ADVANCED DESIGN AND RAPID MANUFACTURE OF COMPOSITE PROPELLERS FOR LARGE UNDERWATER VEHICLES TO ENABLE HEIGHTENED EFFICIENCY, REDUCED DETECTABILITY, AND EXTENDED OPERATIONAL LIFE WHILST AT SEA

Problem

The conventional use of metallic alloy materials for marine propellers in underwater vehicles and defence vessels poses significant challenges. Corrosion in maritime environments significantly diminishes traditional metallic alloy propellers' structural integrity and lifespan, leading to increased maintenance costs and operational downtimes. The excessive weight of these metal components compromises fuel efficiency, manoeuvrability, and overall performance, hindering the vessels' responsiveness to dynamic naval scenarios.

Furthermore, the inherent acoustic and magnetic signatures generated by conventional metal propellers pose a substantial threat to the stealth capabilities of defence vessels, potentially compromising mission security. As maritime operations demand heightened efficiency, reduced detectability, and extended operational life, there arises a critical need to adopt alternative materials such as fibre-reinforced polymer (FRP) composite for marine propeller application. FRP composite materials offer a compelling solution by providing corrosion resistance, substantial weight reduction, improved efficiency, acoustic signature mitigation and a significantly lower magnetic signature. The incorporation of composite propellers is essential to address these challenges comprehensively, ensuring a technologically advanced and operationally effective fleet of underwater vehicles and defence vessels.

Need and relevance to Defence

In the realm of Naval activities for Defence, the imperative for adopting composite marine propellers stems from a crucial incorporation of operational requirements and strategic considerations. Traditional metallic propellers, susceptible to corrosion and associated maintenance challenges, present a vulnerability that directly impacts the reliability and readiness of Defence vessels. The weight reduction offered by composite materials not only enhances fuel efficiency but also allows for increased payload capacity and manoeuvrability – each crucial factors in dynamic and strategic naval operations. Additionally, the corrosion-resistant nature of composites significantly extends the lifespan of marine propulsion systems, reducing the frequency of maintenance and ensuring sustained operational readiness.

Moreover, the innate acoustic signature reduction and lower electro-magnetic signature of composite propellers align seamlessly with Defence objectives. Minimising both noise emission and magnetic visibility is paramount in naval operations, contributing to enhanced stealth and reduced detectability by potential adversaries. This becomes particularly vital in military scenarios where surprise, covert manoeuvres, and strategic positioning are integral components of mission success.

As Defence vessels continue to evolve in response to emerging threats and challenges, the adoption of composite marine propellers emerges as a strategic imperative for intermediate-size vessels such as large and extra-large autonomous underwater vehicles. The need for advanced materials that offer a comprehensive solution to issues of corrosion, weight, and acoustic and magnetic signatures underscores the relevance of composite propellers in fortifying the operational capabilities and strategic advantages of naval defence platforms.

The use of additively manufactured composite propellers can substantially shorten lead-time compared to traditional manufacturing of metallic propellers and also composite propellers. This reduction in time from design to delivery will greatly enhance the fleet availability.

Research question

Can we develop a sovereign capability to rapidly produce advanced composite propeller designs with minimal tooling costs for large and extra-large underwater vehicles?

Can advanced manufacturing technologies, such as robotic and additive manufacturing, be used for both the metallic hub and composite blades? And if so, can we develop advanced connection designs to leverage the advantages of these technologies.

How can we rapidly produce such composite propellers with consistent and high quality at the required scale?

Expected outcomes

To demonstrate the production of a composite marine propeller prototype using advanced manufacturing techniques, to a manufacturing readiness level of five. The propeller design will be based on large and extra-large autonomous underwater vehicles for defence applications. The prototype will be expected to have significant weight reduction, demonstrate potential shortened lead times and enhanced durability over metallic alloy propellers.

Methodology/approach

DSTG will provide an initial propeller geometry of around 800mm diameter to use for more detailed design for manufacture of composite blades and metallic hub.

The design of the composite layup to be based on manufacturing constraints and operational load requirements using a validated optimisation scheme. This is expected to achieve lightweight, improved efficiency, and high durability. Manufacture of composite propeller blades using automated composite manufacturing techniques such as automated fibre placement to achieve a consistent and high-quality product.

Manufacture of metallic hub using suitable additive manufacturing approaches, such as Wire Arc Additive Manufacturing (WAAM).

Utilising the benefits and differences with additive manufacture, complete bench-scale assessment of blade to hub interface designs performed to inform design for manufacture. One or more blade to hub joint interface designs are likely to be considered.

Finally, demonstrating the successful integration of a manufactured composite blade and metallic hub.