Beyond the lab: greasing the future of wind energy

Wind turbines operate in some of Earth's harshest environments, causing equipment stress, leading to accelerated wear. To better understand how critical lubrication is to ensuring components function as designed, PES spoke with Matthias Stammler, Senior Engineer at Fraunhofer Institute for Wind Energy Systems IWES, and Ulf Rieper, Shell Lubricants Global Product Application Specialist, who came together to discuss their joint investigation into high-performance lubricants that withstand demanding conditions. They discuss their latest research findings and what's next for the industry.

PES: Matthias, Ulf, it's great to have you both here. Industry and research don't always collaborate, but we have both of you in one conversation today. What brought Fraunhofer IWES and Shell together?

Matthias Stammler: Thank you for having us here. Our team at Fraunhofer IWES leads collaborative research projects with industry partners, academic institutions and standardization bodies to help ensure advancements align with global industry needs. Working with stakeholders from across the industry, encompassing most major wind turbine and bearing manufacturers, centers on the real-life conditions operators face daily.

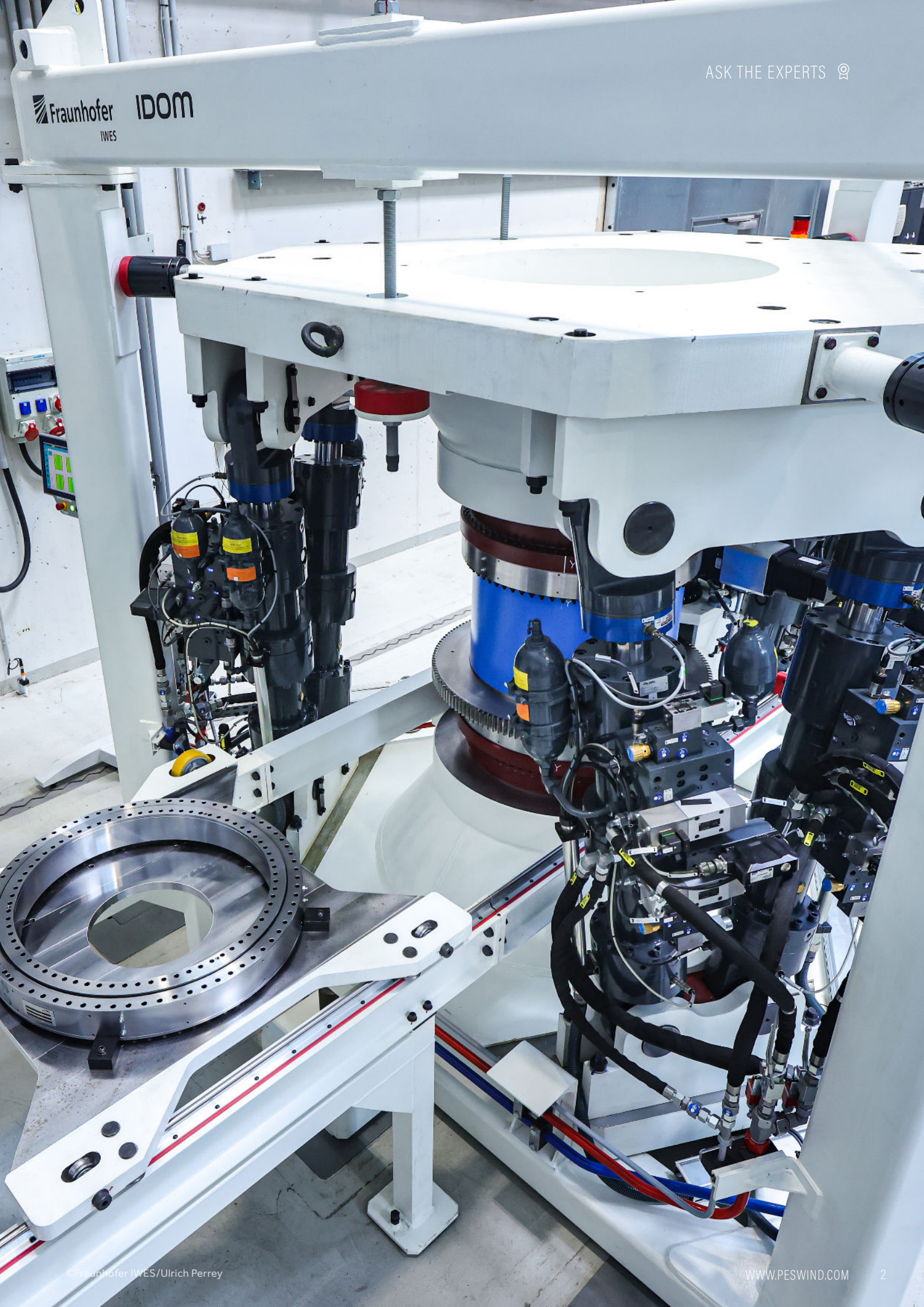
Lubrication is essential to turbine reliability, yet we identified a gap in understanding how demanding environmental conditions truly impact wind turbine systems, particularly greases. Standard testing methods weren't accurately capturing real-world operating dynamics.

Ulf Rieper: It's great to be here as well. To build on what Matthias said, at Shell Lubricants, we focus on developing greases that operators can trust and we know that wind farms don't operate in perfect laboratory settings. The location of many farms can cause grease that can't be broken down due to the harsh environment. Without proper lubrication, the moving parts in the turbine can overheat, wear out faster, or even fail, leading to unexpected downtime.

So, our goal was to ensure our wind lubricant products provide long-term protection while maintaining efficiency under real-world stresses. That's where independent validation, like our work with Fraunhofer IWES, benefits the entire industry as a whole.

PES: Ulf, you touched on grease breakdown. We know one of the biggest challenges for turbine operators is lubrication failure in harsh conditions. You aimed to capture real-world challenges that turbines face daily. How did your methodology address these issues?

UR: Exactly, grease failures can lead to costly maintenance and unexpected stoppage, so exploring the nuances of how lubricants perform in practical environments is



Matthias Stammler

Ulf Rieper

fundamental. We worked with Matthias' team to design an investigation that replicated how a grease would perform over time in the real world. Condensing a year-long timeframe of worst case stress scenarios into a 14 hour cycle, we mimicked a year's worth of extreme wear in a compressed timeframe. This allowed us to observe grease breakdowns, performance shifts and long-term durability in ways traditional assessments couldn't.

MS: Precisely. The methodology we designed needed to mimic the real world at particular speeds and loading conditions. Our facility tests bearings ranging from 200 mm to 6 m in diameter. This scale and scope enable application to real-world conditions, where regular tests often are on small scales with accelerated motions at high frequencies, typically between 7 and 25 Hz. However, wind turbine pitch systems are large machines with bearings that move at much lower speeds, around 0.5 Hz, with one movement every two seconds.

Additionally, standard tests often rely on fixed oscillation cycles, but in reality, turbine bearings don't operate in controlled repetitive motions. In our testing, we replicated these to simulate real operational stress better.

PES: You've tested a range of commercially available greases. What stood out about the greases you tested?

MS: We focused on wear resistance, water contamination tolerance and long-term stability under oscillating conditions.

One of the most significant takeaways was how different greases reacted to moisture exposure. Pitch bearing greases have to operate with significant amounts of water in the ranges of up to 10%. Some greases struggled with lower levels of water ingress failing with just 3% water contamination, while others maintain integrity with up to 10% water content.

UR: That's a significant insight for operators. A grease's ability to maintain integrity with water exposure gives it a clear advantage in offshore and onshore environments. The finding is that Shell Rhodina BBZ remained stable far exceeded the field of greases we looked at. This ability to maintain structural integrity is crucial, and some greases struggle to maintain stability when exposed to high levels of water contamination, which is especially concerning.

Shell Rhodina BBZ demonstrated excellent flow properties, ensuring consistent lubrication in turbine bearings while protecting against fretting wear. Another grease, Shell Gadus S5 V110KP 1, showed strong performance in preventing corrosion and maintaining lubrication in both wet and dry conditions, making it reliable for offshore and onshore applications.

PES: What was the most surprising finding?

MS: One of the most surprising findings we observed in some greases, including the Shell greases we tested, was the ability of greases to sustain good lubrication throughout the testing cycles. Initially, wear marks appeared on the bearing surfaces, but over time, the grease supposedly facilitated the redistribution of wear particles, removing superficial wear from the surface. Where we could see wear after 14 hours of testing, 300 hour tests came out with raceways as good as new.

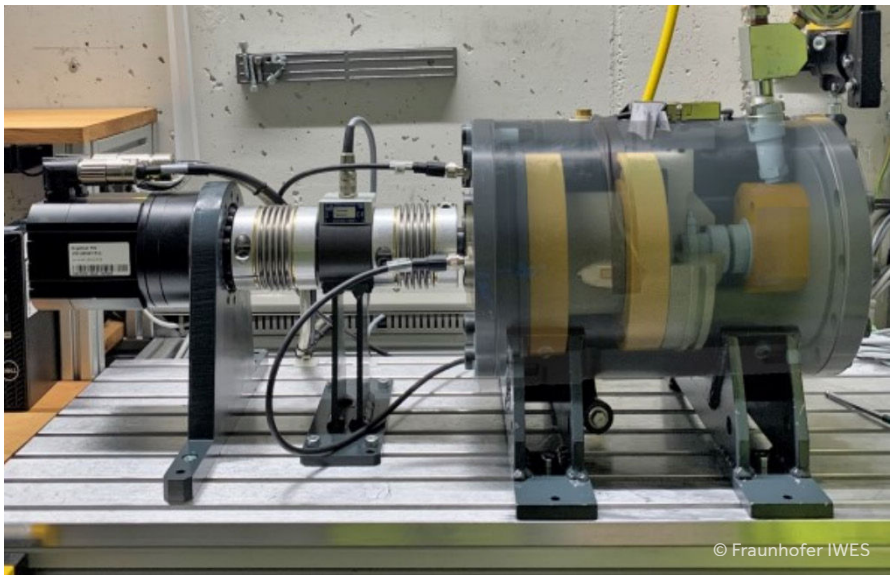
The ability to maintain performance under severe conditions is a key factor in reducing maintenance needs and ensuring the long-term stability of wind turbines. This is something we are keen to explore further.

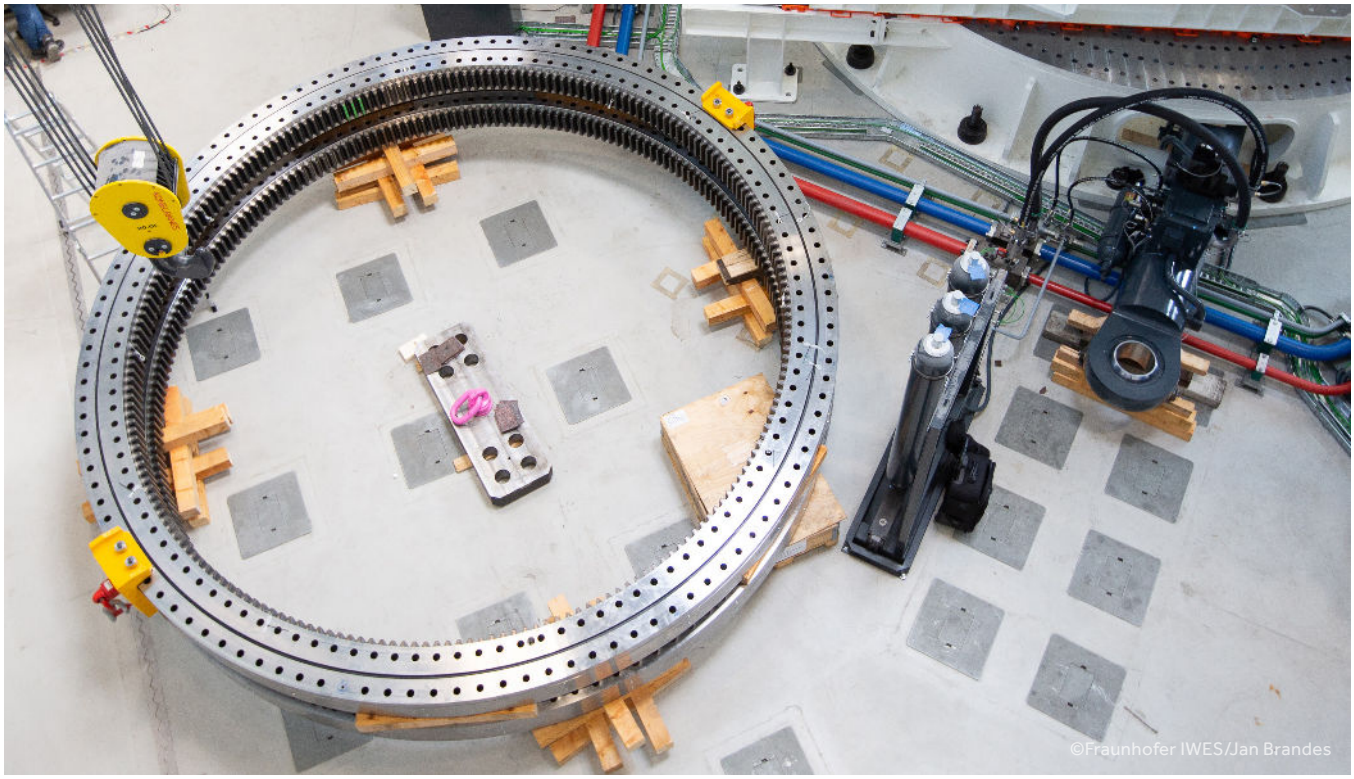
PES: When it comes to maintaining turbine performance, how critical is the ability of a new grease to integrate with existing lubricants and what challenges can arise in this process?

MS: It's essential. Flushing out old grease thoroughly in large wind turbine bearings is almost impossible, so ensuring compatibility between different lubricants is crucial. Our testing assessed how new greases performed when mixed in 25% increments with existing lubricants. The results showed no significant adverse effects, which is reassuring for operators looking to transition without risking performance degradation. Shell greases showed seamless compatibility with other products, ensuring a smooth transition without extensive cleaning or downtime.

PES: Offshore turbines face a host of environmental challenges beyond water contamination. From extreme cold to salt exposure and fluctuating loads, how do these conditions influence grease performance, and what trends are emerging in the industry to address them?

UR: Onshore and offshore turbines face a combination of environmental stressors that demand specialized lubrication solutions. Low temperatures, particularly in northern climates, can be just as much of a challenge as water exposure. Some turbines operate in environments where temperatures drop to -30°C or lower, which can cause the grease to become too stiff, removing its ability to properly lubricate the bearing surfaces, leading to increased wear and potential failures.





Our tests down to these freezing conditions showed that some greases maintained their lubricating qualities exceptionally well; in particular, Shell Gadus S5 V110 PK 1 showed low temperature pumpability and minimal wear, making it particularly suited for Arctic conditions.

The industry is responding to these challenges by investing in specialized grease formulations designed to withstand these extreme conditions. There is also an increasing focus on predictive maintenance, using sensor technology to monitor lubrication performance in real time, allowing operators to address potential issues before they become critical.

These innovations will help drive greater reliability and efficiency in wind energy moving forward. The ability to perform across a wide temperature range is essential, especially for operators managing fleets that span multiple climate zones.

PES: Looking beyond individual product performance, how does your research contribute to broader industry advancements in lubrication?

MS: Wind turbines present various challenges, from oscillatory loads to water ingress to extreme temperature swings. Our research underscores the need for standardizing testing procedures that reflect these real-world conditions. If manufacturers can align around common testing benchmarks, it will help turbine operators make better informed decisions when selecting lubrication products.

UR: There is clear potential for further enhancements in grease formulations. Many greases in the market are adapted from other industries and are not explicitly designed for wind turbines. Future grease formulations could be tailored for wind turbines, and innovations could include new additives, modified thickener systems or modified base oils to improve further water resistance and overall performance in wind turbine applications.

PES: What do you see as the biggest challenge in wind turbine lubrication going forward?

MS: The biggest challenge is understanding the long-term effects of lubrication in actual operating conditions. Many industry tests last only weeks or months, whereas wind turbines are expected to run for decades. There's still a gap in our knowledge regarding aging effects, especially with exposure to varying environmental stressors.

We must also establish clearer industry standards for acceptable water content limits in grease formulations. Some products fail at low water contamination levels, while others can handle much higher percentages. Some greases are able to handle high levels of moisture without degradation. Defining these thresholds will be crucial for offshore wind operators who need to know their lubricants can withstand continuous moisture exposure.

UR: Choosing the proper grease is essential for ensuring reliability in pitch bearings, which experience high variable loads and deformations and require specialized lubrication. However, beyond grease selection, a strategic lubrication approach, considering both product choice and application, plays a critical role in maintaining durability and efficiency. Factors such as pumping frequency, timing, and volume significantly impact performance and long-term protection.

Switching from a time based lubrication schedule to an on demand system, applying grease only, when necessary, based on real-time load conditions rather than at fixed intervals, can help operators extend bearing life and reduce unnecessary grease consumption, ultimately lowering operational costs.

Additionally, static lubrication schedules may not be effective in highly variable wind conditions. However, controlled, lower volume grease injections at higher frequencies help maintain lubrication while preventing excessive buildup, ensuring optimal application based on real-world stresses.

PES: Where can readers go to learn more about these findings?

MS: The full Fraunhofer IWES Water Ingress Study provides deeper insight into our research, operators and manufacturers alike will benefit from understanding the results.

IWES Study: Short-Term Influence of Water Ingress on Wear in Pitch Bearings of Wind Turbines

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