK turbine generators produce electromagnetic signals that can cause signal interference to piezoelectric systems.

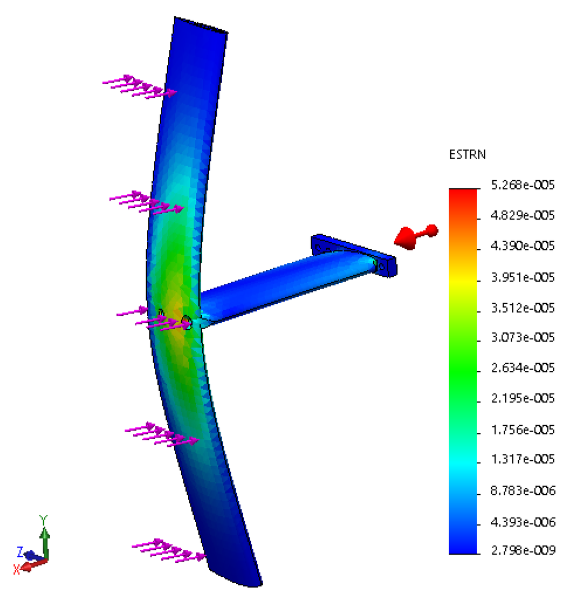
OBJECTIVE

The primary goal of this work is to demonstrate the feasibility of FBG sensors for measuring dynamic strains on a scaled MHK turbine.

METHODS

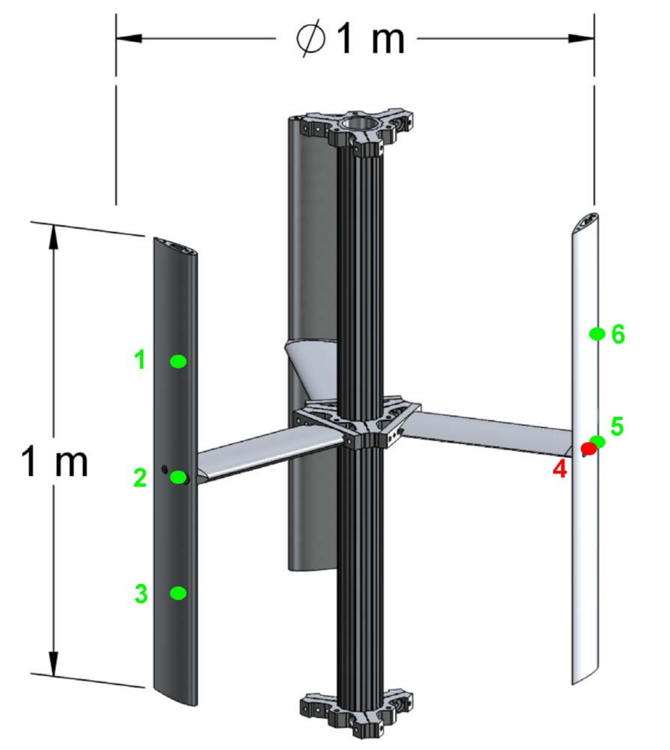
- Six FBG sensors were mounted to the University of New Hampshire's Reference Vertical Axis Turbine (UNH-RVAT), a one meter tall, one meter rotor diameter, three bladed turbine
- The turbine was towed at the 36.6 meter long, 3.66 meter wide and 2.44 meter deep UNH tow tank for 31 test cases with different tip-speed ratio
- Blade strain, inflow velocity, shaft angular velocity, torque and thrust were measured simultaneously
- A fiber optic slip ring (rotary joint) was used to transfer the measurement signal off of the rotor

The Micron Optics os 3200 FBG sensor

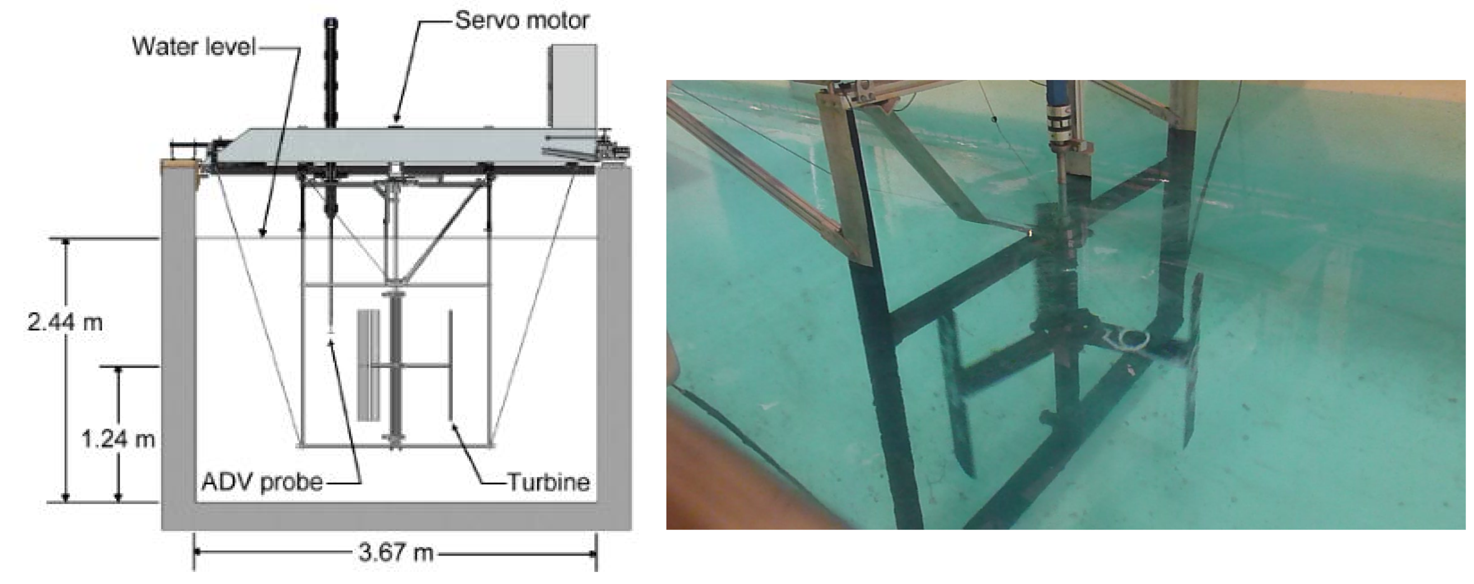


Strain distribution predicted by a finite element model

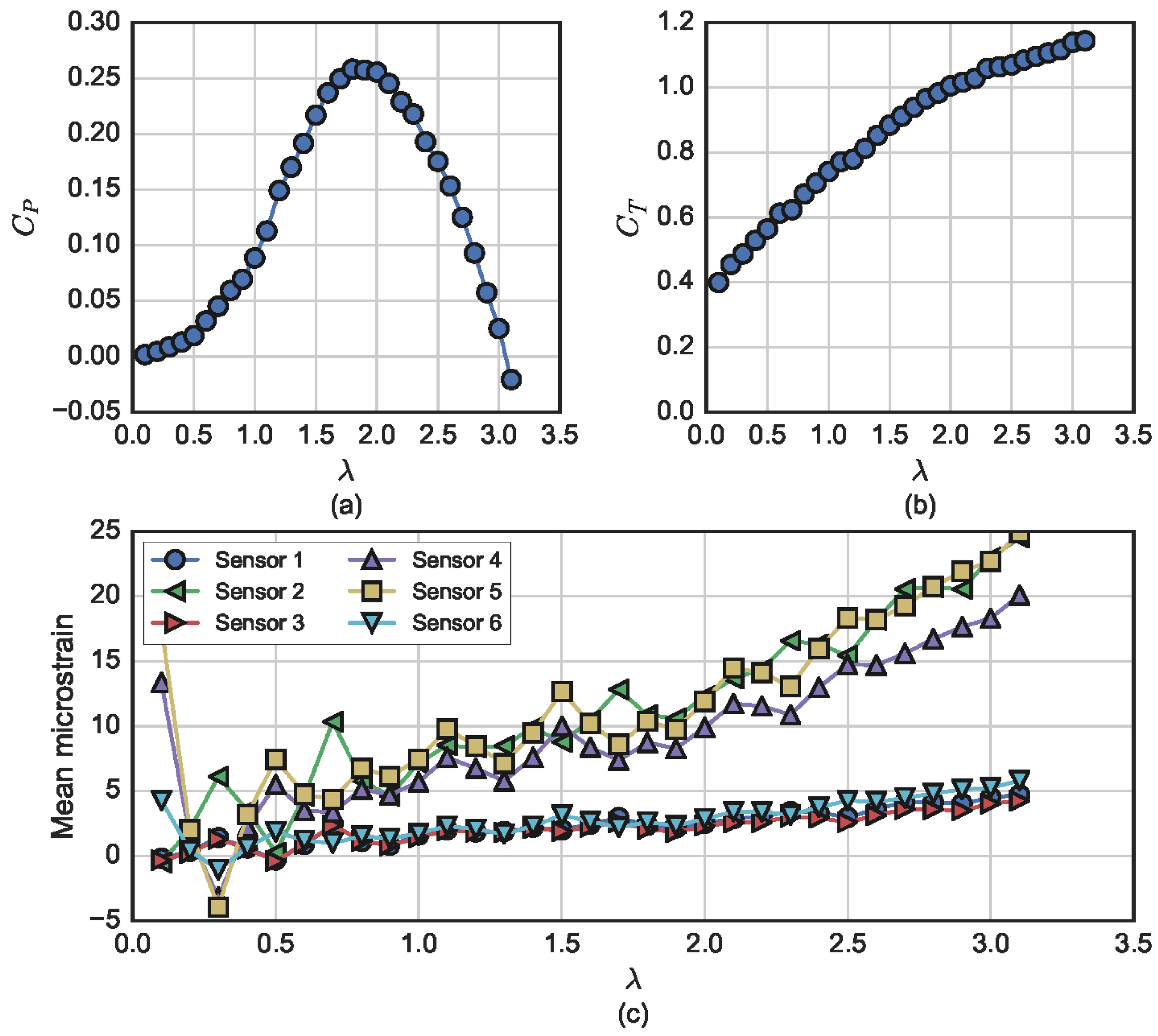
The bare os 3200 FBG sensor used for testing



Sensor placement; Sensor 4 is at 50% chord span, others are at 30% chord span



UNH-RVAT experimental set-up



Power coefficient, thrust coefficient, and mean strain as a function of tip-speed ratio

RESULTS

- Power (C_P) and thrust (C_T) coefficient curves were developed using data collected from 31 test cases. The power coefficient peaked at a tip-speed ratio of 1.8, while the thrust coefficient increases with tip-speed ratio.
- Mean strains are similar for sensors that are located at the same blade spans. Sensors 1, 3 and 6 were located at the same blade spans, 25% or 75% blade span. Sensors 2, 4 and 5 were mounted at 50% blade span.
- Each set of these sensors have similar mean strain values, and the values are in the same order of magnitude as those predicted using the finite element model.

CONCLUSION AND FUTURE WORK

This experimental test demonstrates that FBG sensors can be successfully used for measuring strain on a rotating hydrokinetic turbine. The sensors were not damaged even though they were kept underwater for approximately one week. Longer underwater testing in the field is required to determine whether FBG sensors are suitable for long-term MHK measurements, under real field condition.

ACKNOWLEDGEMENTS

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