OAK RIDGE NATIONAL LABORATORY

Harmonizing Oil and Water to Aid Marine Energy Development

As the saying goes, two things that are "like oil and water" are irreconcilable. When it comes to marine energy production this adage is quite literal. Marine energy devices create energy by harnessing the movement of waves, currents or tides, requiring partial or total immersion in water. At the same time, they must be adequately lubricated to work.

This creates a logistical conundrum that so far has prevented marine energy technologies from reaching their full potential: Conventional lubricants are effective at keeping the device in working order but require additives that are toxic to aquatic life in the event of a leak or spill, while eco-friendly alternatives have not been up to the task of keeping the gears lubricated. Recently, however, researchers at Oak Ridge National Laboratory have come up with a solution.

Finding the Right Chemistry

ORNL brought together a multidisciplinary team with the goal of finding or creating lubricant additives that are superior to or as high performing as conventional, commercial products, but non-toxic and biodegradable. The researchers zeroed in on a relatively new class of chemicals invented at ORNL, two groups of ionic liquids (ILs) called short-chain ammonium phosphate and phosphonium phosphate. These organic liquid salts are stable at a wide range of conditions and temperatures, mix well with oil and do a great job of reducing friction and wear. The researchers hypothesized that they would find a winning combination among ILs that have hydrocarbon chains with four carbon atoms or less, which are generally less toxic.

MARINE ENERGY BY THE NUMBERS

220
Terawatt-hours
Estimated amount of power that could be derived from tidal sources in the US annually

5%
Tidal energy's potential contribution to annual electricity generation in the US

129 Million
Number of US residents who live in coastal counties that could benefit from marine power



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Putting ILs to the Test

The team tested the ILs against a slate of lubricants that were already available on the commercial market, including conventional gear oil and bioderived additives that are considered eco-friendly.

Tribological Performance

ORNL researchers conducted rolling-sliding tests to simulate the operation of a tidal turbine gearbox bearing. The lubricants containing merely 0.5% of the ILs outperformed the commercial gear oil, demonstrating 40% lower friction, a 45% reduction in wear loss and substantially less rolling contact fatigue-induced surface damage.

Aquatic Toxicity

The team conducted chronic ecotoxicity tests using two different aquatic species. The researchers used *Ceriodaphnia dubia* (water fleas) as a representative proxy for life found in freshwater settings, and a shrimp-like creature called *Americamysis bahia* for saltwater environments. The researchers evaluated the effect of each test substance on the survival, growth and fecundity of the animals. The water fleas showed a 90 to 100% survival rate over a period of seven days after the ILs were introduced into their environment. Survival rates for *Americamysis bahia* ranged from 70 to 90% once exposed to ILs. In either case, the ILs can be categorized as 'Not Toxic' according to the US Environmental Protection Agency's acute toxicity classification. Conventional lubricants and additives killed all organisms in both tests.

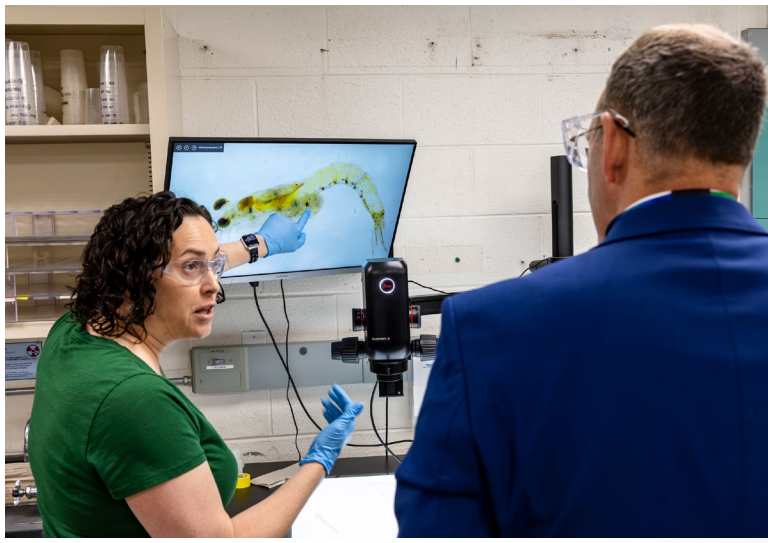
Biodegradability

Standard tests showed the ILs boosted oil decomposition. The base lubricant had a decomposition range of 60 to 80% over a 10-day window without the addition of an IL. With the IL in the mix, its decomposition rate reached a higher level, with 80 to 95% of the oil decomposing over a 10-day period. In contrast, a commercial bio-derived additive slowed down the oil degradation to below 50% over a 10-day period.

The next frontiers

The further development of these ILs could significantly aid the growth of marine energy by making it safer, cleaner and more effective. However, these new substances could be useful anywhere that lubricating materials pose a risk to the environment, and could be beneficial in many other venues such as agricultural settings, maritime trade and transportation and hydraulics, among many others.





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