8

ANTI-WEAR PROPERTIES

Even smoothly machined surfaces are quite rough, when examined by high power microscopy. As a result, mating surfaces do not achieve mutual contact over the entire surface, but touch only at the highest asperities. When a load is applied, these asperities are elastically, or even plastically deformed. The normal random distribution of asperity heights results in a progressive engagement of more asperities as the load increases. The area of true surface contact is thus proportional to the loading force. Under moderate loads, smooth sliding contact will tend to promote varying degrees of abrasive wear.

When mating surfaces slide over one another under such boundary conditions, the asperities in contact are not only deformed, but are frequently also heated to extremely high temperatures. These so-called local 'flash temperatures' may be so high that momentary welding of the lowest-melting asperity to its higher-melting counterpart occurs, a certain degree of metal transfer ensuing as continuing relative motion tears the weld apart, resulting in adhesive wear or 'scuffing'.

Despite the manufacturers' efforts to promote favourable conditions of operation within components, the many variables (pressures, temperatures, relative speeds and geometry of mating surfaces) frequently preclude hydrodynamic lubrication. Under the prevailing boundary conditions, frictional forces – and eventual wear – are largely dictated by the metallurgy of the contacting surfaces, lubricity of the hydraulic fluid and content of chemically active additives.

The addition of anti-wear additives to hydraulic fluids is principally to alleviate 'scuffing' wear between highly loaded sliding surfaces of steel on steel. Such additives are normally based on chemically bound

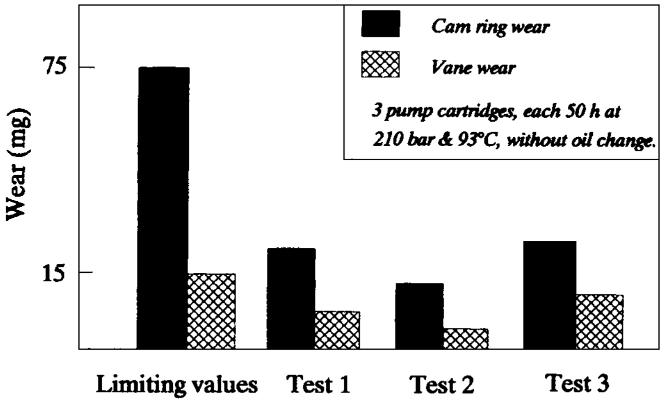

Fig. 8.1 Wear test, Vickers 35VQ25 (typical results).

phosphorus (aryl phosphates) or sulphur/phosphorus compounds that reduce mechanical wear by a form of 'chemical polishing'. This phenomenon involves the additive reacting with the metal surfaces wherever high local temperatures ('flash temperatures') occur due to friction between surface asperities in contact through the lubricating film. The resulting formation of a surface layer of reaction products prevents dynamic welding together of asperities and the subsequent catastrophic scuffing wear that would otherwise take place at highly loaded steel surfaces. This is of particular importance with respect to the stator ring and vanes of high pressure vane pumps and motors. Among the variety of standardized test methods to evaluate this aspect are the well-known tests utilizing Vickers pump types V104(5)-C and 35VQ25. In these methods the former pumps are usually operated at twice their normal rated pressure (140bar). As system pressures have increased significantly during recent years, these tests are being superseded by the more demanding 35VQ25 procedure at 210 bar, which is considered more representative of modern equipment. Figure 8.1 shows typical test results for a fluid possessing satisfactory anti-wear properties.

Another test method, increasingly favoured within Europe, is the FZG (*Forschungsstelle für zahnräder und getriebebau, Munich*) gear test rig DIN 51 354, representing one of the main test criteria of HLP oil types as defined by the German specification DIN 51 524. This method evaluates the ability of the test fluid to prevent scuffing wear between spur gears under closely specified conditions of load, time and temperature (see Chapter 16).

Table 8.1 illustrates the progressive improvement of anti-wear properties resulting from the introduction of new additive types.

Table 8.1 Reduction of wear by use of improved additive systems

Additive system	With rust and oxidation inhibitors	With arylphosphate	With + ZDTP
Vane pump test IP 281 (250 h, 17 Mpa, 1450 rpm) Total wear (mg):	690	240	30
FZG test – IP 334 (Type A/8.3/90°C) Failure load stage:	6	8	10–12
Shell 4-ball test – IP 239 Wear scar, 20 kg load (mm):	0.60	0.30	0.30
–/– –/–, 40 kg load (mm):	Welding	Welding	0.39

In addition to the test methods mentioned above, many other standardized and in-house procedures are specified by component manufacturers for evaluating the anti-wear properties of hydraulic media.

It is imperative to exercise caution when selecting anti-wear additives for a specified application, in order to avoid undesirable side effects, for example less satisfactory frictional characteristics with certain other metal combinations or reduced corrosion inhibition. Sliding contacts of yellow metals–steel appear more sensitive towards the viscosity of the lubricant than its composition, though under high load conditions the more chemically active additives are notably less satisfactory. One classic problem area in this respect is the disproportionately high wear of phosphor bronze slipper pads in certain high efficiency piston pumps. Research in latter years has been directed towards developing additive systems affording satisfactory protection to the more sensitive metals, whilst at the same time achieving adequate performance in the important FZG test. This desirable combination of properties is commonly referred to as 'multi-metal compatibility'.

The successive evolution of anti-wear additive systems through the years, is depicted in Fig. 8.2.

Most yellow metals (copper, bronzes, brass) are best lubricated by fluids containing relatively mild anti-wear additives, or even by turbine oils without any form of chemically active additive.

Aluminium and alu-alloys seem to be generally compatible with most of the usual additive systems utilized in hydraulic fluids (but not with all base fluids), although highly loaded combinations of aluminium bronze–steel may be problematic. Silver overlays on bearing surfaces,

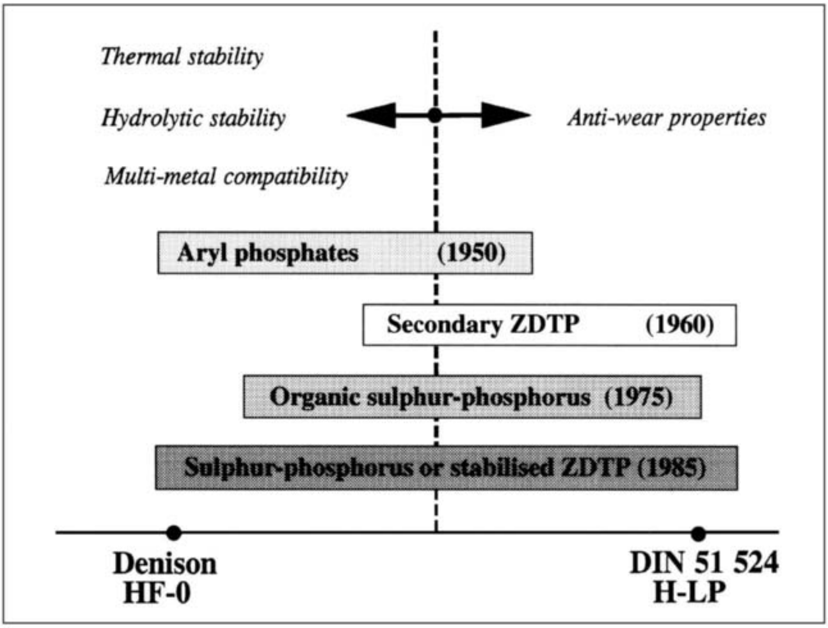

Fig. 8.2 Development of anti-wear additive systems.

less common today, are rapidly attacked by the active dithiophosphate additives, and fluids formulated using relatively mild additives, e.g. ISO type HL or turbine oils, may be preferable when silver is present.