Condition based oil changes on wind turbines

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In the wind turbine industry a revolution is happening within oil maintenance. Changing oil used to be based on time and operation hours, but many wind turbine owners see this method as obsolete. Studies have shown that way too much oil and too many components have been prematurely replace, when following this type of preventive maintenance regime (see ref. list). The new and improved way of triggering an oil change is looking at the condition of the fluid, e.g. using oil analyses. The benefit is longer oil life - often 3 times depending on environment and filtration level, e.g. from 2 up to 6 years in service.

This paper will focus on wind turbine gear oil and hydraulics, but can in principle be used for most oil systems.

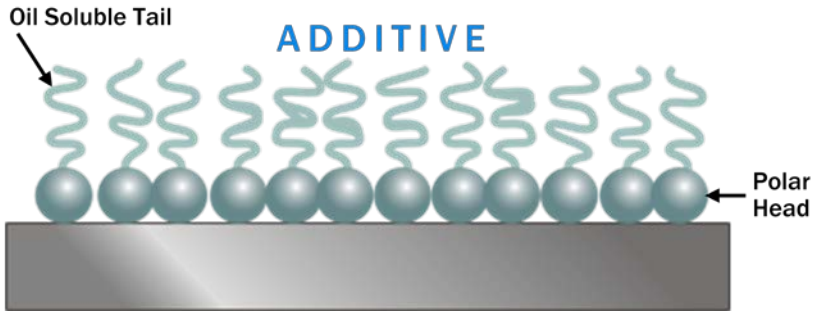
Why is oil changed in the first place?

A common answer not so long ago could be: "The oil was dirty, so I replaced it".
This is an expensive mindset, since effective filtration can remove solid particles and water quite easily. This is especially important for oil systems which are difficult to access, e.g. offshore wind turbines.
Most oil in service will only need to be replaced, when the oil is degraded and the properties are no longer intact.

Base oil and additives

Lubricating and hydraulic fluids consists of base oil plus 2 – 15% additives. Typical additives are: anti-oxidants, anti-wear, anti-foam, corrosion inhibitor and for gear oil also viscosity index improvers, EP additives and sometimes pour point depressants.
Hydraulic oil is, together with turbine oil, some of the oil types with least additives. Engine lube oil will, in comparison, often contain 20 – 30% additives.

The base oil degrades due to heat, air, water and metal catalysts such as iron and copper. To fight premature oil degradation robust base oil is used together with anti-oxidants (often ZDDP; Zinc Dialkyl Dithio Phosphates).



1) Polar additives (source: Noria Corporation)

ZDDP doubles as a polar, metal wetting anti-wear additive (AW), which forms an ash-like film to protect against adhesive wear (metal-to-metal contact) between components in the oil system, e.g. pumps, gears, valves, etc.

The AW additives are normally not sufficient to protect a gear from wear, so gear oil contains polar EP additives (Extreme Pressure), which are designed to protect gears during boundary lubrication i.e. poor oil film thickness during cold start-up, shock load, vibrations etc.
These EP additives are most often based on Sulfur-Phosphorous, which form adherent surface film on gear teeth. They get active and transform into a ductile metal soap layer, when the temperature increases locally in the gear due to asperities touching. The process is actually chemical wear, but is much better than the adhesive wear that would happen otherwise (local spot welding).

However, polar additives will degrade with water and heat as catalysts and will deplete with excess amounts of particles in the oil. This is one of the reasons why the level of water and particles has to be monitored in oil.

Oil analysis – new oil as baseline
Oil analyses can be used to check remaining oil life by looking at the base oil and additive package. As a rule of thumb, the additive level in used oil has to be minimum 70% of the additive level in new oil (Ref. Noria Corp.)
It is therefore vital to sample every incoming oil drum/batch to establish the base line. This will also help to prevent a faulty oil batch from being used.

A good oil analysis report should give information about:
- Is the oil suitable for further use: Are base oil properties and additives still intact?
- Condition of the machine: Has a critical wear situation developed?
- The level of contaminants: Are seals, breathers and filters operating effectively?
- Is oil degradation speeding up: Could a severe varnish problem be occurring soon?

2) Degraded hydraulic oil compared to new oil (source: C.C.JENSEN)

Condition based oil changes
As mentioned earlier, replacing oil based on time or operation hours is expensive and unnecessary. Condition based oil changes is the optimum way. If you want to trigger oil changes based on the lubricant health, the five listed are the primary modes of measure (ref. Noria Corp.):

- Viscosity
- AN
- FTIR
- Elemental Analysis (wear and additive level)
- Water by Karl Fisher

Oil samples need to be taken and analyzed on a regular basis, and it is important to compare the result with the base line (new oil) and the historic trend. This means only one oil analysis per year would require a very long period to establish a trend.

The following routine oil analyses should be performed on the wind turbines (6 month/every service visit)

- Viscosity and viscosity index (+/- 10% is acceptable. Increase in viscosity can indicate oil degradation)
- AN (increase in acidity indicates base oil degradation. 0.5 mgKOH/g above new oil AN is caution level)
- FTIR (the oil's "finger print", will show oil degradation, water, mix with other fluid types, etc.)
- Elemental Analysis (will show dirt ingress, wear metals and additive level)
- Water by Karl Fisher (very accurate determination of moisture level in oil)
- Particle count according to ISO 4406 (hard particles from dirt and wear)

Additional recommended oil analyses

- Water release properties (Demulsibility test according to DIN 51599, ISO 6614 or ASTM D1401)
- Foaming tendency and air entrainment tests (according to ISO 6247 or ASTM D892)
- Ferrous density - relation between large/small magnetic particles (DRF, WPC or PQ-index)
- Oil degradation and varnish test (MPC - Membrane Patch Colorimetric, Voltametry/RULER test)

Conclusion

Replacing oil based on oil analyses is the optimum way - both for the machine and your economy. A good oil analysis laboratory can interpret the data and indicate whether the oil is suitable for further use. Each result will need to be compared to the base line and the historic trend, since a stand alone result doesn't give much information.

Oil analysis gives most value if a person is assigned to collect all the oil analysis reports, understand them and take action e.g. write a work order to replace a filter or the oil. A log book including levels for the baseline, caution and critical levels is a great tool.

Please see next pages for an example of log book and recommendations to wind turbine oils.

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Oil analysis log book

Example of hydraulic oil analysis including new oil base line, caution and critical levels

Parameter	Base line	Caution	Critical
Particle Count (ISO 4406)	15/13/10 (pre-filtered)	17/15/12	19/17/15
Viscosity	32	Low 29 High 35	Low 25 High 38
Acidity (AN)	0.5	1.0 – 1.5	Above 1.5
Moisture (KF)	100	200 – 300	Above 300
Elements in ppm Fe	7	10 – 15	Above 15
Al	2	20 – 30	Above 30
Si	5	10 – 15	Above 15
Cu	5	30 – 40	Above 40
P	300	220	150 and less
Zn	200	150	100 and less
Oxidation (FTIR)	1	5	Above 10
Ferrous Density (WPC, DR)	-	15	Above 20

Appendix

Typical levels for elements in hydraulic fluid used in wind turbine pitch systems.
Source: WearCheck Ibérica, Tekniker, Spain

	Normal	Caution	Danger
Water content (ppm)	<200	200-300	>300
Al content (ppm)	<20	20-30	>30
Ca content (Difference in %)	100	<70	<50
Cr content (ppm)	<10	10-15	>15
Cu content (ppm)	<30	30-40	>40
Fe content (ppm)	<10	10 - 15	>15
Mg content (Dif %)	100	<70	<50
Mo content (Dif ppm)	<10	10-20	>20
Na content (ppm)	<50	50-80	>80
P content (Dif %)	100	<70	<50
Pb content (ppm)	<10	10-15	>15
Si content (ppm)	<10	10-15	>15
Sn content (ppm)	<10	10-20	>20
Zn content (Dif %)	100	<70	<50

Reference list

WearCheck Ibérica, Tekniker, Spain; “Typical levels for elements in hydraulic fluid, WT pitch systems”

Noria Corporation, Jim Fitch & Drew Troyer; “Oil analysis basics”

Studies; Effects of preventive maintenance:

“One out of every three dollars spent on preventive maintenance is wasted.” - *Forbes Magazine*

“60 percent of hydraulic pumps sent in for rebuild had nothing wrong with them.”
- *Hydraulics and Pneumatics Magazine*

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