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WHITE PAPER

High Throughput Screening of Wind Turbine Gear Box Samples Utilizing the LaserNet 230 and Automatic Sample Processor (ASP)

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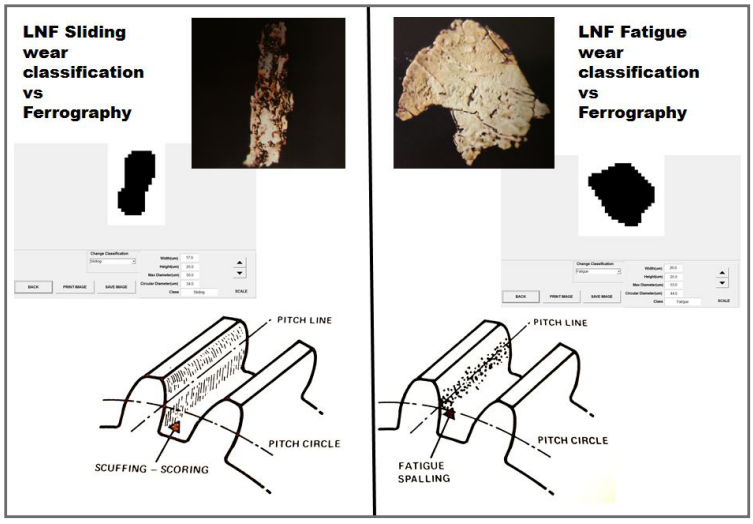
Introduction

The major issue for premature failure in wind turbine gearboxes is bearing failure, which leads to gearbox failure. A wind turbine gearbox will not survive if the oil is not clean and especially if the hard ferrous particles are not removed from around the bearings [1]

The LaserNet 230 particle counter and ferrous debris monitor has been shown to be an excellent analytical tool for end users to be able to diagnose wear faults in various machine applications such as gear boxes, engines and transmissions. The wear generated in a wind turbine gear box is a function of load, speed and lubricant condition. The lubricant must be correctly specified for the turbine gear box's idealized operating load and speed and its condition must be carefully monitored in order to maintain the required lubricant film thickness in these regimes. Ever-changing wind conditions and large variations in climates make wind turbine condition monitoring extremely challenging. As a result careful continuous automated monitoring of these critical and expensive assets is required. The National Renewable Energy Laboratory (NREL) is an existing user of the LaserNet Fines® (LNF) technology in drive train wind turbine monitoring. They have demonstrated and recommended that condition monitoring using the LNF is critical to avoiding premature failures in wind turbines. [2]



Combined rolling and sliding gear tooth wear patterns

Existing particle counter/auto sampler setups are not ideally suited to processing heavy batches of wind turbine oil samples which can also vary considerably in contamination level. Extra dilution steps for the viscosity and the contamination levels are required making them unsuitable compared to the standard clean oil hydraulic applications for which they were initially designed for.

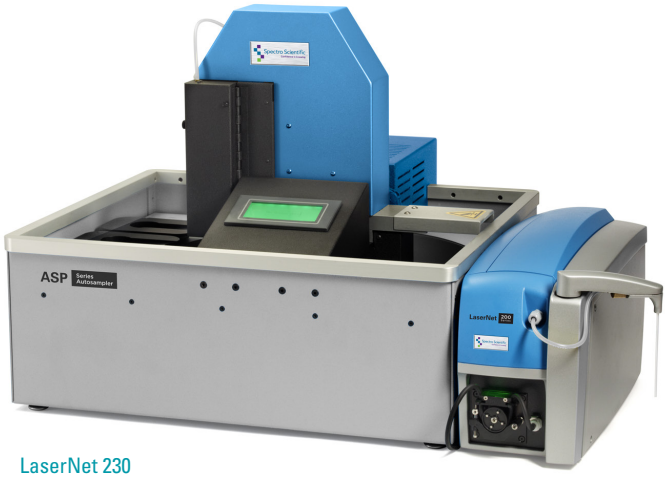
Wear particles typically found in a gearbox and how they are generated

The abnormal wear generated in any gear system typically comes from the pitch line of the gear tooth (fatigue) or the tip of the gear (severe sliding). At the pitch line, the contact is rolling so the particles will be similar to rolling contact fatigue particles. The gear contact has an increased sliding component as the root or tip is approached and the particles will show signs of sliding morphology. This morphological wear data is extremely beneficial to the end user and abnormalities in the gearboxes caused by large particle generation are easily identifiable when trends are established that can distinguish ferrous from non-ferrous material. Another critical feature of a wind turbine gearbox is the bearings are both on the low and high speed stages and any misalignment of these will induce failure.

High throughput

Online techniques are offered as site solutions for customers with multiple wind farms, but these are costly and not sensitive enough. Centralizing the testing analysis by sending samples to a regional service center offers the best cost to monitoring benefit when large volumes of turbine samples are involved. Contract labs with the right high throughput screening tools are well equipped to turn around data quickly and recommend further action and/or testing if necessary.

In a high sample throughput scenario, such as a contract lab running over 100 samples per day, it's very important to be able to screen samples accurately so that a more thorough and in-depth ferrography analysis can be undertaken on those select samples that show abnormal LNF /ferrous readings. Ferrography is still one of the leading root cause analysis techniques but it requires a complimentary screening methodology that closely links particle size distributions, morphology and ferrous content.



LaserNet 230 and ASP

LaserNet 230 and ASP combination

By coupling a fully equipped LaserNet 230 with ferrous capability to an automatic sample processor (ASP), a full tray of 24 heavy (320cst) windmill gear oil samples can be analyzed in ~2.5 hours. This is continuous operation including sample preparation, and system cleaning. This can all be accomplished with no operator intervention and can yield the following results:

- Particle distribution >4um (ISO 4,6,14 Codes)
- Wear Shape classification and distribution >20um (p/ml)
- % large Ferrous >20um (p/ml)
- Total Ferrous (ppm)
- Free water*

*Additional information on free water contamination present in the gearbox can also be reported from the water droplet classification.

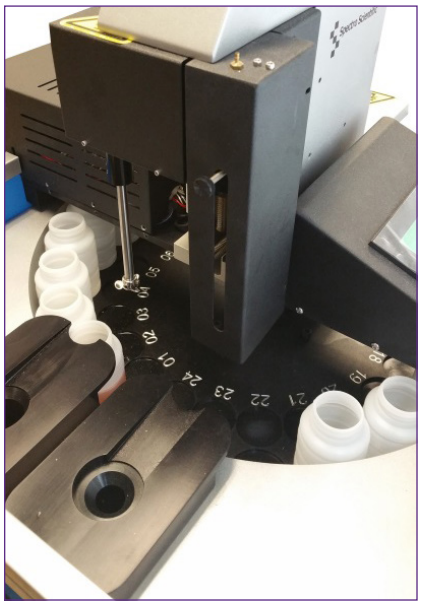
Key automatic sample preparation steps critical when analyzing heavy gearbox oils

The ASP has been uniquely designed to complement the LaserNet 230 by using stir and wash sequences which are used to simulate the typical manual sample preparation steps like shaking and rinsing during routine LNF analysis. The particles in the sample are homogenized using a special stir motor which rotates at an optimally selected speed. The stirring creates a vortex effect in the oil which sucks the particles from the bottom of the bottle and into the sample volume creating a homogenized sample. The speed is selected so as not to introduce excessive bubbles into the sample (the LaserNet 230) easily classifies bubbles >20um and does not count them).

The stirring method using the ASP is ideally suited for heavy gear oils compared to manual shaking on a standalone system. The viscous forces of the heavy oil make manual shaking and homogenization of the particles impossible. The remaining bubbles left in the bottle also take a much longer time to be removed by vacuum degassing or ultrasonic methods.

Once the sample has been stirred, the contamination on the stirrer and sipper are cleaned using solvent spray jets in the wash tanks. The stirrer is then spin dried ready for the next sample.

By running samples in this exact same mechanical manner over and over the repeatability from sample to sample is excellent and any deviation in sample data from a well-established trend can easily be identified by an analyst.



ASP stir and sipper sampling and wash stations

Continuous operation of the ASP / LaserNet 230 system is very important when dealing with hundreds of gear box samples a day with various levels of wear and contamination. In a typical batch of windmill gear box samples it's not uncommon to have very high levels of water or additive breakdown often being reported as >2million particles. The LNF imaging system can easily handle such high levels of contamination without any issues but it's important that the next sample is not cross contaminated. This is achieved by using a specially developed dynamic flush sequence that varies the amount of flushing required by continuously monitoring the particle count as the flush is taking place. A cleanliness threshold is set in the software and once the count gets below this value the flush stops and the sample progresses. This is very important as a typical windmill gear box running on a relatively new oil may only contain 1300 to 10,000 p/ml or and ISO code from 18 to 20. The incorporation of a bubble valve into the ASP flush line simulates a manual operator adding pockets of air which has been demonstrated to dramatically speed up flushing and removes excessive contamination quicker than a straight stream of solvent.

Conclusion

The ASP /LaserNet 230 ferrous combination is an ideal screening solution for windmill gearbox applications where sample volumes are high. The system can accurately and repeatably identify problem samples from a trend based on particle size distributions. The source of the wear can be identified using the shape classifier and the ferrous information.

The ASP system offers the following advantages:

- Output of high quality condition based wear metrics; size distributions, wear shape classification, ppm ferrous, ferrous vs non-ferrous particles.
- Screening for ferrography and further root cause analysis tests becomes easier.
- Enhanced analytical repeatability using mechanical stir and rinse modes.
- Continuous operation over a wide range of contamination levels 1000p/ml - > 2Mil p/ml
- No batch processing based on sample cleanliness is necessary due to the dynamic / Intelligent flush capability which prevents carryover.
- Ability to analyze and screen over 100 samples a day without dilution or sample preparation.
- Superior sample homogenization compared to shaking using vortex stirring method.

REFERENCES

1. Andy Milburn – Milburn Engineering, Wind Turbine Gearbox Wear and Failure Modes and Detection Methods, NREL – Wind Turbine Condition Monitoring Workshop – September 19-21, 2011
2. Shawn Sheng – NREL, Investigation of Various Wind Turbine Drivetrain Condition Monitoring Techniques – 2011 Wind Turbine Reliability Workshop August 2-3, 2011 Albuquerque, NM

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