Fluid Contamination & its Control

This article explains about various types of contaminations present in hydraulic fluids and its proper control.

Introduction

Fluids are subjected to various kinds of contamination. Contaminants can affect the physical and chemical properties of fluids. If the contaminants are not monitored or controlled, the fluid is likely to be subjected to various kinds of failures. These failures include the deterioration of the fluid properties and consequent fluid breakdown. At the system level, the contamination can affect the performance and service life of the components and cause their erratic operation, increased heat generation, frequent fluid replacement, catastrophic system failure, and higher costs.

Contaminations in Hydraulic Fluids

Fluids are exposed to various types of contamination (particles, water, air, compounds, and biological matters). Dust, dirt, and sand are contaminants can enter the system from outside. The system itself can generate metal particles from component wear or other byproducts from chemical reactions. 70 to 80% of the failures are due to the adverse effects of contaminants. Even minute particles can damage them due to the existence of minuscule clearances in today's system components. Excessive water contamination is liable to accelerate the aging process of fluid.

Solid Particles

It includes hard particles (dust, dirt, silica, wear metals) and soft particles (elastomers, fibres). Silts are particles less than 5 μm; chips are particles greater than 5 μm. Silt particles of a size corresponding to the typical tolerance are most dangerous to the system than larger chip particles. The system itself can generate metal particles from component wear. Abrasive particles scrap metal from the surfaces of hydraulic components. The freely-circulating particles can cause premature wear of parts.

Chemical Contaminants

They are formed by the breakdown of additives, due to chemical reactions. The reaction products can generate other contaminants in the form of acids or oxidants, in the presence of water/heat. They can cause physical and chemical changes in the additive elements. These changes can lead to the deterioration of additives and subsequent fluid breakdown.

Water

Water is introduced into the fluid by the condensation of humid air. Unprotected reservoir opening, leaking seals, and ineffective heat exchangers are other means of entry of water. Fluid can dissolve water up to its saturation point. Above the saturation point, water remains in the free or emulsified state. A mineral fluid can permit water content up to100 ppm (0.01%). The moisture is capable of providing the oxygen for the chemical reactions.

Air

Air can exist either in the 'free state' or in the entrained state. An air pocket trapped in a part of the system is an example of free air. Air bubbles typically less than one mm in diameter dispersed in the fluid medium is the entrained air. Air can enter into the fluid medium through system leaks, pump aeration, or reservoir fluid turbulence. Air entrained can cause cavitation and foaming, as it cycles through the system. The entrained air tends to make the system operation spongy and system response weak

Contamination Control

Contamination control involves the removal of particles, water, air, sludge, acid, and chemicals. Particles can be removed by installing correctly-sized filters at appropriate locations. Removal of acids, sludge, gums, varnishes and other oxidation products requires the use of an adsorbent filter with active type clay/charcoal/activated alumina. Magnets installed in the tank can remove the ferrous particles and rust matters. Air contamination can be eliminated by providing air bleeds and diffusers. Installing a water-removal filter or a vacuum dehydrator removes the water.

Fluid Cleanness Standards

Cleanliness of fluids needs to be monitored for maintaining components of hydraulic systems at a satisfactory level. Many national and international organizations have developed standards for specifying 'particle size classification' and 'contamination concentration levels'. The particle size classification standard is the ISO 11171:2010. The standard for specifying the contamination concentration levels is the most widely used ISO 4406:1999.

Particle Size Classification Standard

The standard ISO 11171 specifies the three-dimensional size of particles (i.e., 4, 6, and 14 microns), for representing the concentration levels of fine as well as coarse particles. Earlier standard ISO 4402 specified the two-dimensional size of particles (i.e., 5 and 15 microns).

Fluid Cleanliness Level Standard

ISO 4406:1999 specifies the cleanness level of a given sample of fluid by a three-number range code representation, such as 18/16/14, based on the number of particles of size greater than 4, 6, and 14 microns respectively, present in one ml of the sample fluid.

Range code	Number of particles per ml	
	>	<=
21	10 000	20 000
20	5 000	10 000
19	2 500	5 000
18	1 300	2 500
17	640	1 300
16	320	640
15	160	320
14	80	160
13	40	80
12	20	40
11	10	20

Cleanliness Level Targets

Hydraulic equipment manufacturers, fluid suppliers, and fluid power associations have established target fluid cleanliness levels applicable for the general types of hydraulic components.

Components	Range codes
Flow control valves, cylinders	17/18/15
Gear pumps/motors	20/17/14
Vane and piston pumps/motors	19/16/13
Directional & pressure control valves	19/16/13
Servo valves	17/14/11

Hydraulic Fluid Analysis

Fluid analysis can be carried out to ascertain the health of a fluid medium. Fluid analysis essentially counts the number of contaminant particles, detects its level of oxidation, identifies the component wear, determines the condition of the additives, establishes the overall level of contamination, and verifies the composition of the fluid. If the analysis meets the necessary cleanness target, then we only need to continue to maintain the filters and retest the fluid periodically. If not, appropriate actions must be taken to rectify the problems. Depending upon the sensitivity, analysis can be conducted on a fluid sample by (1) Patch test, (2) Portable laser particle counter, (3) Laboratory analysis, and (4) On-line fluid monitoring.

Patch test

It is a simple visual analysis of the fluid sample extracted from a hydraulic system, using a fluid analysis kit. It consists of 100x magnification field microscope, filter test patches, a vacuum pump to extract fluid samples, sample bottles, and visual correlation charts or photographs. 100 ml of fluid is passed through the filter media of the test patch. The patch is then dried and analyzed under the microscope for both color and content and then compared to the reference photographs of known particle concentration levels to determine the approximate ISO cleanness code and the type of particles captured on the patch.

Portable Laser Particle Counter

Particle counting is the most popular method used to derive cleanness levels. Contamination can be measured and controlled by using laser particle counters. Calibrated to the ISO 11171 and evaluated to the ISO 4406 the portable particle counter identifies and reports the range code for the number of particles, of size greater than a specified size, present in one ml of the sample fluid.

Laboratory Analysis

The laboratory analysis is a complete scrutiny of the fluid sample. Most of the laboratories offer the following important fluid parameters: Viscosity, Total Acid Number, Particle counts, Water content, etc.

Online Fluid Monitoring

With the advancement of computer technology and the introduction of sophisticated online fluid monitoring instruments, analysis of a fluid can be done on-site in a consistent manner while the system is in operation. Today's on-line contamination monitoring instruments can detect changes in the quality, contamination level, and chemical composition, of a given volume of fluid.

Reference: JOJI PARAMBATH, Industrial Hydraulic Systems – Theory and Practice, Universal Publishers, Boca Raton, USA, 2016. Please visit: http://www.universal-publishers.com/book.php?method=ISBN&book=1627340580

Note: A comprehensive account of the topic is given in the textbook on 'Industrial Hydraulic Systems-Theory and Practice' by Joji Parambath.