Metal Contamination: Comments from Trade Publications & Manufacturers

According to the bearings division of TRW *"contamination is the number one cause of bearing damage that leads to premature removal"*

Machine Design Magazine reports that "*less than 10 percent of all rolling-element bearings reach the fatigue limit because contamination usually causes wear or spalling failure much earlier."*

According to Caterpillar, *"dirt and contamination are by far the number one cause of hydraulic system failures."*

J.I. Case states that *"one thing that holds true for hydraulic systems: the systems must be kept clean, spotlessly clean, in order to achieve the productivity, they are capable of."*

Studies by the US Navy show that the cost of contamination on marine and aviation equipment per operating hour exceeds **60%** of the cost of fuel per hour on the same equipment.

Massachusetts Institute of Technology states that *"6% to 7% of the gross national product ($240 Billion) is required just to repair the damage caused by mechanical wear – wear that occurs as a result of contamination."*

Oklahoma State University reports that when fluid is maintained 10 times cleaner, hydraulic pump life can be extended by 50 times.

Types of Contaminant Induced Failures

There are many types of contaminant induced failures in machinery. The most common are wear, seizure, erosion, and corrosion. Contaminants involved include solid particles, moisture, air, chemicals, and other materials foreign to the system. Of these types, abrasive wear caused by solid particles is substantially the most serious. According to Vickers division of Trinova/Aeroquip, *"abrasive wear accounts for about 90% of failures due to contamination."* This abrasive wear is the result of particles (too small to be seen) that cut and plow rolling and sliding surfaces.

The rate at which contaminants enter the fluids of hydraulic and lubricating machinery is typically greatly underestimated and understated. The effectiveness of filters at removing fluid contaminants in field systems is greatly overstated.

Tests by machinery manufacturers show that filters have great difficulty achieving the formidable task of removing particles from the fluid at the same time as they are entering (ingression) in the field where they are subjected to conditions of frequent and large changes in temperature, fluid viscosity, pressure, and flow (surges) plus the effects of shock, vibration, and fatigue. Other common problems are filter bypass valves stuck open, damaged or missing filter gaskets, and filters that are installed backwards or crooked.

As a result, fluid contaminant levels must be frequently monitored, to verify filter performance and to provide the essential "feedback" that gives integrity to a contamination control program.

Hydraulic Maintenance Savings

After Nippon Steel implemented a hydraulic system contamination control program plant wide, involving both improved filtration and rigorous fluid cleanliness monitoring, pump replacement frequencies were **reduced to one fifth** and the cumulative frequency of all tribological failures (i.e. failures relating to wear and contamination), was **reduced to one tenth.**

Kawasaki Steel implemented a similar contamination control program and achieved an almost unbelievable **97%** reduction in hydraulic component failures.

Such claims as these spurred the British Hydromechanics Research Association (BNRA) and the U.S. Navy to conduct their own studies to substantiate the benefits of proactive contamination control maintenance.

The results of the BHRS study showed a dramatic relationship between fluid contamination levels and service life. Improved system cleanliness achieved extended actual mean time between failures from 10 to 50 times, depending on cleanliness.

A study by the Naval Air Development Center in Warminster, Pennsylvania performed on aircraft hydraulic pumps showed nearly a 4 fold wear life extension with **66%** improvement in filtration and a 13 fold wear life extension with a **93%** improvement in filtration.

Bearing Life Savings

The bearing division of TRW states that *"contamination is the number one cause of bearing damage."* The amount of damage caused by solid contaminants passing between the rolling and sliding surfaces of an anti-friction bearing is proportional to the size and concentration of the contaminants. This contaminant induced wear reduces bearing life to as little as **5%** of its rated life.

Diesel Engine & Gas Turbine Maintenance Savings

From a number of important new field and lab studies we can now conclude that lube oil contamination is the primary cause of engine wear that begins what is referred to as the chain reaction to failure.

In diesel engines, high local stresses associated with sliding contact wear result in abrasive removal of material surfaces. When loads are concentrated on the effective area of a small particle, the resulting surface stresses can be greater than 500,000 psi. Oil film thickness, between which particles can reach and attack surfaces, are typically in the 10-micron range. This explains why, according to a wear study by Cummins Engine, particles small than 10-microns generated about 3.5 times more wear (rods, rings, and main bearings) than particles greater than 10-microns.

Other Documented Studies on Engines

Pall Corporation, in participation with Detroit Diesel Allison (DDA), investigated the influence of improved lube oil cleanliness on the performance of 150- ton diesel trucks operating in an open pit mine. The study revealed substantial reduction in wear metal concentration.

AC Delco Division of General Motors, tested DDA engines and found an 8-fold improvement in wear rates and engine life with lower lube oil contaminant levels. General Motors reports, *"compared to a 40-micron filter, engine wear was reduced by 50% with 30-micron filtration, wear was reduced by 70% with 15-micron filtration."*

A study conducted by Albertson's (supermarket chain) on a series of over the road Cummins tractor diesels found markedly reduced wear rates with greater lube oil cleanliness. After analyzing six engines 600,000 operating miles, Albertson's reports, *"engine crankshaft journals showed only 0.0005 inches of wear. The rod and main bearings had not even worn through to the copper layer. Compression ring and oil ring wear were negligible."*

An independent European University study, as published in Lubrication Engineering Magazine, reports a reduction in diesel engine wear by a factor of 14 when better lube oil cleanliness is maintained. In reference to gas turbine engines, the U.S. Department of Defense states that *"approximately 30% of all engine failures are caused by metal particulate contamination in lubricating oil systems."*

Suggested Steps to Implementing Proactive Contamination Control Maintenance

- Predictive maintenance is usually implemented concurrently with preventive maintenance and targets both the warning signs of impending failure and the recognition of small failures that begin the chain reaction that leads to big failures (i.e. damage control).
- Establish the target fluid cleanliness levels for each machine and fluid system.
- Select and install filtration equipment, or upgrade current filter ratings, and contaminant exclusion techniques (ferrous metal extractors) to achieve cleanliness levels.
- Monitor fluid cleanliness at regular intervals to verify that targets are being achieved.
- Adjust filtration and contaminant exclusion techniques, as required, to stabilize target cleanliness
- Generally speaking, fluids and lubricants have indefinite life when protected from excessive heat, moisture, air, and particles. In fact, some power generation lube oils have achieved a service life in excess of 10 years. Referring to the Nippon Steel reports, they stated that the influence of rigid contamination control practices contributed to a reduction of oil consumption by **83%**. Pall Corporation claims that by improving fluid cleanliness oil change intervals by extended by a factor of 2 or more.

Machine Failure Signs

When a machine failure is in progress there is a precipitous generation of wear debris resulting in an abnormal presence of particles in the fluids. This chain-reaction of few particles generating more and more particles is an incontestable indication of progressive failure. The resultant accelerated particle level in the lube oil is therefore the earliest signs of impending failure.

Summary & Conclusions

Proactive maintenance is presented as an important means to cure failure root causes and extend machine life.

Fluid contamination control is established as an essential technique to implementing proactive maintenance.

Substantial savings are based on cases involving hydraulic, bearing, engine, and gas turbine studies. Numerous examples of ten-fold maintenance cost improvements are given.

As opposed to traditional predictive maintenance, contaminant monitoring is cited as being key to achieving contamination control and proactive maintenance. Contaminant monitoring offers the preferred "first defense" against mechanical failure.