Performance and monitoring of gear oils for wind turbines

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Abstract

The literature dealing with the influence of gear oils type and quality on energy efficiency and reliability of the wind turbines and monitoring of the gear oil condition in these systems is examined. Operation and maintenance activities are estimated to be about the third of the electricity cost from wind generators. Consequently, development of efficient maintenance is critical in the wind industry. Lubrication is the important part of the maintenance activities. Identification of the performance differences between different types and formulations of the lubricating oils can give the information for the validation of gearbox power loss and lifetime of the lubricant. This is important since the mechanical failures of the gearboxes are not unusual and repair cost of it is usually very high. To prevent this development of sensor-based continuously monitoring of the wind turbines lubricated system are developed.

Keywords: Wind turbine, Gear oils, Energy efficiency, Lubricant monitoring, Corrosion

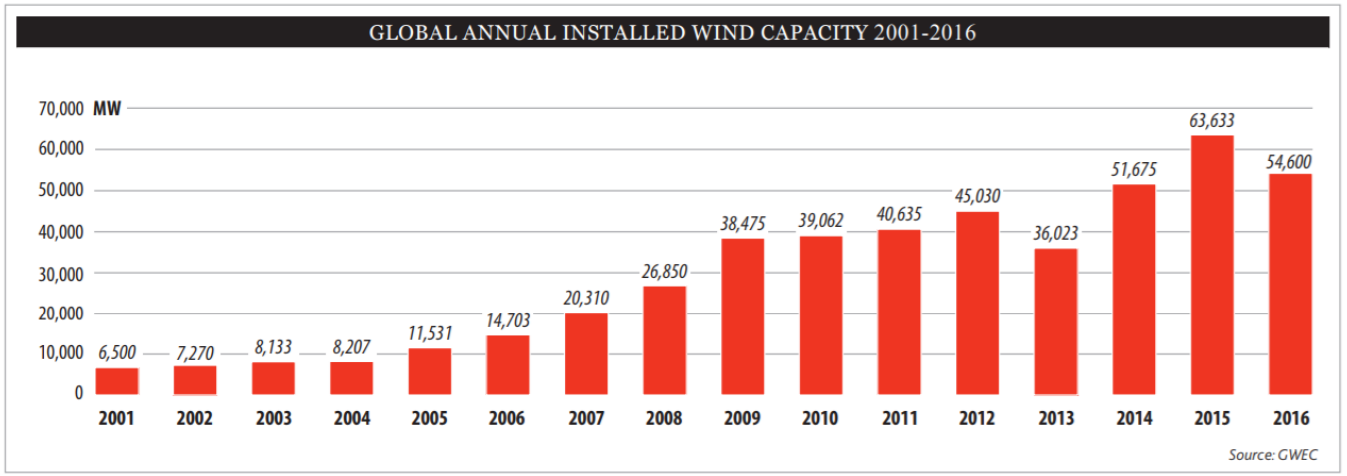
Introduction – Wind Energy in General

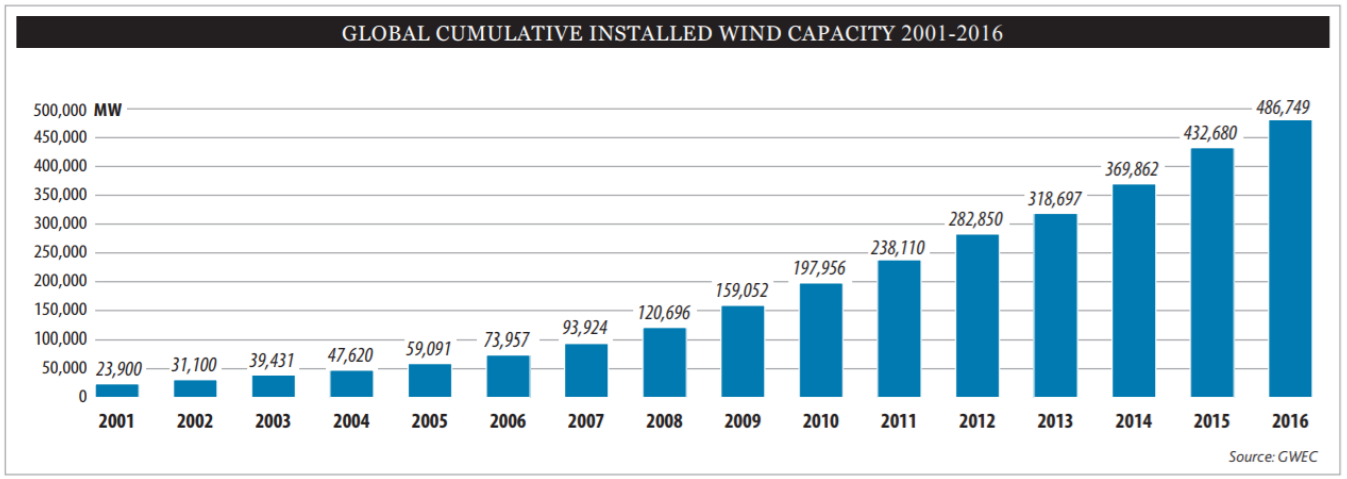
- Main sources of renewable energy are:

  solar, hydropower, **wind**, geothermal and biomass.

Wind is a source of clean and sustainable energy and one of the fastest growing among them with leading position in the first decade of the XXI century [1].

[1] K. Kaydusuz, Wind Power for a Clean and Sustainable Energy Future, Energy Sources, Part B: Economics, Planning, and Policy, 4 (2009) 122–133





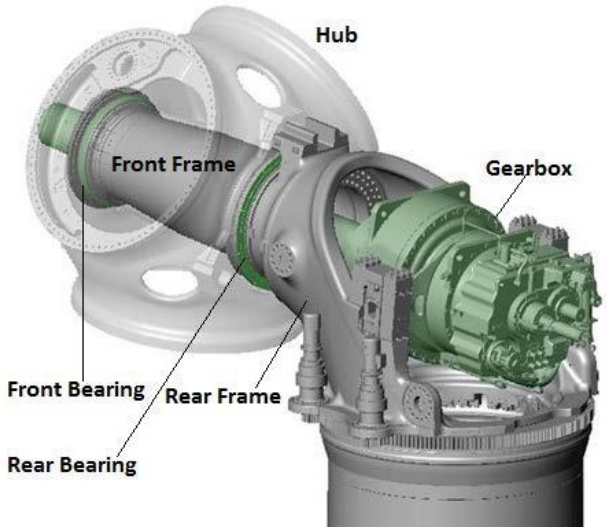
Introduction – reliability of WT

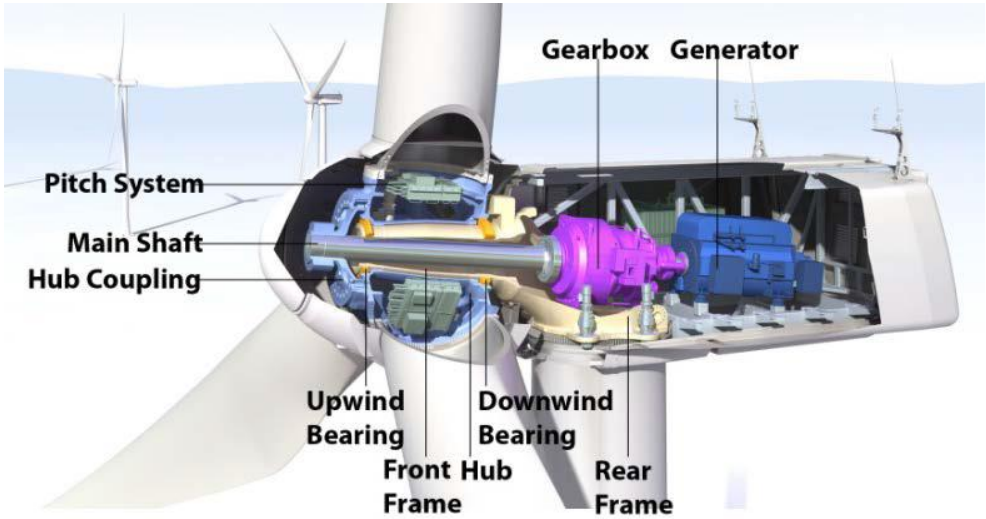
- The major targets for wind energy industry are the improvement of equipment working life, and to reduce energy losses and equipment downtime. Fortunately, these aims are directly connected and the fulfillment of one of them positively affects others.
- **Gearbox units for wind generators are designed for a twenty year lifetime;**
- ***nevertheless, in practice real lifetime is considerably smaller.***
- In many cases, the premature failure of is lubrication related, and consequently careful choice of the lubricant (gear oil) is critical.
- Additionally, sophisticated gearbox and lubricant condition-monitoring systems are developed. Predictive models also provide improvement in the prediction and prevention of wind turbine gearbox failures.

Introduction – energy efficiency

- Efficiency is a major requirement for wind turbines. Gear units for this purpose have up to three stages and a global efficiency up to 95%.
- Main source of gearbox power losses are friction losses in gears and rolling bearings.

Since these losses are transformed in heat warms up the lubricant and promotes its degradation and loss of properties. Lubricant degradation requires more frequent lubricant change, cause gear failures and operating downtimes of the wind turbine.





Figures from:
Improving Wind Turbine Drivetrain Reliability Using a Combined Experimental, Computational, and Analytical Approach
Y. Guo and J. van Dam
National Renewable Energy Laboratory
R. Bergua and J. Jové
ALSTOM Wind S.L.U.
J. Campbell
ALSTOM Wind
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LUBRICANTS – Types of Oils

WTGs use both mineral oil and synthetic lubricants.

Use of synthetic lubricants increases due to their advantages:

- increased oxidational and thermal resistance,
- better low temperature properties,
- high viscosity index,
- lower evaporation losses,
- improved lubricity,
- lower tendency to form residues,
- improved resistance to ambient media.

However, they have disadvantages: higher price, more prone to reactions in the presence of water (hydrolysis and corrosion) and material compatibility problems.

LUBRICANTS (Synthetic)

Commonly used synthetic lubricants today are designed from:

- synthetic hydrocarbon oils (SHC),
- polyalphaolefins (PAOs),
- polyalkylene glycols (PAGs) and
- synthetic esters;
- Oil soluble PAG (OSP) based oils have recently been introduced into field operation.

The most important parameters for the WTG lubricants (oils) are:

- Viscosity Index
- Coefficient of friction
- Service life

LUBRICANTS (Viscosity Index)

For the wind generators with power over 250 kW almost exclusively the ISO VG 320 oils are used. Influence of VI is high since 320±10% mm^2s^{-1} at 40 °C can be 22 to 55 $mm^2 s^{-1}$ at 100 °C, for VI range from 80 to 240 or 43 to 90 $mm^2 s^{-1}$ at 80 °C (usual working temperature) in the same VI range.

- **The influence on the lubrication film thickness and wear protection is obvious.**

Table 1 Typical viscosity index for ISO VG 320 fully formulated oils by type

Type of base oil	Method	Viscosity index
Mineral	ASTM D2270	85
PAO	ASTM D2270	150
Ester	ASTM D2270	160
PAG	ASTM D2270	240

Value of VI for mineral oils can be improved by use of specific additives. It can even reach the levels of PAO or Ester based oils. Alkyl methacrylate copolymers (PAMA) can be used as improvers of rheological properties of mineral gear oils for the WTGs but it is rarely utilized due to the long term viscosity stability of the lubricant.

LUBRICANTS (coefficient of friction)

Very important parameter for the lubrication oils is friction coefficient of friction (COF).

Two COFs of importance are:

- the COF in boundary lubrication conditions (μbl) and
- in elastohydrodynamic (EHD) lubricating conditions (μEHL).

They are different for various types of bearings but average values of both relatively to mineral gearbox oil at working temperature are given in the Fig. 1.

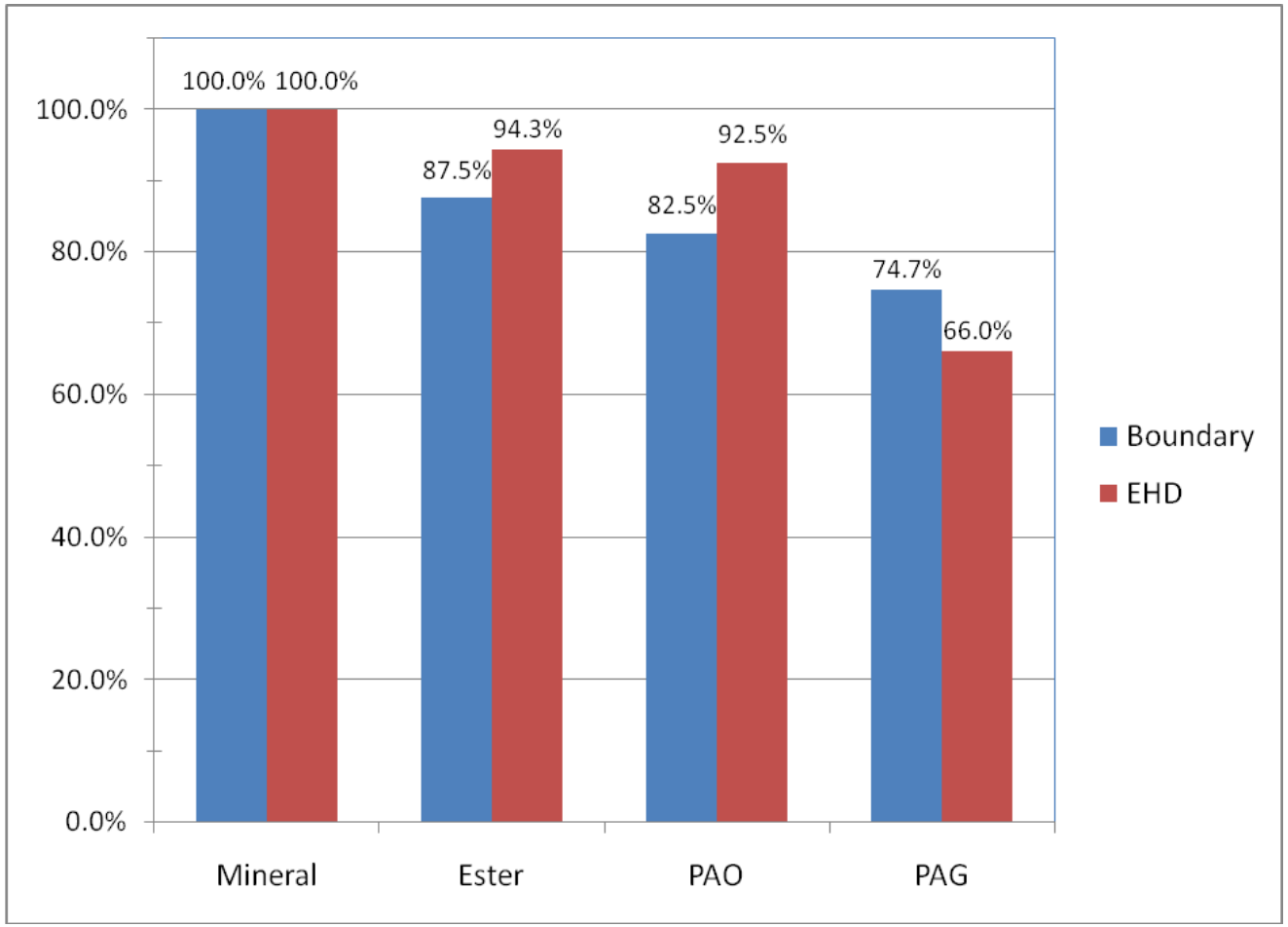

Figure 1 Boundary (μbl) and EHD (μEHL) coefficient of friction for bearings

LUBRICANTS (Service Life)

- Finally, synthetic oils have a longer service life than mineral oils. In the Table 2 are shown average oil change intervals of gear oils in general. Although service intervals can be somewhat longer due to special (additional) additivation, ratios from the Table 2 can be used for WTG oils.

Table 2 Approximate oil change intervals of gear oils at an operating temperature of 80 °C

Type of oil	change intervals	extension factor
Mineral	5000 operating hours	1
SHC	15000 operating hours	3
PAO/Ester	20000 operating hours	4
PAG	25000 operating hours	5

Lubricant monitoring systems

It is especially important since difficult access to sites and the harsh working conditions. These problems are more significant in the case of offshore installations. Operations and maintenance costs can be significantly reduced by developing and use an appropriate management strategy utilizing combination of reliability centered maintenance (RCM), e-condition monitoring and e-maintenance technologies.

From the pure technical aspect of the lubricant monitoring systems (LMS) development of the specific sensors and specific instruments:

- inductive wear debris sensors,
- Optical fiber sensors:
  - classical
  - spectral response
  - Lossy mode resonances (LMRs)

Not only the maintenance costs are reduced but also downtime of the facilities.

These methods optimize the consumption of materials and the engagement of the highly skilled personnel.

Conclusion

Following conclusions can be drawn from this work:

- The PAG based lubricants have the best power loss behavior from all the lubricants tested, whereas the mineral based had the worst performance.
- The Ester and PAO based lubricants had similar characteristics, and they are very useful since have better characteristics than mineral and HC based oils.
- Synthetic gearbox oils have substantially higher price but show better ageing, thermal and load resistance, as well as lower friction. This allows longer oil change intervals, less power loss and extremely lower costs of maintenance and maintenance-related downtime. Finally, considerably higher plant yield is certain and proven in practice.
- Lubricant monitoring systems based on resent sensor technology and complemented by remote maintenance activities can identify possible failures and prevent them. These systems lower operational and maintenance costs and contributes to greater cost-effectiveness of wind farms.

Acknowledgments

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Thank you for your attention!!!