Title: Consequences of Oil Degradation and its Prevention

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Mechanical and thermal stress among other factors leads to oil degradation and oil oxidation. The residues of this process, the degradation and oxidation products can have harmful consequences on many components of the system in which the oil has a function.
Whether it be a hydraulic system, a gear or lubricating system the oil is put under stress the intensity of which is dependant on a number of factors.
In wind turbines the gear oil is not only contaminated by solid particles caused by wear and tear and water due to the temperature differences in the wind turbine gearboxes and the consequential air humidity entering the system but also by varnish, the accumulation of the products of the chemical reaction taking place through oil degradation and oil oxidation.
Common causes of oil degradation among others are oxidation, hydrolysis, thermal degradation and wear particles as well as other contaminants. Oxidation here means the breakdown of the oil with oxygen as reagent. Hydrolysis is the process where water serves as the reagent for the oil's breakdown. With thermal degradation the oil's breakdown is activated by heat, Furthermore, the existence of wear particles and other contamination facilitates the oil degradation by providing reactive surfaces such as copper.
The results of oil degradation are considerable. In the oil there is an accumulation of acid compounds which in turn lead to corrosion and wear. Furthermore the degradation residues increase the oil viscosity, so the oil can no more fulfil it's lubricating function properly. Friction, wear and a loss in the efficiency of the system are the consequences. The degradation products can accumulate as sludge, and if not removed form a sort of varnish, a sticky layer on the system's components.

Varnish has a number of harmful effects on the oil system's components. Apart from the abrasion on the surfaces this varnish and an increased wear of the components this varnish leads to a general reduction of the machine's performance. The efficiency of heat exchangers decreases, small tolerances are clogged, filters block and valves stick. The oil flow is restricted and the oil system necessitates increased maintenance resources.

In the wind turbine sector, oil degradation is accelerated by the following circumstances: during night or at still stands the oil is cooled down drastically and – during the wind turbine's operation – heated up again. Although compared with other applications, the oil is not constantly put at excessive temperature, it is still heated up locally and at these hot spots thermal degradation takes place. The contact of the oil with the ambient air in combination with the differing temperatures (ambient temperature and oil temperature) lets the oil oxidate via the air and the air moisture entering the oil.

Taking these phenomena into account during the design of the wind turbine can lessen the hazardous effects on the oil but not prevent them. There will remain a contact of the oil with air and water, there will remain thermal stress (even if locally restricted) and there will also remain the contact of the oil with copper and other catalysts for the degrading process of the oil.

Preventing degradation of the oil is one measure, another should be the removal of the inevitably occurring degradation products. As to the sticky character of the varnish an oil change is no solution. The degradation products remain in the system even if the whole oil volume is exchanged.

A continuous filtration of the gear oil can remove the degradation by-products before they have time to react further and form sludge and varnish. Unfortunately, not every filtration method is applicable for the removal of oil degradation products. Due to the small size (< 1 µm) traditional filters are not suited for this task. Neither are filters based on the centrifuge principal since there is no difference in density between the oil and its degradation products.

One suitable measure to this means, apart from electrostatic filters and the BCA technology, is a filtration with a depth filter made of cellulose fibres. This mesh of fibres not only retains solid particles. The cellulose fibres themselves absorb water and thanks to their many polar sites adsorb resins.

Strictly speaking, the process is a combination of adsorption and absorption. The large active surface of the filter insert provides a great amount of polar sites. First, the oil degradation products are adducted to the fibres (Adsorption) and then are drawn further inside the fibre where the stick to cellulose molecules (Absorption). This combination of film diffusion, macro and micro diffusion takes places on / in each of the innumerable cellulose fibres of which the filter insert consists.

The oil degradation products accumulate in the filter insert and not in the system, where they would form resins and varnish.
A positive side effect of an oil kept constantly free of oil degradation products derives from the oil's equilibrium behaviour. When passing the system and the accumulations of resins, the clean fluid picks up some of the contamination transporting it until it is absorbed by the cellulose fibres. Thus, in the course of time, not only the oil, but the whole gear oil system is cleaned from oil degradation products.

It is recommended to monitor the oil contamination with degradation products. This can be achieved by a viscosity test, an analysis of the TAN (Total Acid Number) , a Millipore membrane test, a colorimetric or gravimetric analysis, an ultracentrifuge test or with infrared spectroscopy.

As said before, the generation of oil degradation products cannot be avoided completely, but it can be diminished by an installation of an off-line filtration system which can remove degradation products. Furthermore, working at the oil temperatures recommended by the machine and oil manufacturer is advantageous. Oil filtration should continue after the machine stop, the sufficient flow over the bearings should always be assured, and an oil analysis should be taken as often as possible.

The fundament for good lubrication: A clean, dry oil – as cool as possible.

Steffen Dalgaard Nyman, C.C.Jensen A/S, Education and Coaching, "Oil Degradation and Filtration", 2006