Making wind turbine lubrication a breeze

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With renewable wind energy set to grow faster than ever, minimising wind turbine maintenance is increasingly important for operators and original equipment manufacturers (OEMs). Only fluid formulations with a careful balance of synergistic additive chemistries can guarantee long-term reliability. Afton considers the demands on these highly specialised lubricants and shares how new screener tests support developments.

In 2024, new wind turbine installations hit an all-time high. Wind energy is clearly considered cost-effective, available and mainstream, with countries on every continent backing its expansion through national policies and investment. COP28 targets are set to triple renewable energy capacity by 2030 so attention is drawn to the needs of the growing wind turbine population.

For equipment that requires a very significant capital investment, performance data from proven lubricants and additives carry considerable weight. As hardware evolves, new ways to replicate real world failure modes in the lab are always needed. We look at the demands on lubricants and how testing can help offset risk.

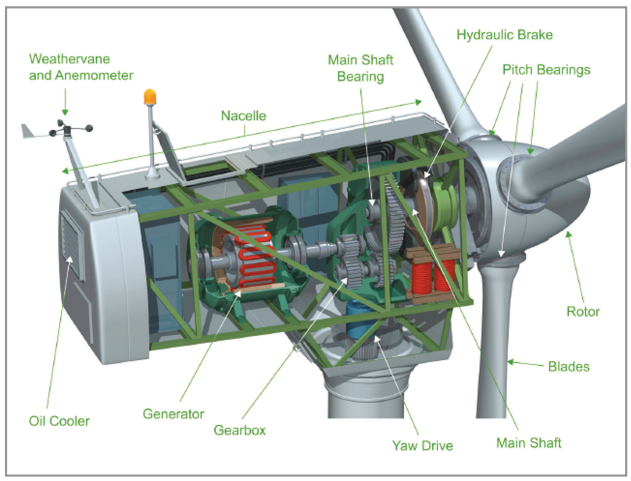

***Figure 1:** Wind turbine nacelle cutaway showing key parts*

Where are wind turbine fluids used?

For reliable turbine operation, lubricant needs include synthetic gearbox fluids, hydraulic fluids for brakes and the greases used in bearings. As gearbox failures are the main cause of wind turbine downtime, gearbox lubricant performance is understandably a key focus area.

Unique challenges

Wind turbines face challenges similar to other industrial gearboxes, but often to a greater extent. Higher speeds, temperatures and pressures, coupled with smaller oil sump sizes and harsher environments, create severe operating conditions. Gaining access to nacelles up to 100 metres high to maintain gearboxes requiring hundreds of litres of lubricant is difficult.

Operators need high performing fluids to maximise oil drain intervals and reduce maintenance complexity and cost. OEMs demand that lubricants ensure reliable operation throughout warranty, requiring a carefully balanced, durable formulation that can maintain excellent protection. With most operators not realising a return on investment for at least five years, efficient, reliable performance is crucial to help lower the total cost of ownership.

What does the fluid need to do?

Operators and OEMs look for five key aspects of fluid performance...

1) Viscosity control

On remote hilltops or at sea, wind turbines operate in much colder, denser air. To lubricate critical parts effectively, fluids must retain viscosity characteristics at all temperatures. Synthetic base oils are preferred, particularly metallocene polyalphaolefin (PAO), thanks to a naturally high viscosity index. But PAOs bring additive solvency challenges; balancing chemistries

and solubility enhancers are essential for holding vital additives in solution.

2) Extreme pressure and wear protection
Metal gear surfaces require excellent extreme pressure and wear protection to operate in fluctuating wind conditions that can inflict severe, intermittent loads on gearboxes. Shock loading may push the outer limits of gearbox design parameters. Only the right sulphur chemistries will work in synergy with base oils and other components.

3) Compatibility and corrosion protection
Fluids must not be aggressive towards gearbox materials. Afton formulates for multi-metal compatibility to avoid gear and bearing corrosion and sludge formation.

For wind turbines in desert regions, it is vital that abrasive dust and sand particles do not penetrate the gearbox and fluid doesn't leak out. Lubricants must be compatible with elastomer seals, keeping them in optimal condition without swelling or hardening.

Condensation may form in gearbox fluid from repeated heating and cooling caused by stop-start operation while offshore turbines must handle salinity on top of humidity, making corrosion as a result of acidic species in the fluid being more likely. Good corrosion and rust protection are key; strong performance in dynamic EMCOR saltwater testing is a prerequisite for bearing lubricants.

4) Filterability
Paramount for wind turbines is fluid cleanliness. Filtration catches water, particulate contamination and any corrosion by-products that form despite good metal, elastomer and coating compatibility.

Passing the Flender filtration test at relevant operating temperatures and retaining good foaming performance remains a core OEM requirement. Achieving the right balance of base oil and antifoam chemistry ensures a formulation will work in harmony with filtration systems. As end-users deploy finer filters this will become an increasingly important area.

5) Oxidation control
When lubricant oxidises, performance degrades and undesirable by-products form, so proven antioxidancy is essential. Excellent thermal properties also help heat dissipate quickly from the fluid, preventing or at least slowing oxidation.

This is partly why re-refined base oils are unlikely to be trialled in wind turbines just yet: as they pose a higher risk to early onset oxidation. Within Europe, higher cost fluids with proven longevity provide greater reassurance than regularly replacing lower cost fluids, although cost sensitivity can vary in other geographies.

Looking ahead
Field trial and test data form the evidence base for durable real world performance. Those wishing to validate new technology face the same challenges as wind turbine operators, which bring cost and complexity.

As well as meeting current needs, additive companies aim to future-proof against future hardware changes. Journal bearings containing bronze are starting to feature more often in wind turbine gearboxes thanks to their resistance to white etching cracking. Static multi-metal compatibility tests, carried out at high temperatures over extended periods by Afton, show that the right sulphur and corrosion inhibition chemistries can deliver EP protection without attacking bronze.

However, the gearbox fluid is anything but static. Afton therefore developed a new dynamic screener test, that approximates real-world boundary and mixed lubrication regimes, using a rotary tribometer rig to demonstrate more effectively how well-balanced formulations perform in correlated real-world testing. This new test replicates real world degradation in a controlled, accelerated manner: just 4 hours' test data are equivalent to a multi-year field trial.

With wind energy forecast to keep growing over the coming decade, the industry must ensure that high performing lubricants are available to meet demand and maximise efficiency and reliability for operators. Collaboration between OEMs, additive companies and oil marketers is key; drawing on proven expertise and laboratory insights will help to make it a breeze.

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