Power meets Profits: How Castrol Lubricants Enhance Wind Turbine Output

A milestone trial result independently consulted and validated

OEM recommendations. Lubricant manufacturer claims. Laboratory testing. These are the criteria on which wind farm operators typically base their turbine lubricant choices.

Now, Castrol has conducted a rigorous long-term lubricant field trial; more than two years' of real-world operation, methodologically robust and independently verified by a world-leading classification specialist.

The results are a milestone moment because they show with new clarity that wind farm operators can easily make low cost, measurable and commercially valuable gains in power output, as a direct result of lubricant selection.

Independent trial partners

wood. ONYX Insight DNV

Castrol

The turbine drivetrain: the quest to minimize energy loss

To generate more wind power, we are seeing an increase in tower height and rotor diameter. New blade designs and advanced materials also help, as well as optimizing turbine placement. All this innovation is boosting wind farm efficiency.

Can reducing energy losses make an important contribution to wind's levelized cost of energy (LCOE) too?

The mass and scale of wind turbine drivetrains mean power losses are inevitable, and efficiency gains can be hard to find. While the gearbox and main bearing are most critical, all along the drivetrain, lubrication can have an important impact on performance. Reducing friction can directly improve the performance output of a wind turbine.

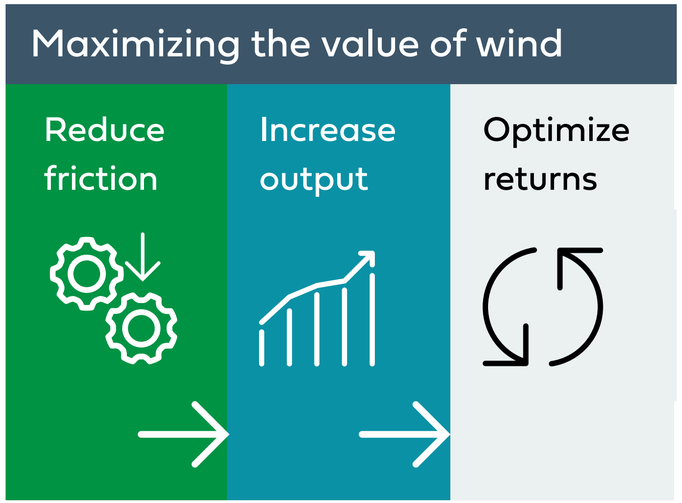
And this scale is increasing. In the quest for more capacity, most OEMs are now producing turbines with outputs in the 2.5 to 5MW range. The longer heavier blades needed to achieve these outputs put immense strain on the huge main rotor bearing – even when the turbine is static. Turbine components have not in all cases kept pace with turbine power and size growth.

The link between lubricant performance and reliability is widely recognized. The link between lubricants and energy output is less well understood.

Reliability and wear control matter too. All turbines, those offshore most of all, present costly maintenance challenges. Bad weather makes access for scheduled or unscheduled maintenance complex, dangerous and costly in terms of downtime.

So, the link between lubricant performance and equipment reliability is widely recognized. The link between lubricants and energy output, however, is less well understood.

Evaluating this connection and its potential impact on wind farm profitability is one of the key motivators behind Castrol's major investment in a large scale field test.

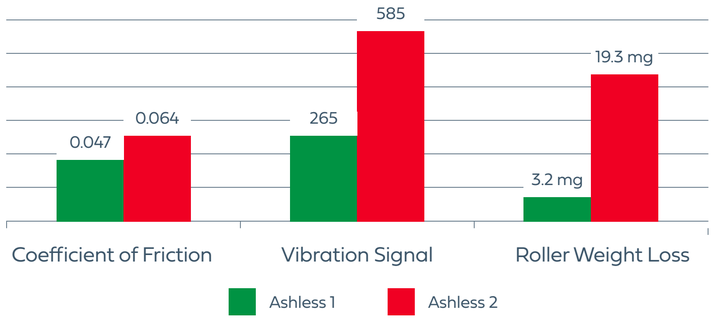


The journey to the field trial

Castrol lubricants are rigorously tested during the R&D phase of their development.

Initial findings validated in Micropitting Rig (MPR) endurance testing with a third party established some important baseline performance advantages for Castrol's gear oil products in comparison with a widely used ashless OEM-recommended gear oil.

Performance of EP Additive Systems MPR Endurance Testing



The Castrol product demonstrated a lower coefficient of friction and registered a significantly lower vibration signal, while demonstrating excellent performance in controlling wear as evidenced by lower roller weight loss.

These are positive laboratory findings. To reinforce them, Castrol instigated a full-scale bench test to explore potential performance advantages in a wind turbine gearbox.

The full scale bench test

The test was carried out on an 850kW test bed used for drivetrain quality control before installation in a turbine. To optimize the test method, Castrol engineers worked in partnership with independent testing specialist ONYX Insight.

ONYX Insight is a leader in predictive maintenance, monitoring over 28,000 turbines across 35+ countries.

This Highly Accelerated Lifetime Test (HALT) protocol (undertaken in partnership with the University of Porto and another global energy company) provided an optimized testing environment where real-world variables including temperature and wind strength could be fully controlled, generating very robust results.

The test clearly demonstrated the extent to which lowering friction through lubricant choice can have a material impact on power increase and profit.

Bench test power increase result:

0.8%

Castrol lubricants with unique low friction additives were shown to produce a 0.8% increase in power generated - a highly significant increase in the context of power generation.

This result is important. But at Castrol, we understand that, to commit to a change in lubrication, wind farm operators need to validate test bed results with real world testing in the field.

For such tests to be valuable, the test regime must be rigorous, thorough and independently validated. Which is why, in 2021, Castrol committed to undertaking one of the most robust long term lubricant tests carried out by a lubricants company.

The trial protocol – long term, big data.

Field trial goals were simple and clear – to robustly measure change in turbine efficiency as a result of lubricant choice in the main bearing, gearbox and generator.

	Start of Trial (September 2021)	Halfway switch (October 2022)	End of Trial (November 2023)
Turbine 1	Castrol	Competitor	
Turbine 2	Castrol	Competitor	
Turbine 3	Castrol	Competitor	
Turbine 4	Competitor	Castrol	
Turbine 5	Competitor	Castrol	
Turbine 6	Competitor	Castrol	
Control 1	Castrol		
Control 2	Competitor		

September 2021; the milestone two-year field trial begins.

To ensure the results that were truly robust and unbiased, the operational elements of the trial, including choice of wind farm, test turbines and trial methodology, were based on recommendations by Wood plc, industry-leading consultants, engineers and project delivery experts.

A typical US Midwest wind farm with 133 turbines each generating 1.6MW was chosen as a highly suitable test venue.

From the full turbine array, 4 side-by-side pairs of GE 1.6 MW turbines were selected for the test. To maximize the integrity of the results from a test which, by its nature has a wide range of variables, turbine selection was rigorous, based on a strict suite of criteria recommended by Wood.

The power of the side-by-side method

Side by side testing as recommended by Wood plc delivers high quality data by removing major uncertainties:

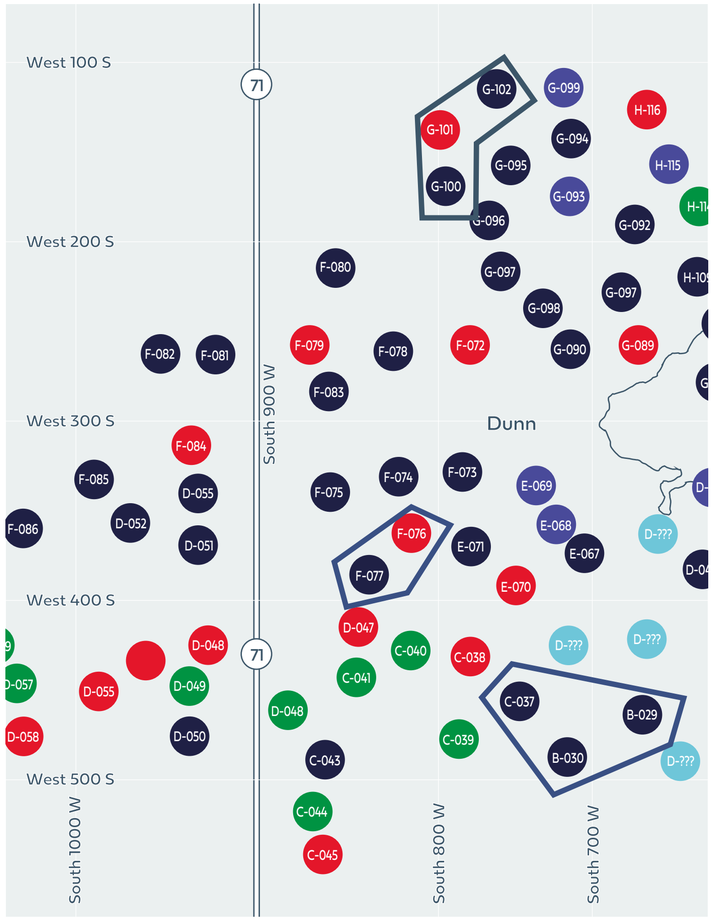
- Power measurement uncertainty neutralized
- Atmospheric effects (air density, TI, shear, veer) are the same on both turbines so neutralized

Other uncertainties are well understood and easily quantified including:

- Statistical uncertainty in power to power relation
- Statistical uncertainty in measured power curve
- How well the power curve can be reproduced in the testing period

Test venue

US Midwest wind farm, 133 1.6MW turbines



Criteria to control differences:

Same gearbox model across all test turbines: Winergy 4410.2

- No major maintenance activity prior to or throughout the test
- No abnormal oil analysis results prior to or throughout the test
- No abnormal vibration signatures prior to or throughout the test
- Turbines closely aligned in terms of wind speed, wind rose and power output
- Turbine pairs selected to minimize wake effects: clear mutually unwaked directions

To ensure that a truly meaningful quantity of data could be gathered and account for seasonal variations, the test was conducted over two years.

The testing structure specified three turbines running on Castrol Optigear Synthetic gear oil and Tribol greases in year 1 to be cleaned out and refilled with OEM recommended competitor lubricants for year 2. In parallel, three further turbines would run on the competitor lubricants in year 1, on Castrol products in year 2.

Two further turbines acting as experimental controls were run for the full two years without lubricant change.

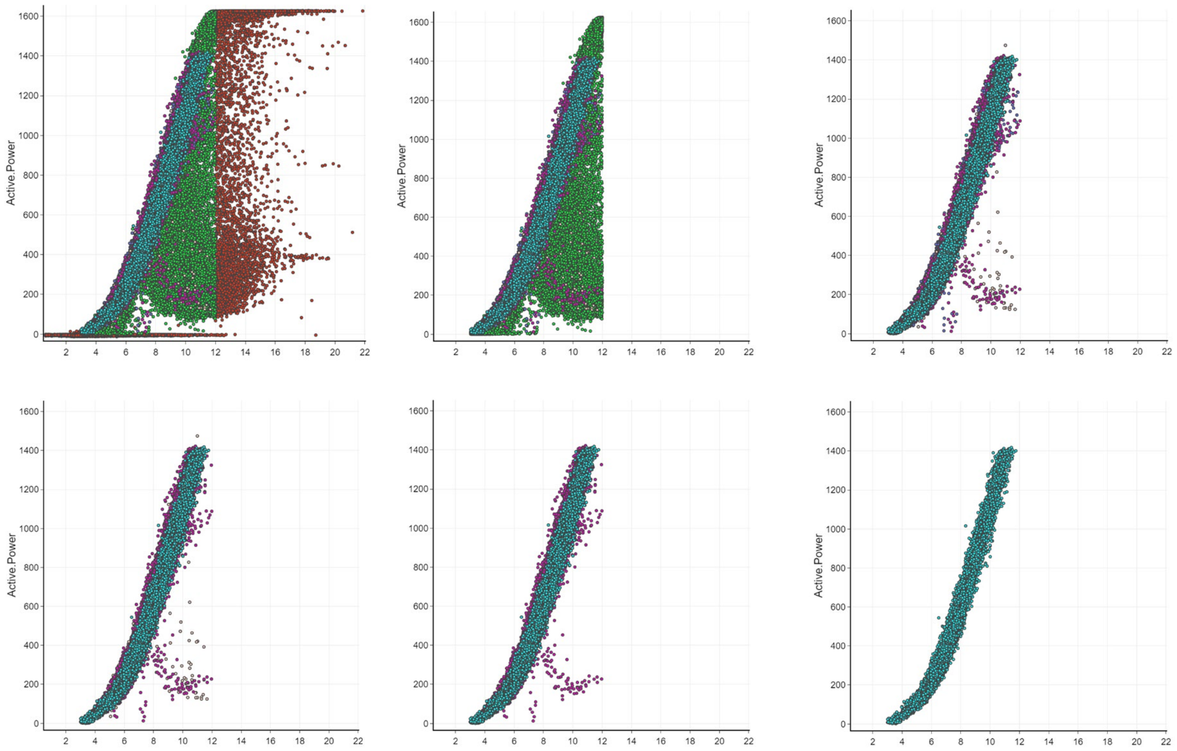
Throughout the test, data were collected from multiple sources to maximize the total data set:

The wind farm's own Supervisory Control and Data Acquisition (SCADA) data, uploaded periodically

- Castrol's expert used oil/grease analysis data
- Data from ONYX Insight's own proprietary Condition Monitoring System

Data filtering – from large scale to high quality

The scale and duration of the Castrol field test generated a wealth of data – some 134,000 raw data points from all participating turbines over the two year period of the test.



Such was the test rigour, more than 97% of the available data was rejected through a series to filtering processes, to ensure the data used to inform the final test results were genuinely robust and valid.

The filtering processes removed data outliers across important test variables, making it possible to focus tightly on results relating directly to lubricant performance.

Filtering variables

- Wind power range (turbine self-limiting)
- Pitch regulated (grid constrained))
- Possible icing effects
- Appearance of fault conditions
- Waked yaw direction (turbine not facing the wind)

The output:

A data set of approximately 4,000 data points representing a power curve on which a lubricant performance comparison can be based with a very high level of confidence.

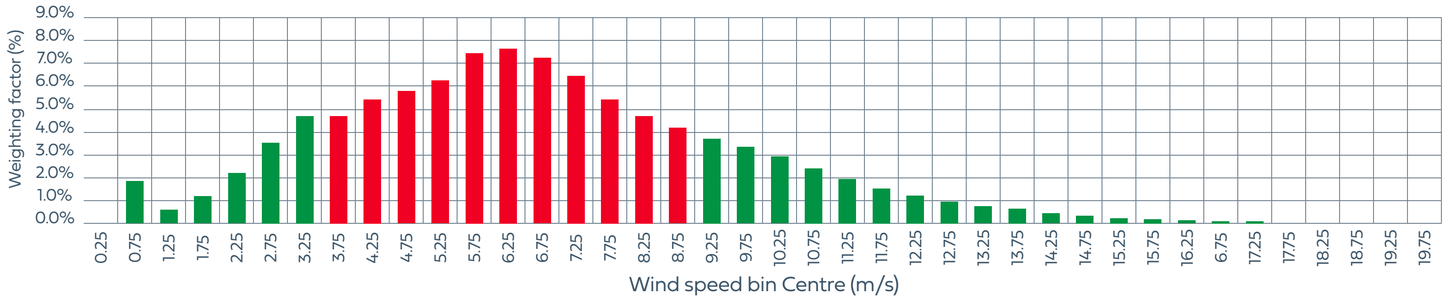
The numbers that matter.

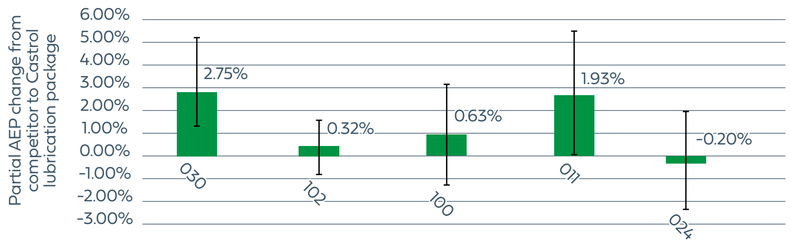
+1.09%.

+0.72%.

Two years of continuous data collection and analysis, a major financial investment and extensive independent scrutiny yielded two pivotal values for power output percentage change (weighted by site wind speed distribution).

Against the OEM recommended comparison lubricants, the low friction Castrol product delivered a mean +1.09% AEP increase in the wind speed region where the lubricant can impact the turbine's performance.





Allowing for overall site wind conditions, mean percentage power increase was +0.72% AEP. These results align well with the expectation set on the test bed.

For every wind farm operator focused on efficiency and revenue. These results matter.

Based on these power gains, these 1.6 MW turbines with 27% capacity factor could generate an estimated $1,250 additional revenue per turbine year. This is a conservative estimate; with larger turbines and a higher capacity factor, additional revenue could be more.

Powerful independent approval

Castrol's field trial has been audited by DNV-GL and their recommendations implemented to ensure the data is of high quality. DNV-GL is a globally recognised independent expert in assurance and risk management.

Low cost. Measurable. Commercially valuable.

As result of this field test, wind farm operators can with genuine confidence conclude that switching wind turbines to advanced low friction lubricants can have a significant and lasting positive impact on energy productivity and revenue in the real world. In addition, lower friction leads to better protection to equipment and ultimately increases component reliability and turbine life.

In comparison with other potential efficiency solutions, making grease and oil changes is a relatively low cost and easy-to-implement way to achieve worthwhile gains.

If you would like to know more about this milestone test and its implications for your operations:

Contact your regional Castrol Wind Energy representative
www.castrol.com/wind-us
1-888-Castrol