Biofilm research informs marine coatings design

Studying slime growth is aiding the design of money-saving hull coatings for the shipping industry.

The industry-led research, funded by BBSRC and Innovate UK, could help to reduce the costly impacts of slimy biofilm formation on ships.

Biofilms are sticky layers of microorganisms, which form coatings on damp surfaces. Biofilms, and other marine organisms such as barnacles and algae, often accumulate on underwater surfaces and result in 'biofouling'.

Researchers from International Paint Ltd[1] and the University of Southampton developed a new device to study biofilm growth and examine their mechanical and physical properties.

The findings are helping researchers understand how biofouling causes drag for ships, and accelerating International Paint's research and design process by speeding up the testing of antifouling coatings.

Despite current antifouling measures, removal of slime and other marine organisms still incurs significant costs for the shipping industry.
Image: Michael Elleray

A sticky situation

Biofouling causes major problems for the shipping industry and naval fleets, as fouling on a ship's hull increases drag and slows the ship down, forcing it to burn more fuel. Studies on the economic impacts of biofouling on naval ships found that microorganism colonies on large ships increase fuel consumption by 18 %[2]. They also promote colonisation by larger organisms such as barnacles and mussels, which cost the US Navy an extra $180-260 million per year in fuel and cleaning costs[3]. In addition, the increased fuel usage and resulting CO_2 production has a considerable effect on the environment[2].

Current antifouling coatings, such as textured surfaces or paint containing Teflon, help prevent organisms attaching themselves to ship hulls. These save the shipping industry around $60 billion per year[4], but researchers and ship owners are continually seeking new ways to further reduce the effects of biofouling.

A fresh approach to testing coatings

The researchers, led by Jennifer Longyear at International Paint Ltd and Professor Paul Stoodley at the University of Southampton, developed their new device by first adapting an existing method called spinning disc rheometry. Discs of around 40cm in diameter are attached to a shaft, which is spun by a motor. When the spinning discs are submerged in a tank of water, the torque, or resistance to the motor, is measured. "If something's got a lot of barnacles and seaweed on it, it'll have a relatively high torque. You can use that relationship between the speed of rotation and torque to get an idea of the drag," explains Stoodley. Researchers use this approach to study biofouling-induced drag and to screen how an antifouling coating might perform, by comparing discs with different coatings that have been submerged in the ocean.

The discs used by the team are much smaller than the 1-metre discs which are usually employed in spinning disc rheometry. This means up to 24 discs can be mounted onto one board to allow multiple coatings to be screened at once. This 'rapid screen' is a more efficient and cost-effective way for coatings companies to screen expensive or difficult-to-apply coatings, such as patterning, without having to coat a much larger disc.

The team then combined this technique with another existing device called a flow cell, which measures the loss in

IMPACT SUMMARY

A new device for studying slime growth is accelerating the research and design of ship hull coatings.

Biofilms are sticky layers of microorganisms, which form slimy coatings on wet surfaces such as ship hulls. They cost the shipping industry and naval fleets billions of pounds each year in cleaning costs and extra fuel due to increased drag.

Researchers at International Paint Ltd and the University of Southampton developed a device to help understand the drag caused by biofilm growth on ship hulls, using funding from BBSRC and Innovate UK. The marine biofilm flow cell is used to see how different surface coatings, such as antifouling paint, affect how biofilms grow and cause drag.

The flow cell is being used by industrial partner International Paint Ltd (part of the world's largest paints and coatings company AkzoNobel) to speed up the testing of new antifouling coatings for ship hulls.

water pressure caused by friction as water flows through a channel in a long acrylic box.

The same discs that were used in the spinning disc method were incorporated into the wall of a flow cell. By running seawater through the cell, biofilms can be grown on discs treated with different coatings. The drag caused by these biofilms can be studied by measuring the water pressure in the flow cell, or by transferring discs back to the spinning disc rheometer to compare the biofilm drag on different coatings.

"We are using the flow cells to examine how different coating technologies influence biofilm properties, and to probe the relationship between biofilm properties and hydrodynamic drag penalty," says Longyear.

By fitting the flow cell with a clear plastic lid and monitoring the biofilms with an optical coherence tomography (OCT) camera, usually used for medical imaging, the researchers were also able to study how biofilms move as water flows over them. This produces a 3D image of the biofilm surface

Biofilms

Biofilms form on all sorts of surfaces, often where they are not wanted. The slimy extracellular matrix which binds the bacteria together increases their resistance to antibiotics and disinfectants. They can cause infections when they form on medical equipment and implants, and can spread foodborne illnesses by colonising food processing machinery. Biofilms are even present on our teeth in the form of dental plaque.

However they are not always problematic, and can in fact be advantageous when harnessed in clever ways. For example, many sewage treatment plants grow biofilms on filters to extract and digest organic compounds from waste[9].

in real time, revealing how it deforms under the flow of water, and how that movement affects drag.
"The energy from the water as it's flowing over the biofilm is making the biofilm flow. So, the biofilm might have a much larger effect on the pressure drop than you might expect from its roughness," explains Stoodley. "As we turn up the flow, we can see how the biofilm deforms."

"With the combination of quantitative imaging and drag measurements we are now able to explore microbial fouling in a pragmatic and accessible way, and we are taking full advantage," says Longyear.

The new device was developed alongside Dr Stefania Fabbri (AkzoNobel) and Dr Simon Dennington (Southampton) using a £73,000 grant via the UK Biofilms Programme funded by BBSRC and Innovate UK[5]. Marine coatings specialists International Paint Ltd are part of the world's largest paints and coatings company, AkzoNobel, who employs more than 3,500 people in the UK[6].

Further funds via the UK National Biofilms Innovation Centre[7], supported by BBSRC, Innovate UK and STFC's

With 1520 vessels and a total carrying capacity of 73.3 million tonnes in 2018[8], managing biofouling on the UK's owned and managed trading fleet poses a major challenge. Image: Dirk Dallas

The effects of shipping on marine ecosystems

Economic costs and carbon emissions are just two examples of the effects of biofouling. It has also been identified as a major contributor to ecosystem changes through the transfer of invasive aquatic species[10].

Marine organisms can travel thousands of miles on the hull of a ship, and find themselves displaced from their native habitats to new environments, where they become an invasive species.

Invasive species can out-compete native species, upsetting the biodiversity and health of an ecosystem.

Hartree Centre, are allowing the group to continue their research and develop new materials which behave like biofilms, with which they can calibrate and refine the system.

"It's been a very successful project. I really hope it continues and I'm really interested to see what International Paint want to do with this," says Stoodley.

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