Varnish in turbine oils

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Abstract

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The appearance of varnish in turbine oil can lead to hydraulic malfunctions and to increased bearing temperatures. The consequences are unplanned downtimes and high costs. Varnish are oil aging products that form gel-, resin-like or solid varnish-like deposits in the fluid system. Among other things the reason for these deposits is the limited dissolution capacity of varnish in modern turbine oils. Furthermore, these oils also have low electrical conductivity, which causes electrostatic discharges in the system. This results in accelerated oil aging, and damage to sensors and filter elements.

In the past an oil fill had a service life of usually 15 to 20 years. Today the service life of modern oils is significantly less than ten years. In order to avoid critical system operation, the routine laboratory examination parameters must be expanded. Early recognition of the risk of deposits and the use of adapted fluid care will increase the safety of operations and reduce operating costs.

Introduction

The condition of the oil in lubrication and hydraulic systems is indicative of the health of the entire system. There are two essentials for ensuring productivity, for avoiding malfunctions and for reducing operating costs:
– Monitoring the fluid condition, on the one hand, and
– Continuous maintenance of operating equipment.

Varnish refers to oil aging products that form deposits in the fluid system which have a gel/resin-like consistency or resemble solid varnish (Figures 1 to 4). These oil aging products are readily deposited on cool surfaces such as the tank, valve housings or coolers. This causes an increase in bearing temperatures, malfunctions in hydraulic valves and cooling problems. In most cases, however, the above malfunctions are not correctly attributed to the real cause. This results in ineffective, and often very expensive, repair work.

The subject of oil aging is not new by any means; in fact it has always been an issue. However, as a consequence of the introduction of more highly refined base oils, the characteristics of turbine oils have changed. Whereas in the past, oil had a life of 15 to 20 years, today the service life of modern turbine oils is considerably less than 10 years. This means that fluid monitoring and fluid conditioning are becoming more and more important.

This scientific paper provides an overview of the changes in base oil characteristics, laboratory analysis procedures for detecting oil aging, and fluid conditioning measures for the removal of oil aging products, with a view to eliminating possible faults.

Alteration in base oil characteristics and the consequence

The base oils generally used today for the production of turbine oils have changed in recent years. They reflect the increased demands with regard to higher turbine efficiency, higher bearing temperatures and reduced levels of hazardous substances. Whereas oils used to be produced exclusively by the distillation of crude oil (ASTM Group I oils), for some years now further refinement processes have been employed. The procedures used, such as hydrotreating or hydrocracking, result in superior chemical purity and oil of uniform quality with global availability.

These changed production processes produce base oils with lower levels of unsaturated polar hydrocarbons (ASTM Groups II, II+, and III). Base oils in the ASTM Groups II and III are also usually free of sulphur. During production of the turbine oil, a sulphur-phosphorous additive is generally therefore added.

There is a problem with this refinement in that varnish has a polar structure. Polar substances tend to dissolve more readily in polar substances. If the proportion of polar hydrocarbons in oil is reduced, oil aging products / varnish cannot dissolve as easily. The effect is oil turbidity (Figure 5) or deposits in the system. These changes usually start once the oil has been in operation for 3 to 4 years.

Due to the low proportion of polar substances, these oils also have low electrical conductivity, which causes electrostatic discharges in the system. This results in accelerated oil aging, and damage to sensors and filter elements.

Fig. 1. Varnish on the cover plate of the hydraulic pump.

Fig. 2. Varnish on the filter element.
mixing can result in chemical reactions, which under certain circumstances may lead to the precipitation of reaction products and to deposits within the system.

**Laboratory analysis procedure for detecting varnish in turbine oils and the limit for critical system condition**

Scope of testing for a usually half-yearly routine inspection

The scope of testing for the half-yearly routine inspections is listed with the appropriate procedure in Table 1. The presence of varnish in oil cannot be detected with these routine inspection parameters. Given the increasing problems with deposits in turbine systems, other procedures have been added to the routine inspection parameters.

**MPC value determination**

The MPC value records the changes in colour of a laboratory filter membrane with 0.45 µm filtration rating. Critical system conditions occur if the MPC value is over 40. The effect of this is that more deposits occur in the system, as shown in Figure 1 to Figure 4.
Particle counting at room temperature and at elevated oil temperature

The size, number and composition of particles significantly impact the wear and the function of hydraulic components and systems. The size and the number of particles is determined using automatic photomicroscopic particle counters and is displayed as cleanliness classes to ISO 4406. The relevant standard for particle counting is ISO 11500. The standard maximum cleanliness classes for turbine lubrication systems are: ISO 18/15/12 and ISO 17/14/13, if the steam control system is supplied by the same tank. In this case an increase of one cleanliness class equates to a doubling of the particle count in each case.

The solubility of oil aging products/varnish is dependent on temperature; it increases at higher temperatures and decreases at lower temperatures. As soon as the solubility threshold is reached, oil turbidity occurs. The particle counter is able to detect this turbidity due to the high particle count before it is visible to the naked eye. If two identical oil samples are analysed – one at room temperature (approx. 22 °C), and the other at 80 °C – there will be a difference in particle quantities in the evaluation if there is varnish in the oil.

Example: Figure 8 shows just such a particle evaluation. The measurement was carried out using a FCU/BSU 8000 (Figure 9) produced by HYDAC Filter Systems GmbH. The particle distribution class at room temperature (in this case 22 °C) was ISO 23/18/12. The same measurement when the oil was heated to 80 °C resulted in a particle distribution of ISO 18/15/12. From the substantial particle differential, we can conclude that there is a high proportion of undissolved oil aging products/varnish in the oil.

Determining the remaining proportion of antioxidants

Antioxidants are added to the oil to slow down oil aging and hence the formation of varnish. These additives (e.g. amines and phenols) degrade as the oil ages. In order to increase the proportion of antioxidants, one of the usual options is to make up the oil quantity lost during operation with new oil. The addition of new oil, which still has 100 % antioxidants, will increase the overall concentration of antioxidants in the oil.

Removal of varnish based on the example of a turbine lubrication system

An application on the lubrication system of a steam turbine is explained below.

System description
- Lubrication system of a steam turbine
- Oil quantity in the system: 12,000 l
- Age of oil: 27,000 operating hours
- Conductivity: < 10 pS/m at 21 °C
- Oil type: Turbine oil with EP additive, base oil ASTM Group II

The initial problem centred on malfunctions on the steam control valve, which led to problems on shut-down of the turbine. The cause was found to be deposits between the valve body and the valve spool due to oil aging.

Oil aging products/varnish are problematic in that they are initially highly filterable and the valve functions are unaffected. Individual particles are less than 1 µm in size. For comparison: Standard valve clearances are...
within the range of several micrometers. As a result of ongoing oil aging or when the oil has cooled down (e.g. during a system shutdown), these particles agglomerate, become larger, and form varnish-like coatings. These then have the effect of increasing the actuation forces in the valve and of causing the above malfunctions.

In order to clean the varnish in the oil, a VarnishMitigation Unit produced by HYDAC (Figure 10) was used. This system is similar in construction to an offline filter and works 24h per day, 365 days per year. The separation of varnish takes place by adsorption onto a specific resin. Once the adsorption capacity of the resin is exhausted, the quantity of varnish in the oil rises again. When the critical MPC value of 40 is exceeded, the resin-filled elements are changed. Figure 11 shows the progression of the varnish content in the oil of this system when using this offline filter unit, measured by the MPC value.

**Summary of results and outlook**

Immediately after commissioning the conditioning unit on 16 February 2012, the MPC value fell drastically. On 25 April 2012, the separation capacity of the resin was exhausted. The filter element was replaced on May 2nd, 2012. With this second element, the service life increased to over 3 months. The varnish separation itself had no negative influence on the antioxidant content in the system: the antioxidants behave neutrally in reaction to the cleaning process. After cleaning the oil circuit, suitable inhibitors are added during operation.

**Conclusion**

The term varnish is used, amongst other things, for oil aging products in turbine lubrication systems, and accurately describes the consistency of these substances. The increase in the efficiency of turbines and the reduction of oil volumes (circulation indexes) increase the load on turbine oils. Modern turbine oils with higher chemical purity and low levels of hazardous substances reduce the solubility or load capacity for oil aging products. Where the filter load is too high or the filter selected is too fine, the extremely low conductivity of these modern oils can also lead to electrostatic discharges in oil. These discharges cause an extreme thermal fluid load due to hot spots. The result of this high thermal load is usually accelerated oil aging.

In order to avoid critical system operation, the routine analysis parameters have to be broadened. By sizing & selecting the system filtration correctly, the electrostatic load in the fluid is eliminated and the fluid lifetime is extended.

Fluid maintenance measures such as the separation of varnish, offline filtration, dewatering and degassing reduce the fluid load and thus extend the service life of the oil as well as the components. Simultaneously this contributes to trouble-free operation of the overall system.

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**Membrane Patch Calorimetrie MPC**

 Colour assessment of filtrate taken from 100ml on a 0.45 µm micron filter membrane

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**Fig. 9. HYDAC Particle counter FCU/BSU 8000.**

**Fig. 10. HYDAC VarnishMitigation Unit VMU.**

**Fig. 11. Graph plotting the MPC value; limit at MPC 40.**
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We design and supply turnkey hydraulic control and drive systems including the electronic controls for mobile and stationary machines and systems for a diverse range of industries.