Composites Research Network

Feasibility Study: A Polymer Composite Rotor Shaft for Vertical Axis Hydrokinetic Turbines

SUMMARY

Instream Energy Systems Corp. is a Canadian based company active in the field of hydrokinetic systems for tidal streams and inland applications. The company's vertical axis hydrokinetic turbines convert the kinetic energy of flowing water into electricity in a sustainable fashion. Instream's technology provides cost-competitive electric power with no or minimal environmental impact.

In this project the feasibility of replacing a stainless steel rotor shaft in a hydrokinetic turbine with a fiber reinforced polymer composite shaft was examined. Current shafts are made of stainless steel, which has the drawbacks of high material and manufacturing costs and the heavy weight of the system. In this feasibility study, researchers from the University of Alberta contributed their expertise in design, simulation and modeling of cost-effective and lightweight composite components toward an improved turbine shaft design.

Instream Energy Systems Corp.
Vancouver, BC

Instream is a pioneering developer of hydrokinetic systems for near shore tidal and inland applications.

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CHALLENGE

The focus of this project was the turbine shaft, which is immersed in the water flow and supports the turbine blades. The current stainless steel shafts provides adequate strength and stiffness and corrosion resistance, at the detriment of high material and manufacturing cost and a high shaft weight. The trade-off between acceptable weight and shaft stiffness also limits the use of longer blades, which would increase power performance.

In the vertical turbine design developed by the industrial partner, a cantilevered shaft is used that is supported at the top end where it joins to other mechanical systems and the electrical generator. This arrangement provides for a challenging loading scenario necessitating a shaft design that supports superimposed torsional and cyclic bending loads without failure.

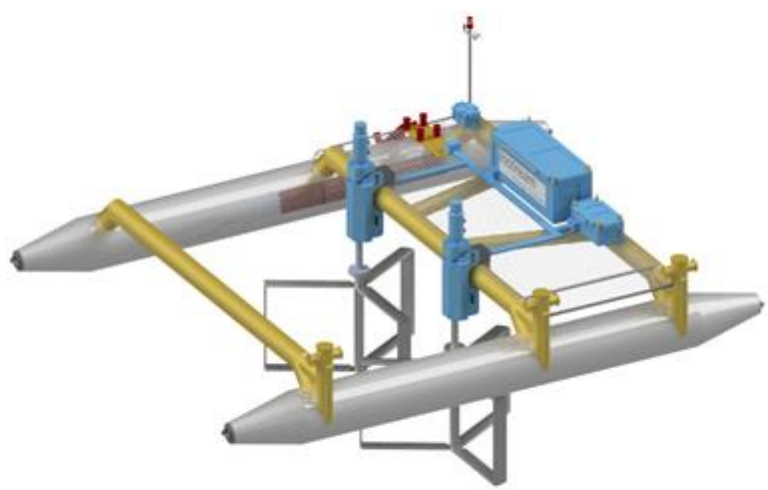

Figure1: Schematic of a future marine tidal hydrokinetic turbine system.

Polymer composites have been considered by the company but their limited experience and analysis capabilities with these materials have prevented the development of an alternative shaft design, which requires in-depth knowledge of the interrelated tasks of constituent material selection, composites fabrication, mechanical design and performance prediction.

APPROACH

The collaboration between industrial experts and university researchers fostered an effective and creative project environment. Through the course of this feasibility study, analytical and numerical techniques were employed to examine the effect of design and manufacturing parameters such as the type of fiber material, fiber orientations, stacking sequences and shaft geometry on the performance and potential cost of the FRPC shaft. The industrial partner was instrumental for jointly developing design specifications, given their perspective and expertise in the field of hydrokinetic turbines.

Different material systems, including glass and carbon fiber reinforced polymers were considered for the shaft design. Employing a tapered composite shaft was another promising solution for achieving a superior design in terms of weight and cost while also reducing flow induced drag and thus bending loads. The envisioned shaft design lends itself to filament winding, a cost-effective composite manufacturing method.

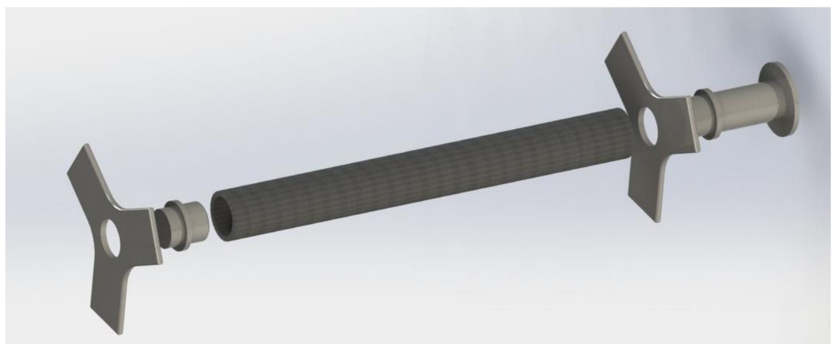

Figure 2: Rendering of a composite turbine shaft design concept.

The attachment of metallic elements like flanges and blade yokes to the composite shaft was an additional challenge in this project. Several solutions such as adhesive bonding, component co-curing and mechanical fastening were studied and analyzed to assess their capabilities, practicality and feasibility for the target application.

Figure 2: Small-scale turbine shaft that was fabricated to demonstrate the feasibility of a filament-wound design.

OUTCOME

The project was supported by an Engage Grant by the Natural Sciences and Engineering Research Council of Canada (NSERC). In collaboration with the industrial partner, design specifications for a composite turbine shaft were developed and documented. Subsequent analyses in conjunction with the study of manufacturing process parameters indicated the feasibility of a polymer composite design for this application, including metallic elements for the attachment of other turbine components. A sample small-scale composite shaft was also manufactured to demonstrate the suitability of the chosen fabrication process. Through this project the industrial partner was provided with comprehensive information for a future detailed design of a turbine shaft prototype.

> "*Working with CRN enabled us to consider the use of composite materials to mitigate fundamental cost and performance limitations of our current hydrokinetic turbine design. The feasibility study undertaken with the University of Alberta in Edmonton was a critical first step and has highlighted both design and material recommendations to replace our current stainless steel turbine rotor shaft with one made from fiber reinforced composite material and deliver both cost and performance benefits. This investigation and design recommendations have demonstrated the value of adopting a composite design and has set the groundwork for a detailed design with commercial potential. Leveraging the expertise of the CRN has advanced our development of a superior turbine system and given us a path forward to realize these benefits."*
>
> David Leboe, Director, Product Development, Instream Energy Systems

IMPACT

The project facilitated a cooperative knowledge transfer between Instream Energy Systems and the university researchers, which provided mutual benefits to the involved parties. For the university researchers a rewarding training opportunity for future composite engineers was created. At the conclusion of this feasibility study the results were transferred into a follow-up project which targets the development of a detailed prototype design that will enable Instream Energy Systems to engage composite fabricators in order to realize a full-scale composite turbine shaft prototype.

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