WindTiPS

Digital Ebook | A Wind Power World Resource

Inside

Courtesy of Mobil™ Industrial Lubricants

Company Profile

ExxonMobil Helps Wind Turbine Operators Generate Success

Courtesy of ExxonMobil

ExxonMobil Fuels & Lubricants has been at the forefront of development in the wind energy sector for more than 30 years, championing thought leadership and best practices from the advent of wind power to the sector's current burgeoning growth. We understand the challenges equipment builder engineers and wind farm operators face. Our advanced lubrication products and services can help cost-effectively maximize wind turbine productivity by improving equipment performance and reducing the need for maintenance.

Proven in the wind sector

ExxonMobil has firmly established a reputation within the global wind energy sector for accomplishments in research and development (R&D), close collaboration with industry decision makers and excellence of service. Our innovative wind lubricant technology and application expertise have supported this growing industry from its nascent stages by helping to reduce maintenance requirements and operational costs. Mobil-branded fully-synthetic lubricants are specifically formulated to overcome difficult operating conditions associated with offshore and onshore wind farms.

Engineer-friendly technology

ExxonMobil's global network of Equipment Builder engineers works from with turbine builders and other key component manufacturers from the initial design stage to ensure the appropriate lubricant choice, taking into account specific operating conditions. To develop a range of high quality lubricants, our lubricant technologies undergo vigorous laboratory and rig testing before field trials commence.

ExxonMobil's fully synthetic lubricants and application expertise have a proven track record of operating effectively in

Company Profile

ExxonMobil Helps Wind Turbine Operators Generate Success

(continued)

some of the most demanding applications. This includes the largest turbine models, designed to feed energy to extensive power grids, with rotors up to 400 feet in diameter and churning up to six megawatts of electricity.

Since wind turbines are often situated in remote environments, either onshore or far out to sea, operators do not have the luxury of a simple oil change or frequent maintenance intervals. Given these increasingly challenging operational conditions, ExxonMobil recognizes that maximizing equipment performance and durability are among the most essential requirements for success.

Fully integrated portfolio

ExxonMobil's offer goes beyond a portfolio of cutting-edge products to address lubrication holistically. Our application-based counsel and technical guidance enable customers to make informed decisions about lubricant selection and performance. For example, to help operators navigate the broad portfolio of Mobil-branded oils and greases, ExxonMobil created Looble℠, a user-friendly, online industrial lubricant selector tool that provides targeted product recommendations with performance ratings based upon users' specific industries, applications and equipment.

In addition to helping wind farm operators maximize productivity and extend oil drain intervals, ExxonMobil recommends incorporating an oil and equipment condition monitoring program as part of a proactive approach to maintenance. ExxonMobil's SIGNUM℠ Oil Analysis service is designed to help address potential lubricant and equipment issues before unscheduled downtime occurs. To obtain the greatest benefit from oil analysis, it is imperative to work closely with an expert lubricant manufacturer and participate in an oil analysis program, typically every six months. DW

Take Wind Turbines to New Heights
Achieving Peak Performance

Courtesy of ExxonMobil

When it comes to wind turbines, Mobil–branded industrial lubricants don't just make them run: they make them fly.

How? By helping you get the most out of your machines.

Designed to excel even in some of the most demanding conditions — such as high heat, heavy load and water contamination — *Mobil SHC*-branded synthetic lubricants and greases will help keep your wind turbines operating in top form. They can help reduce unscheduled downtime, which can lower maintenance costs and even extend oil life.

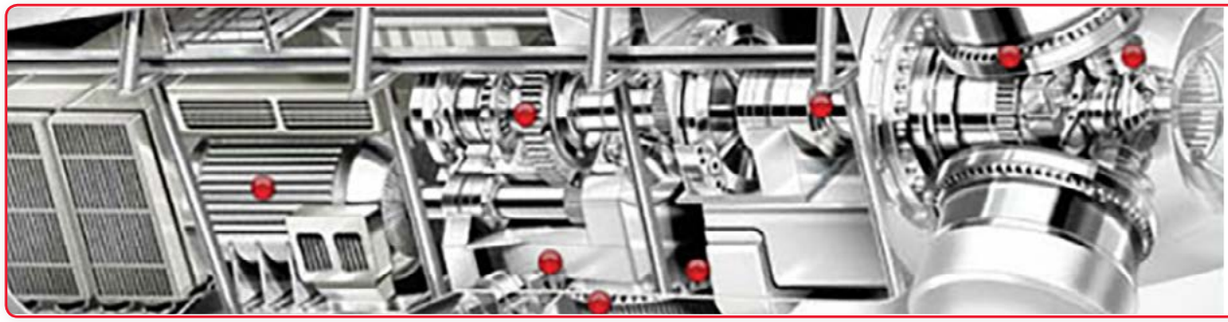
Extensive builder approvals and proven field performance.

Thoroughly tested before they are commercialized, Mobil-branded lubricants and greases are supported by builder approvals and extensive experience. For example, Mobilgear SHC™ XMP 320, our top-of-the-line synthetic wind turbine lubricant, is approved and/or used by several major gear, bearing and wind turbine manufacturers. With extensive builder approvals, it lubricates more than 40,000 wind turbines worldwide. Analysis of over 46,000 used-oil samples of Mobilgear SHC XMP 320 indicates superb wear protection and virtually no alerts due to oil aging.

Count on the technology leadership and application expertise behind Mobil-branded industrial lubricants to help keep your wind turbines running at peak efficiency. DW

WIND TURBINE SCHEMATIC
Discover how our lubricants fit your wind turbine needs

WIND TURBINE BROCHURE
Find out how we can take your wind turbines to new heights



Learn how we can help your:

wind turbine

Used Oil Analysis Data from Wind Turbine Gear Reducers
Helps Define Achievable Oil Drain Intervals

Courtesy of Rick Russo, Kevin Harrington, Sandra Legay – ExxonMobil Fuels &Lubricants

Wind turbines are sophisticated machines, operating in demanding environments. To withstand these demanding conditions, it is important to select the right lubricant, as the proper oil choice can improve wind turbine availability. This article focuses on the challenges in wind turbine lubrication, specifically addressing the use of Mobilgear SHC™ XMP 320 advanced synthetic gear oil in the main wind turbine gearbox.

Since 2000, ExxonMobil has been tracking wind turbine gearbox lubrication, collecting more than 38,000 oil sample results. In order to understand the performance benefits of Mobilgear SHC XMP 320, this article will examine the most relevant factors in determining proper gearbox operation, including system wear, oil oxidation stability, viscosity retention and water contamination.

Wear as indicated by the presence of iron

Inductively coupled plasma (ICP) spectroscopy is used to determine the presence and concentration of wear metals in oil, including cooper, chrome, aluminium, lead, tin, and iron — the most predominant wear metal found in wind turbine reducers. As shown in *Figure 1*, ExxonMobil examined the iron content of 38,680 samples and found 99.5 percent to be below the alert level for iron, with more than 30,000 results under 20 ppm or 10 percent of the limit.

A look at *Figure 2* shows that in the 25,680 samples examined, iron content did not increase with the used age of the oil, verifying the long-term wear protection provided by Mobilgear SHC XMP 320 synthetic gear oil.

Oil oxidation as determined by total acid number

The **Total Acid Number** (TAN) measures the quality of the lubricant, reflecting the oxidative state of the oil and indicating the amount of potassium hydroxide in milligrams that is needed to neutralize the acids in one

FIGURE 1 – Iron Content by ICP

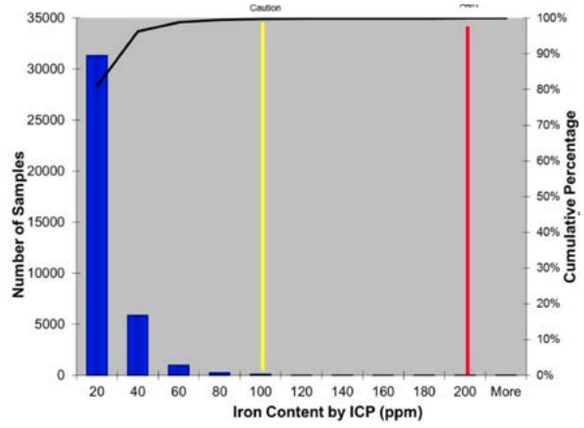
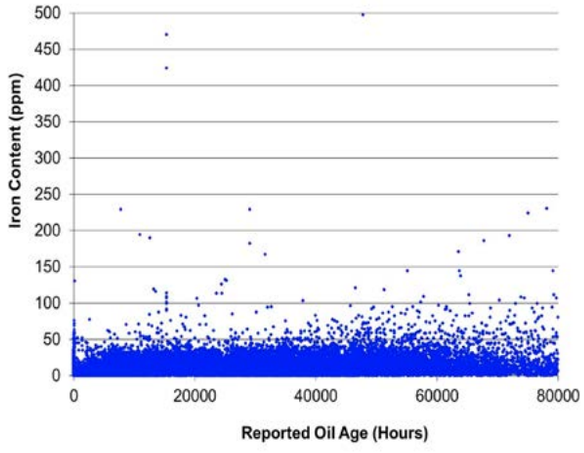


FIGURE 2 – Iron Content vs. Oil Age



Used Oil Analysis Data from Wind Turbine Gear Reducers
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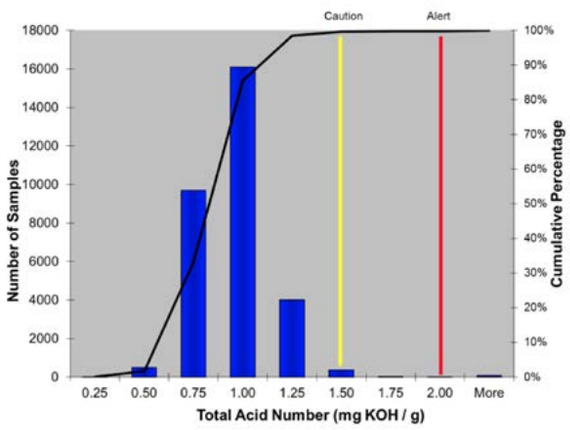

FIGURE 3 – Total Acid Number

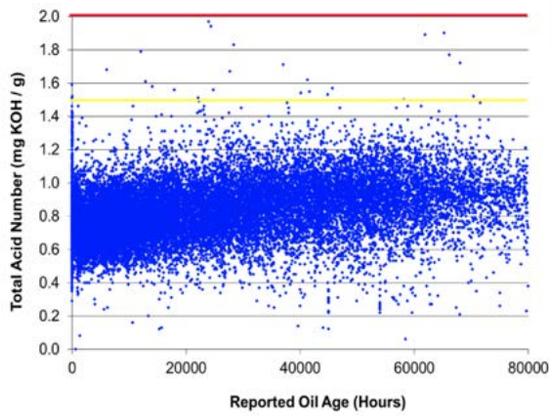

FIGURE 4 – Total Acid Number Over Time

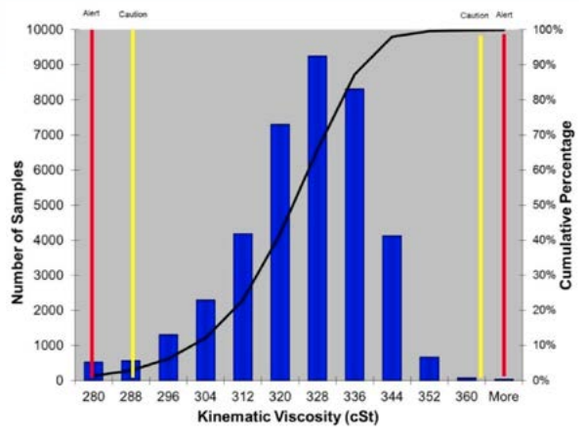

FIGURE 5 – Kinematic Viscosity

gram of oil. As the TAN value of the oil increases, viscosity rises, compromising the lubricating potential of the oil and increasing component wear. In addition, the corrosive tendencies of the oil will increase, further exacerbating wear.

As *Figure 3* illustrates, ExxonMobil examined 30,778 samples and found that 99.8 percent of the results were below the alert levels, with 25,123 results showing little, if any, increase in TAN over time. This means that the life of the advanced synthetic lubricant was not impacted by turbine gearbox operation.

Viscosity retention as an indicator of film strength

Viscosity is a measure of a fluid's resistance to flow. Most used oil analysis laboratories report the measure as kinematic viscosity in centistokes (cSt) at either 40°C or 100°C. ExxonMobil examined over 38,600 data points and found that 96 percent of the readings (*Figure 5*) were within viscosity range for the fluid used.

Furthermore, an in-depth look at 25,674 samples (*Figure 6)* found that there was no oxidative thickening or shear over time, suggesting that the lubricant stayed in viscosity grade throughout the reported service.

This confirms that Mobilgear SHC XMP 320 is able to maintain film strength and provide excellent wear protection throughout its service life.

In-service water levels and wear potential

Water contamination is an extremely relevant concern, as its presence can reduce viscosity, deplete additives, and accelerate the wear of components through hydrogen embrittlement and parts corrosion. Hydrogen embrittlement is the process by which various metals, including high-strength steel, fracture due to hydrogen exposure.

Figure 7 shows the water content by Karl Fischer in just over 22,000 samples, and *Figure 8* shows the water concentration in the oil over time.

The findings show exceedingly low levels of water in the oil, indicating that the levels present did not facilitate wear and further

Used Oil Analysis Data from Wind Turbine Gear Reducers
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(continued)

supporting the assertion that Mobilgear SHC XMP 320 can contribute to prolonged service performance.

Mobilgear SHC™ XMP 320 with five years of service

As a follow-up to this study, ExxonMobil examined the performance of Mobilgear SHC XMP 320 in 74 wind turbines where the oil is known to have more than five years of service life. This step was taken to confirm the findings of the data analyzed thus far.

As shown in *Figure 9*, this data subset mimics the findings of the much larger study revealing minimal component wear, insignificant TAN oxidation, maintained in-service oil viscosity, and low, non-impactful levels of water in the oil.

Conclusion

The use of Mobilgear SHC XMP 320 in the wind turbine main gearbox provides the following features and benefits:

- Reduced Levels of Component Wear – Longer gearbox life
- Insignificant Rates of Oil Oxidation – Extended lubricant life
- Retention of Oil Viscosity – Longer gearbox and lubricant life
- Maintenance of Low Level Water Contamination – Longer gearbox and lubricant life

So, why are these features important? The cost to generate wind energy is well above that of traditional energy sources: 4.5¢ per kWh for coal versus for 7.5¢ per kWh for wind. For wind energy to be sustainable, it is important to control all aspects of the energy

FIGURE 6 – Kinematic Viscosity Over Time

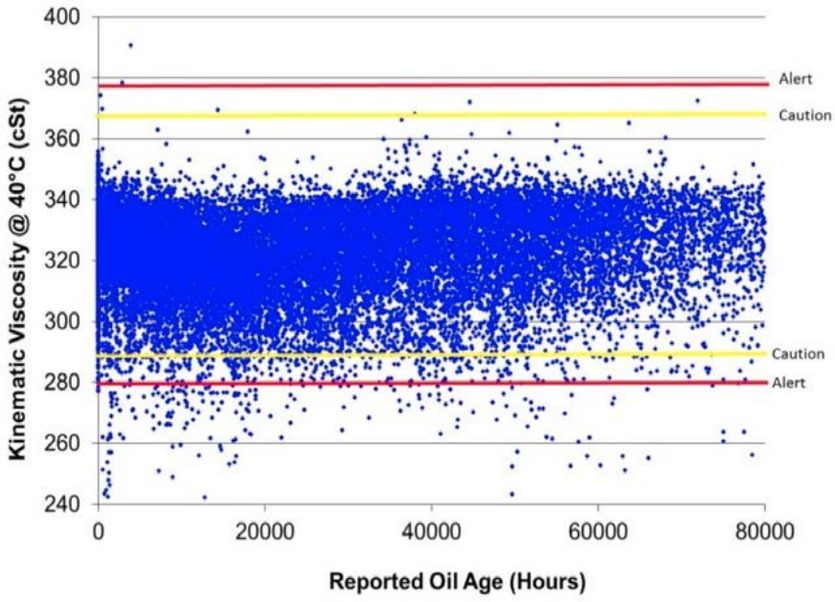
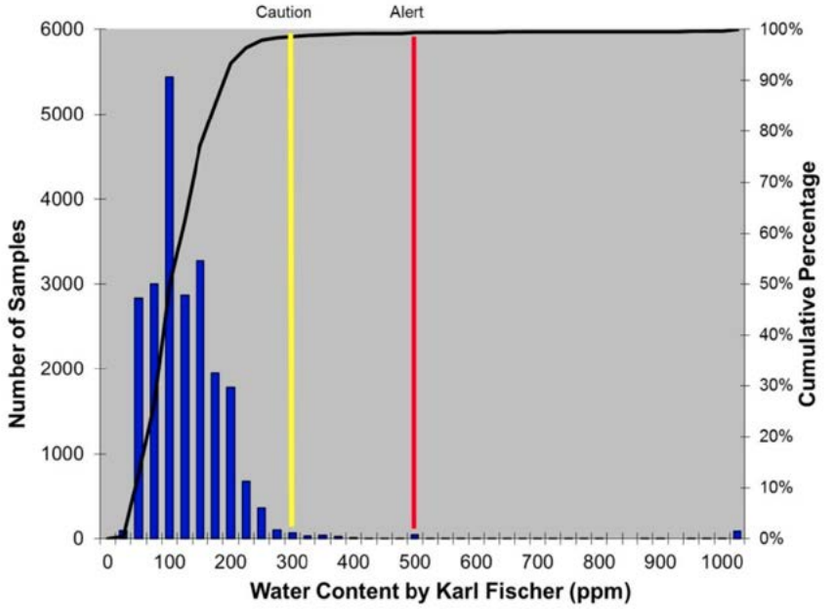


FIGURE 7 – Water Concentration by Karl Fischer



Used Oil Analysis Data from Wind Turbine Gear Reducers
Helps Define Achievable Oil Drain Intervals

(continued)

generation rate. As this study demonstrates, oil longevity and gearbox life are two practices that can be improved.

In wind turbines, extending oil drain intervals means reducing maintenance and extending service life of the lubricant. The original oil used in a wind turbine main gearbox had an expected service life of 18 months. Today, that projection has increased by three to five years. Mobilgear SHC XMP 320 advanced synthetic gear oil has shown that five continuous years of lubricant service can be a reality.

What does this mean for operators? Over the expected 20-year life cycle of a single wind turbine, operators who increase gearbox oil life from three to five years can potentially save (USD) $15,000 per turbine. In more meaningful terms, the operator of an 80 MW wind farm with 40 - 2 MW turbines, can potentially save $600,000 over the life cycle of the wind farm.

The cost of a utility scale wind turbine is about $1.75 million per MW of capacity, with replacement of the main wind turbine gearbox approximately 10 percent of the overall wind turbine costs. For a 2 MW wind turbine, replacing the gear reducer can cost more than $500,000. Over the expected 20-year lifespan of a wind turbine, the average replacement rate for its gearbox is 2.2 times. With the use of synthetic gear oil, gearbox life can potentially be extended by one year, reducing replacement costs associated with the wind turbine life cycle by $77,000. Again, applying this savings to an 80 MW wind turbine farm with 40 - 2 MW turbines could yield a savings of $3.08 million over the life cycle of the wind farm.

ExxonMobil recognizes the need to help wind energy become more sustainable. Mobilgear SHC XMP 320, can help achieve that, bringing to reality the advantages of longer oil and equipment life, reducing the costs to produce wind energy and increasing sustainability. DW

FIGURE 8 – Water Concentration Over Time

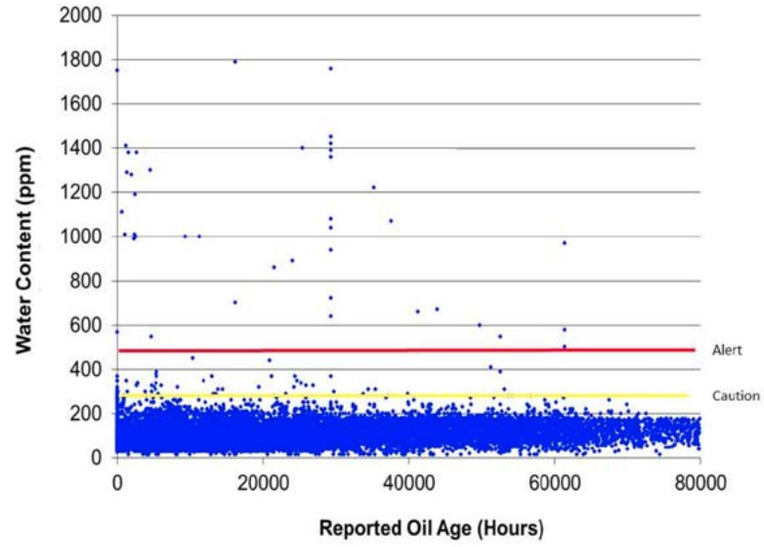
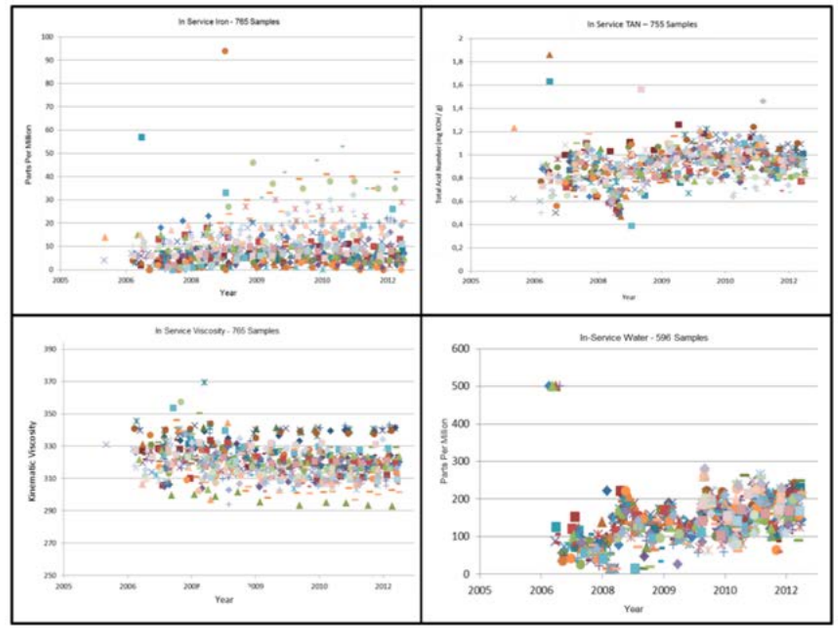


FIGURE 9 – 74 Wind Turbine Study



Wind Turbines: **Lubrication and Filtration Tips**

Courtesy of ExxonMobil

Whether onshore or offshore, keeping complex wind turbines operating at peak performance can be extremely challenging.

For wind turbine operators, choosing the right lubricants is key to prolonging turbine performance and durability.

Recently, we caught up with Rick Russo, industrial products technical advisor, ExxonMobil Fuels & Lubricants, to better understand the lubrication and filtration needs of wind turbines.

Q1 WHY IS LUBRICATION SUCH AN ESSENTIAL COMPONENT OF WIND TURBINE PERFORMANCE?

Russo: Wind turbine maintenance presents many challenges that can impact productivity.

The main gearbox drives the generator and is the heart of a wind turbine. With their advanced designs and overall importance to system performance, gearboxes can be very costly and time consuming to repair or replace after the warranty expires.

For example, when factoring in all expenses, replacing a gearbox for a 1.5 MW turbine can cost a company more than $625,000, including the price of a new gearbox, labor costs, crane rental and lost revenue from turbine downtime.

In remote locations, such as offshore, costs might be even higher and, after the warranty period, the operator becomes responsible for keeping the turbine running for the remainder of its service life.

For the main gearbox, as with all pieces of industrial equipment, lubrication plays a vital role in optimizing performance and minimizing downtime.

Q2 WHAT ARE THE KEY CHALLENGES FACING WIND TURBINE OPERATORS AND MAINTENANCE PERSONNEL?

Russo: Maintaining and prolonging the performance of the main gearbox is the greatest lubrication challenge in a wind turbine. The most common cause of gearbox downtime is related to bearing failure. Considering the variable load, speed and dramatic temperature conditions wind turbines operate under, bearings are put under a significant amount of stress. These factors, combined with improper lubrication, can result in the need for bearing replacements. If damaged bearings are not replaced promptly, significant harm to the gear may result.

The drive to minimize up-tower weight has resulted in compact gearbox designs which, in combination with high loads found in wind turbines, make these surface-hardened gears susceptible to micropitting. This can cause numerous surface cracks. The cracks propagate at a shallow incline to the surface, forming extremely small pits that can reduce gear tooth accuracy and lead to significant gear damage.

In addition to protecting against micropitting and other forms of equipment wear, Mobilgear SHC™ XMP 320 exceeds the performance of traditional oils by extending the interval between oil changes from 18 months to five years or more. Extended oil life translates into a variety of benefits, including reduced volume of oil purchases, used-oil disposal volumes, maintenance effort and lubricant-related downtime for oil changes.

Q3 WHY DOES USING SYNTHETIC LUBRICANTS VS. CONVENTIONAL OILS MAKE SUCH A DIFFERENCE IN WIND TURBINE APPLICATIONS?

Russo: The need for manufacturers to minimize up-tower weight in wind turbines has resulted in compact gearbox designs that

Wind Turbines: **Lubrication and Filtration Tips**

(continued)

incorporate the case hardening of the gear surfaces. Case-hardened gears exposed to unpredictable winds and loads found in wind turbines are susceptible to micropitting and require a gear lubricant that protects against this type of wear.

The extreme conditions to which wind turbines are subjected are easily endured by high-performance synthetic lubricants, mainly due to improved film strength at operating temperature. By comparison, conventional, mineral-based fluids cannot deliver the same level of protection. Upgrading to synthetic lubricants brings a number of advantages, including nearly 50 percent greater film strength at operating temperature, which can help maximize the performance of wind turbines.

Compared to conventional mineral oils, synthetic fluids can often help deliver significant advantages, including longer equipment life, high-temperature capability, excellent resistance to oxidation and protection against wear.

These performance advantages can help companies generate significant bottom line savings and — equally important — enable them to maximize their productivity.

Q4 WHAT ARE THE BEST PRACTICES FOR WIND TURBINE OIL FILTRATION?

Russo: There are several types of oil filters. The first step in identifying the appropriate filter for a turbine is to determine the level of oil cleanliness required for proper functioning.

There are a variety of factors to consider when making this decision, including the machine's OEM cleanliness standards, filter micron size, beta rating and the kinds of containments being removed, be it dirt, water or wear metals.

Manufacturers must also consider oil flow, and determine the flow-rate of the pump moving the oil. Filter capacity has to either match or exceed the pump flow rate to prevent filter malfunction or back-pressure build-up.

It's important that wind turbines be equipped with two oil filtration systems. The primary system filters oil prior to delivering it to the gears and bearings. The auxiliary system is designed to augment the primary system, focusing on maintaining the required system cleanliness. A duplex housing should be employed since duplex housing allows for filter changes during normal operation.

Finally, proactive filter maintenance is critically important. Maintenance personnel should take routine samples to determine overall cleanliness of the oil and the effectiveness of the filter. The filter should also have a tattletale — usually a pressure gauge mounted in the housing — that indicates when the filter needs to be changed.

Q5 WHAT ARE THE MOST COMMON MISTAKES MADE WITH RESPECT TO OIL FILTRATION?

Russo: A common problem is over-filtration. While a filtration system is designed to remove contaminants, removing excessively fine particles may negatively impact oil additive balance. It is crucial to pay close attention to the OEM recommendation for oil system cleanliness, since exceeding that specification provides limited equipment benefit and may actually hinder the performance of the lubricant.

Some manufacturers use price as the deciding factor for their filter purchases. However, it's important to remember that there are a variety of prices for the same "quality" filter. Price is impacted by several different factors — micron size, efficiency, surface area, material type, capacity — and the bottom line is that not all filters are alike. DW

Flushing Procedure for a Wind Turbine Gearbox

Converting to Mobilgear SHC™ XMP 320

Courtesy of ExxonMobil

Lubricants used in oil-pressurized gearboxes come with many different base fluids and additive technologies. Typical fluids may be mineral or synthetic, which may or may not be compatible with each other. Therefore, oil compatibility must be determined. If compatible, a drain and fill is permissible. If incompatible, ExxonMobil recommends flushing the gearbox when converting to Mobilgear SHC XMP 320 oils.

1. This procedure may be used for drain and fill or flushing for Mobil SHC™ wind turbine gearbox lubricants.
2. Determine new oil compatibility with previous lubricant. Consult with ExxonMobil Field Engineering Support team for assistance.
3. Drain oil from gearbox systems, allowing as much to exit as possible.
4. Jog the oil-circulating pump motor on low-speed until all oil is pumped from the lines, stopping at the first sound of pump cavitation.
5. Disconnect and drain all external lines from oil pump. Drain any oil remaining in oil cooler.
6. Clean filter housings of all deposits and debris. Change out all removable filters (use OEM-recommended filters). Reconnect all external lines.
7. Open gearbox inspection covers and look for residue from previous lube charge. If possible, take photos to document condition.
8. If oils were deemed compatible in step 1 and cleanliness observed in step 6 is acceptable, skip to step 13.

Flushing Procedure for a Wind Turbine Gearbox

Converting to Mobilgear SHC™ XMP 320

(continued)

9. Charge gearbox with flush oil (Mobilgear™ XMP 320 or final fill product) to minimum level for oil circulation. This is typically 60% of full oil charge. Consult OEM for minimum volume required to establish oil circulation.

10. Circulate flush oil by selecting high-speed level on multi-speed pump. Allow turbine to operate or pinwheel if possible. Circulate for two to four hours or until oil temperature reaches 60°C/140°F.

11. Monitor filters for plugging during this process. If filter plugging is observed, change oil filters as needed, cleaning filter housing each time. Continue circulating oil until filter plugging ceases. Then, shut down oil pump and secure rotor.

12. Drain oil. Open gearbox inspection covers and examine residue levels. Compare to amount noted in step 6.

13. Repeat steps 8 – 11 as necessary to reach acceptable level of cleanliness.

14. Charge system with Mobilgear SHC™ XMP synthetic gear oil using installed filtration* to achieve target oil cleanliness level (ISO 4406 standard recommended – /14/11).

**Filter media should be of the same type as those recommended by the OEM, typically glass fiber. Diluted method particle count recommended.*

Note: *Implement Signum℠ Oil Analysis to facilitate monitoring oil condition during turbine operation.*

Wind Turbine Gearbox – Oil Conversion Considerations

Courtesy of ExxonMobil

Oil change process

- Objective: Remove used oil from the gearbox to
  - Minimize contamination of the new oil
  - Achieve optimal performance and life of the new oil
- Use of appropriate oil change procedures will ensure proper lubricant and wind turbine performance
  - Gear lubricant performance and drain intervals
  - Filter change intervals
  - Wind turbine productivity and gearbox life

Pursuit of an alternate conversion approach may not deliver optimal lubricant and wind turbine performance (e.g., oil life, filter plugging, foam)

Oil Compatibility	Gearbox Deposits/Contamination	Preferred Conversion Approach	Alternate Conversion Appoach
GOOD	NO	Drain & Fill	
POOR		Drain, Flush & Fill	Drain & Fill (if complete drain is possible)
GOOD	YES	Drain, Clean, Flush & Fill	Drain, Flush & Fill (cleaning agent added to in-service oil)
POOR			

Note: *The Signum℠ Oil Analysis program facilitates monitoring oil condition during turbine operation.*

Wind Turbine Gearbox – Oil Conversion Considerations

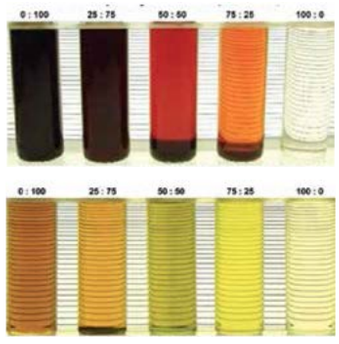
(continued)

Conversion Case Study*: Competitor product (synthetic) to Mobilgear SHC XMP 320

- **Compatibility: fresh oils are conditionally compatible**
  No major issues with used oil

- Low-risk conversion
– Drain & Fill process possible
– Some flushing recommended if > 3% used oil remaining in system

Mix of Mobilgear SHC XMP 320 (fresh oil) & Competitor product (used oil). After 14 days storage at 60° C/140° F (ratios in % oil)



Note: *Shadow at the bottom of container should not be mistaken for deposit*

** Condition of used oil may vary.*

Used Oil Compatibility Testing			
Mobilgear SHC™ XMP 320 (fresh) Competitor product (used)	100 0	90 10	0 100
Viscosity, mm²/s 40° C 100° C	339.4 38.0	339.1 37.5	307.6 32.1
Viscosity Index	162	159	144
Foam Tendency/Stability, ml Sequence 1 Sequence 2 Sequence 3	0/0 0/0 0/0	470/400 570/0 300/170	100/10 550/450 300/90
FZG A/8 3/90, fail load stage	typ > 12	13	> 13
Filterability 5 µm, Time for first 100 ml, s	93	> 1800 plugged	> 1800 plugged
Compatibility after storage	Incompatible – significant impact on filterability; haze and flocculation in some mixtures		

Conversion Case Study*: Competitor product (synthetic) to Mobilgear SHC™ XMP 320

- **Compatibility: fresh oils are incompatible**
  Testing with used oils showed foam and filterability issues

- High-risk conversion
– Drain, Flush & Fill process
– While circulating flush oil, special attention to filter plugging is recommended

Mix of Mobilgear SHC XMP 320 (fresh oil) & Competitor product (used oil). After 14 days storage at 60° C/140° F (ratios in % oil) DW

Used Oil Compatibility Testing			
Mobilgear SHC XMP 320 (fresh) Competitor product (used)	100 0	90 10	0 100
Viscosity, mm²/s 40° C 100° C	328.5 37.8		304.0 29.9
Viscosity Index	165		134
Foam Tendency/Stability, ml Sequence 1 Sequence 2 Sequence 3	0/0 0/0 15/0	60/0 20/0 130/0	650/620 650/0 500/300
FZG A/8 3/90, fail load stage	typ > 12	> 13	
Filterability 5 µm, Time for first 100 ml, s	210	145	173
Compatibility after storage	Compatible – Slight haziness only for some mixtures		

For more information about ExxonMobil visit:

mobilindustrial.com

Looble.com

signumoilanalysis.com

or contact your local Mobil Industrial Lubricants representative.