How do you prolong the useful life of lubricants?

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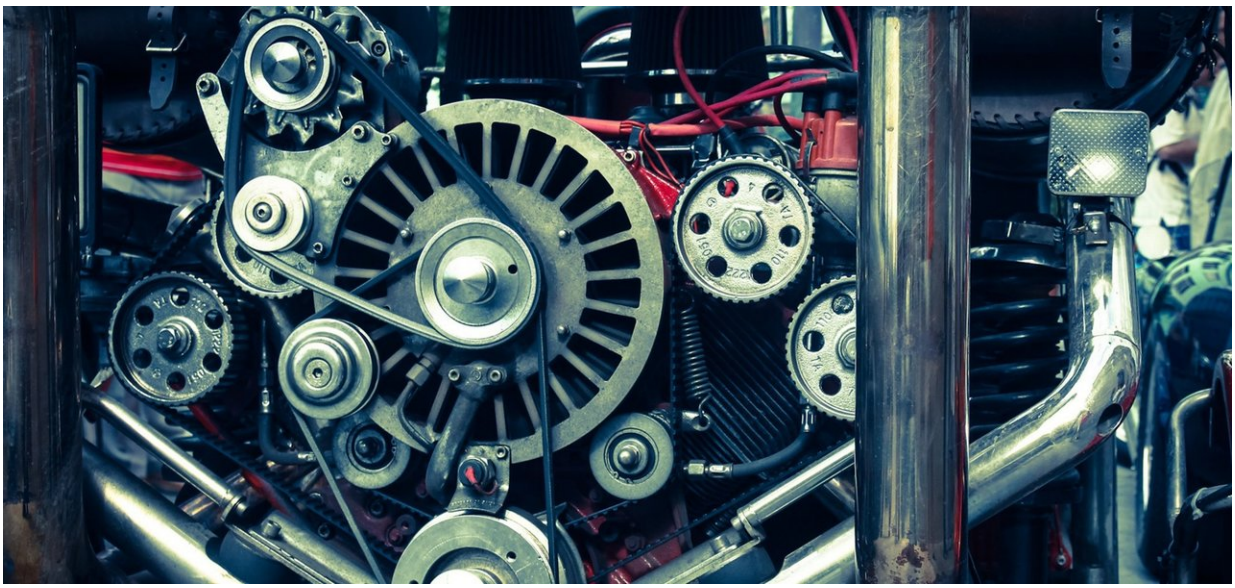

Whether in your car or a wind turbine, foam breaks down the lubricant needed for engines to work efficiently. Credit: Pixabay/phtorxp

Wind turbines towering hundreds of feet over many landscapes herald a future of endless, clean energy.

But in a crucial sense, turbines remain rooted in the past: Much like with your car, their engines require lubrication to run smoothly. The question for many chemical engineers is, how do you prolong the useful life of the lubricants?

In a new study published in the journal *Proceedings of the National Academy of Sciences*, Vineeth Chandran Suja, a Stanford graduate student in chemical engineering, explores one of the core problems: foaming oil.

The problem, he says, is that whether it's in your car or a wind turbine, each time metal gears grind against other metals, oil gets sloshed around and mixed with air. This often results in the formation of tiny bubbles with varying lifespans. If the bubbles don't immediately burst, they soon collect into a foam, which is one of the primary mechanisms of engine decline.

The foam is harmful in a variety of ways. It degrades the lubricant and allows gears to grind. Oxygen trapped in oil foams causes the metal parts to oxidize, that is, to rust. And the foam acts like a thermal insulator, trapping harmful heat in the system. Hence, lubricant manufacturers are actively looking for ways to mitigate lubricant foaming.

To better understand the conditions that give rise to foams, the researchers, led by Gerald Fuller, professor of chemical engineering, adapted a set of techniques originally developed to study the liquid layer that lubricates the exterior of the human eye. These novel techniques enabled them to study the colorful patterns on the surface of individual oil bubbles – a key advance from previous research, which focused on foams in the aggregate.

When Fuller and Suja zoomed in on the iridescent surface of their tiny oil bubbles, they discovered that the color patterns revealed the thickness of the bubble wall. Brighter, more vibrant colors indicated thicker walls that led to more persistent bubbles and, hence, foamier, less-effective oils, says Suja, who was first author on the paper. Darker colors indicated thin-walled bubbles that would quickly pop, so the oils that would last longer and provide better lubrication.

The researchers employed their new color-coding technique to determine why some motor oils tend to get foamy. Their ultimate goal was to figure out how to make longer lasting oils. In the process they made a surprising discovery about how evaporation factors into bubble formation and foaming.

As they zoomed in, they observed that evaporation at the top of each bubble caused its surface tension to change, drawing extra oil toward the top. This additional oil made the bubble wall thicker and stronger, and prevented it from bursting. They captured video of the bubbles pulsating as tears of oil pooled at the top, then rolled down the exterior wall of the bubble only to get wicked up to the top again by evaporation. As the cycle continued, these persistent, thick-walled bubbles tended to become undesirable foams. "Learning that this whole process is driven by evaporation was a bit of an unexpected result," Fuller says.

The researchers showed that this effect is most pronounced in blended, multi-grade oils, but virtually absent in homogenous, single-grade oils. "It turns out, if you want to reduce foaming, you want to use high-purity, single-grade oils," Fuller says.

Suja and Fuller are now pursuing two strategies to find ways to reduce or eliminate foaming. The first is to formalize their understanding of bubble formation, evaporation and foaming with mathematical models that will allow them to simulate how pure or blended oils are likely to perform in real life. This would speed the research and discovery process for new oils. The second is to look for antifoaming additives or other ways to counteract those pulsing teardrops.

This is a fundamental study that elucidates a big problem that plagues lubrication, Fuller says. "It also points us in some interesting new directions."

More information: V. Chandran Suja et al. Evaporation-induced foam stabilization in lubricating oils, *Proceedings of the National Academy of Sciences* (2018). DOI: 10.1073/pnas.1805645115

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