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Failure Prediction by Lubricant Analysis

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The proper selection, analysis, and replacement of lubricants and hydraulic fluids are integral parts of the maintenance demanded by modern automated and ultra-high-precision machines. Analysis of lubricants in use with spectrographic and infrared methods can indicate equipment deficiencies and forecast possible failures. Testing and care of hydraulic fluids before use will help avoid trouble later. Performance tests of hydraulic fluids and other lubricants will produce useful, money-saving data. Daily preventive-maintenance schedules that include programmed equipment lubrication reduce down time and increase on-stream efficiency.

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Failure Prediction by Lubricant Analysis

N. H. MILLER

WHY A PART OF MAINTENANCE

In today's age of automation and ultra-high-precision equipment, lubrication, lubricants, and hydraulic systems have become an important part of maintenance. The selection, testing, analysis, replenishment, and replacement of lubricants and hydraulic fluids must become an integral part of any maintenance program.

Take, for example, hydraulic systems. Oil is used in all hydraulic equipment to transmit force and motion. This is done by a collection of mechanical elements joined by fluid-actuated devices such as pumps, valves, hydraulic motors, and miles of pipes or tubing connecting the various parts.

Yesterday it would have been impossible to apply hydraulics as we do today, as the precision parts did not exist, nor did oil technology. Today, with the required precision and advanced hydraulic oils, the machine builders are using hydraulic systems to replace complex combinations of gears, cams, levers, connecting rods, and so on.

These modern hydraulically operated machines are built to hold extreme tolerances when they are intelligently operated and adequately maintained. Proper selection and maintenance of the hydraulic oils is of major importance to maintaining the operating efficiency of this equipment. Precision parts of the machines can be severely damaged by rust, corrosion, high temperatures, dirt, and products of oil deterioration if the maintenance of the hydraulic fluids is not a scheduled integral part of the regular mechanical maintenance.

The degree of precision a machine can hold will vary directly with the condition of the hydraulic fluid. For example, the wrong viscosity oil in a torque converter will render it inoperative. The wrong type of hydraulic oil, or an improperly maintained oil, in a system can have a marked effect on the machine performance to the extent that neither mechanical or electrical components can be adjusted to compensate for this effect.

Another example is maintenance of precision bearings. Here proper performance is directly related to the type and quantity of grease used. The speed a spindle can attain may be varied from

25,000 to 40,000 rpm by the type and quantity of grease in the bearings. Greases, oils, and other lubricants are just as important as hydraulic fluids in today's modern equipment.

Proper lubrication can mean the difference between maintaining a firm production schedule or being harassed by nonscheduled downtime. Operating problems or erratic machine operation are frequently traced directly to faulty lubrication of the equipment. This may vary from heat-transfer problems to improper dielectric constants.

HOW TO INTEGRATE WITH MAINTENANCE

The time for the lubrication people to do their work on the unit is when an equipment unit is scheduled for a maintenance outage. This outage time may vary from the shift change interval of a few minutes to a turn-around outage of several days. Each outage should be scheduled in advance and an outline or procedure prepared as to just what work will be accomplished at that time. Without this scheduling of maintenance, a division may be operating on the "out of sight, out of mind" basis; and one of the small "out of sight" auxiliaries that has not received any care may very well contribute to a later unscheduled outage (breakdown) on major production lines.

To accomplish the task of servicing all units and equipment on a scheduled basis, it is desirable to establish daily routes as a part of the Division preventive-maintenance program. These routes have a certain number of units to be maintained each day or week. A check-off system should be maintained to show which units have been serviced. Mechanical and electrical deficiencies, and so forth, should be noted and referred to the repair crews during the route check. Large complex units with several lubrication points and various lubricants could have a procedure sheet for the equipment.

Usually the work to be accomplished by other crafts on a maintenance outage have been discovered by the lubrication route men, as they act as an extra set of "eyes and ears" for all maintenance.

ANALYTICAL FACILITIES

Laboratory analysis of routine lubrication

samples may also determine the work to be accomplished by other crafts in maintenance, far in advance of physical trouble, preventing major breakdowns and consequent production dislocations.

Some examples follow of equipment deficiencies detected in advance by laboratory analysis of used lubricants, which, if unattended to, could have resulted in failures or nonscheduled outages:

- worn pistons on hydraulic pumps
- bearings near failure
- cooling-system leaks
- broken piston rings
- leaking seals
- corrosive oils

Laboratory analysis, when used to supplement operating conditions and experience, may direct changes in maintenance procedures which differ from the original equipment manufacturer's instructions. These changes could be in the type of lubricant, length of service, or method of application.

Technical obsolescence has no place in the field of lubrication or maintenance. The lubricants, methods of application, and specifications must be kept current with the new demands brought about by new designs and operating requirements. Consequently, a lubrication engineer of the highest technical competence procurable, and who has no other duties assigned, is essential to efficient maintenance performance. Further, he must stay current with the latest developments in his field. Monthly periodicals, transactions, and regular attendance at professional meetings and seminars are a must.

MAINTENANCE FOR HYDRAULIC SYSTEMS

Choosing the correct hydraulic oil for the particular system is not a simple matter of using a set of specifications. There is no set of oil specifications in the world that will tell you all you have to know. Very often you are forced to rely on performance data -- data that you can get either by running a series of tests yourself or by cooperating with other organizations operating identical equipment.

In selecting an oil for use in a hydraulic/numerically controlled machine tool, it is well to start out with the best grade of steam turbine oil that is obtainable. This will give you the ultimate in oxidation resistance and the ability to prevent rust and corrosion. These oxidation-stable, rust-inhibited, solvent-extracted paraffinic crude oils have an oxidation life well in excess of 3000 hr. The ordinary hydraulic oils

have an ASTM oxidation test rating (D-943) of 1000 hr.

Viscosity is the most important physical characteristic of any hydraulic oil. To get optimum efficiency, the oil you select must have the right viscosity at the operating temperature and pressure. An increase in pressure causes an increase in viscosity. In this respect, paraffinic type oils are affected to a lesser degree than naphthenic oils. This viscosity increase due to pressure, however, is not very significant under 2000 psi. Many systems will operate in the 2000 to 3000-psi range. Some hydraulic presses operate at over 50,000 psi. With pressures of this magnitude, a few degrees variation in the ambient temperature can mean the difference between the hydraulic fluid being in a liquid or solid state. It should be noted that high-viscosity index oil is more desirable for hydraulic control systems, because it can be used over a greater range of temperature with less viscosity variation.

Properly refined low-viscosity index oils may be used in systems where the pressures are low and the operating temperatures range from 10 to 150 F.

Other factors which influence, in some measure, the choice of an oil for a given installation are the kinds of accessory equipment, including type of filter, oil coolers, and oil heaters.

Examples of this influence are:

- 1 A fuller's earth filter should never be used on a hydraulic system where inhibitors are necessary, as a filter of this type may remove the inhibitors.

- 2 A 3 to 10-micron corrugated cellulose filter is recommended for high-pressure hydraulic control systems.

CARE OF HYDRAULIC OIL AND LUBRICANTS

Even if a plant starts out with the finest lubricant possible for the refinery to produce, this lubricant will not perform without a certain amount of care and attention. Once the lubricant is selected, the following suggestions should be followed:

- 1 Keep it clean.
- 2 Keep it dry.
- 3 Keep the systems clean in which it is used.
- 4 Routine testing should be carried out.

OIL CLEANLINESS

It is of utmost importance to keep the oil clean from the minute it is placed in the drum at

the refinery. Premium grades of turbine oil are always packaged at the refinery in new drums, carefully inspected prior to filling. Once oil leaves the refinery, a lot can happen to it. Insist on a clean dust-free storage space for opening oil drums. Clean, covered containers should be used for carrying oil from storage to point of use. The safest way to fill a hydraulic system is to pump the oil directly from the drum to the system through a 10-micron filter. Be sure the filters are clean and dry and are replaced on a rigid schedule. Use clean tools. Even cracking a joint with a dirty wrench can be dangerous. Most manufacturers have designed hydraulic equipment such that dirt cannot easily get into the system.

EFFECT OF WATER

Water gets into hydraulic oil, principally through condensation, either within the equipment itself or by poor handling of the drum, often before it is ever opened. In high-humidity areas, machines will collect considerable moisture when shutdown for weekends. This is caused by the normally hot moisture-laden air getting a chance to cool down and condense out, leaving water in the oil.

The easiest way to rid a system of this water is to frequently drain it off at the low point in the system. Periodically, the oil should be pumped out and replaced with new oil. The used oil should be stored in a special settling tank where the water is removed. Then the oil is filtered, tested, and either returned to service or used as a machine coolant.

To prevent the oil from becoming contaminated with water, do not store it outdoors, even in the unopened drums. If it is necessary for oil drums to remain outside for a short period of time, they should be stored upside down or on their sides, as illustrated in Fig.1.

SYSTEM CLEANLINESS

In order to obtain peak performance, you must start with a clean system and keep it clean. On a new installation, the system should be thoroughly flushed with a light oil (not heavier than 60 SUS at 100 F) or suitable solvent. Several companies have special consultant and cleaning services available, and these should be utilized.

Once a system is clean, it is not too difficult to keep it that way. Use of proper filters, changed on a scheduled basis, and periodic analysis of the hydraulic oil are tools used to keep a system clean. Should a system become contami-

Fig. 1 How water can get into drums and some of the methods of prevention

nated with oxidized oil, gasket sealing compounds, or cutting oils, there are several cleaning oils available that contain compounds for removal of gum, sludge, and loose rust.

PERIODIC TESTS

Testing of the hydraulic oils will do more to prevent trouble before it occurs than any other item in Preventive Maintenance. Whenever a color change occurs in the oil, it is a warning sign that something is wrong. A change in color can indicate that either the oil is breaking down from oxidation or that metal wear is occurring and depositing a particulate matter. Infrared is used to detect oxidation breakdown, while spectrographic analysis can be used to identify metal wear. Several wet chemistry tests may be used for backup or additional information.

CARE AND MAINTENANCE OF ANTIFRICTION BEARINGS

Over-lubrication is the cause of most difficulties in the lubrication of antifriction bearings and is more likely to occur with grease than with oil. The churning effect of excess grease causes heating. Heat softens the grease and causes it to expand, thereby flooding the bearing and increasing the churning effect, which causes further temperature rise. This heat causes pressure which, due to expansion, may damage or blow the seals. Excessive bearing temperatures can start oxidation and decomposition of the grease, which in turn affect its lubricating characteristics. The result is bearing damage.

When overheating caused by too much grease occurs, the natural tendency is to add more

Fig. 2 Grease quantity measure

grease, which only aggravates the situation. When this condition occurs, the bearing should be removed from the housing, cleaned with a suitable solvent, and then repacked by hand. Compressed air should not be used unless it is known to be clean, dry, and filtered. If air is used, the bearing should not be allowed to spin during the blowing.

The best method to prevent over-lubrication of bearings is to install sealed bearings and remove the grease fittings. Where this is not practical and it is necessary to lubricate by gun, antifriction bearings equipped with good seals should be utilized. These bearings should not be lubricated more than once each six months, except in extreme cases. The following procedure should be used for re-lubrication of bearings:

- Most bearings are equipped with two openings, one at or near the top, and the other diametrically opposite. Remove both plugs and apply the grease through the top opening until all of the old grease is forced out and new grease appears at the lower opening. The unit should then be operated for thirty minutes with the lower plug out, allowing the excess grease to be purged out.

- Fig. 2 shows a grease-quantity measuring device developed by the author's company. When precision-type antifriction bearings are hand-packed, the grease-quantity curve shown in Fig. 3 is used.

- For other bearings, pack cavity 25 to 30 percent full.

The choice between use of oil or grease for a bearing is clearly defined by bearing design. For example, ring oiled bearings or circulating systems definitely require oil. Oil provides the best method of lubrication, but design costs and practicality do not always permit the use of oil-

Fig. 3 Graph for determining approximate amount of grease to be used in superprecision ball bearings for bore sizes between 10 and 55 mm. Curves for both extra-light and light series are given

type bearings. Grease lubrication is more desirable to use in extremely dusty locations and where high humidity or water exposure exists. Grease tends to form a seal at the ends of the bearing, creating a barrier to dust and moisture. In a few cases, it may be desirable to change from grease to oil where temperature problems are such that circulatory oil systems are required to dispose of excess heat to a heat exchanger. On the other hand, when leaky oil seals cannot be permitted, it may be desirable to use a light grease. Under no condition should oil and grease be mixed.

CONCLUSION

A few of the current procedures and facilities that are available to most maintenance organizations have been briefly discussed. New developments and methods are forthcoming every day. During the writing of this paper, the author's Division converted to the use of an oscillograph for detecting erratic operation of pump or servo-mechanisms on multi-unit hydraulic systems.

In today's field of automation, those who become burdened with technical obsolescence in maintenance are doomed.

By use of programmed lubrication in our preventive maintenance, our Division has increased the on-stream efficiency from 75 to 85 percent.