WEAR CHECK® AFRICA
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EFFECTS OF TEMPERATURE ON ENGINE LUBRICATING OIL

The effect of temperature on engine lubricating oil is an important consideration to take into account when operating a large fleet of vehicles. Except for electrically powered units, all vehicles are powered by a combustion engine of some description, be it fuelled by gas, petrol or diesel.

All engines require some form of lubrication and this is provided by the oil. This oil is required to carry out numerous different tasks when the engine is in operation, the primary function being to lubricate all the components by reducing friction and preventing or reducing metal to metal contact. The oil stops two components' surfaces from touching one another as illustrated in Figure 1 and Figure 2.

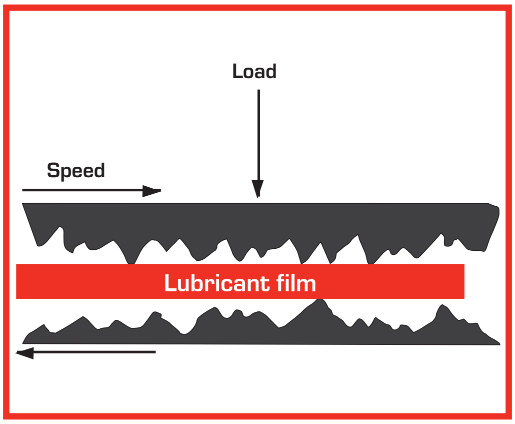


Figure 2: Operation when a lubricant is added

In an endeavor to achieve the best possible friction reduction at normal operating temperature, oils are formulated with specific base stocks and additives in order to carry out specific jobs within the engine. These oils are designed to function in an optimal way at the normal operating temperature range of the engine. As a general rule of thumb, an engine oil's operating temperature should be approximately 10°C to 15°C above the cooling water temperature. Keeping this in mind, the sump operating temperature of the engine oil should not exceed 105°C under normal conditions.

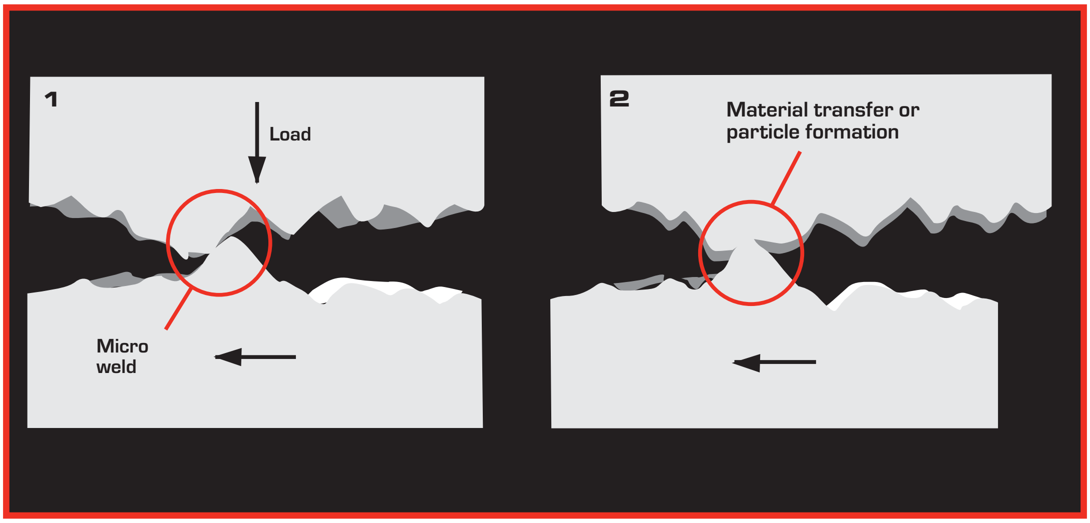


Figure 1: Operation without oil

WEARCHECK
CONDITION MONITORING THROUGH OIL ANALYSIS

VISCOSITY

When an oil is heated up, its viscosity will decrease. The formulation of the oil is such that it keeps the following in perspective: the oil must be able to be pumped through the system as fast as possible when cold on start-up in order to lubricate all components within a few seconds of the engine starting. The same oil must then be able to supply sufficient lubrication to all components at normal operating temperature. Different environments will place different demands on the lubricating oil but it must remain 'thin' (low viscosity) enough when cold so that it can flow and 'thick' (high viscosity) enough when hot to keep moving parts separated.

These characteristics allow engine oils to supply sufficient viscosity at all normal operating temperatures. The minute these temperatures go outside the parameters of the oil's design the lubrication efficiency will be compromised. For example, if an oil with too high a starting viscosity is used, it will take a relatively long time for the oil to reach all the components on cold start-up. If an oil with a very low viscosity is used it will get to all the components within the engine very quickly on start-up but be too thin for adequate lubrication at operating temperature. Multigrade oils contain base stocks and additives that allow them to perform in exactly this manner - not too thick on start-up and not too thin at operating temperature. This is why the correct choice of oil for a vehicle in a particular environment is critical to engine operation and life expectancy. This selection should always be made in conjunction with the OEM.

As mentioned previously, an oil's viscosity will decrease as temperature increases. A standard 15W40 multigrade engine oil, the grade predominantly used in Southern Africa, has a starting viscosity at 40°C of approximately 110mm²/s (centistokes) and an operating viscosity at 100°C of approximately 14.5mm²/s (see Figure 3).

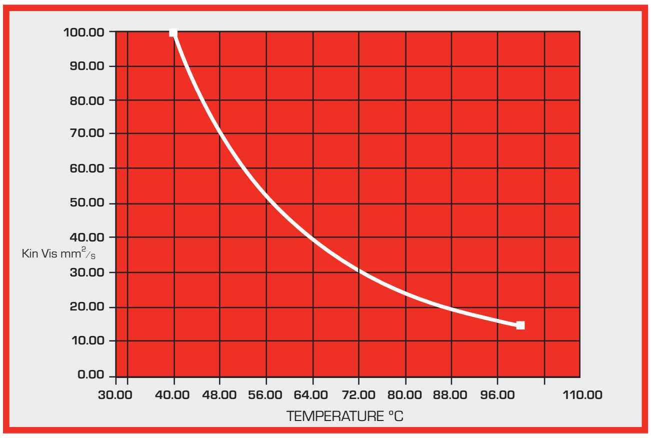


Figure 3

A standard water cooled engine should operate with a cooling system temperature between 80°C and 90°C. Considering that the oil operating temperature should be 10°C to 15°C above the coolant temperature, then the oil operating temperature should be within 90°C to 105°C but should not exceed 105°C.

Another general rule that can be applied to the operating viscosity of engine oil is that, if the operating viscosity of the oil goes below 10mm²/s, then the oil is too thin to lubricate all components within the engine adequately (see Figure 4).

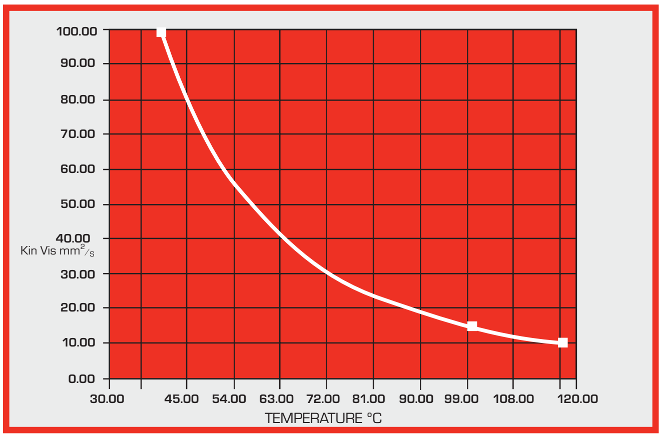


Figure 4

In an engine there are two main lubrication regimes that exist, hydrodynamic lubrication (pressurised lubrication to the crankshaft) and boundary lubrication (non-pressurised lubrication surrounding the pistons). In both cases the viscosity thickness of the oil is important but of primary importance for hydrodynamic lubrication.

Taking into account that as the engine warms up components expand with heat, the engine is designed in such a way that, at optimum operating temperature, components would expand to the optimum size. If the optimum temperatures are not achieved then expansion will be either excessive or insufficient and can cause complications in the running efficiencies of the engine.

HYDRODYNAMIC LUBRICATION

Hydrodynamic lubrication works in the following way: oil is pumped from the oil pump through a heat exchanger and then a filtration system to the crankshaft under pressure. At operating temperature this process occurs almost immediately (see Figure 5).

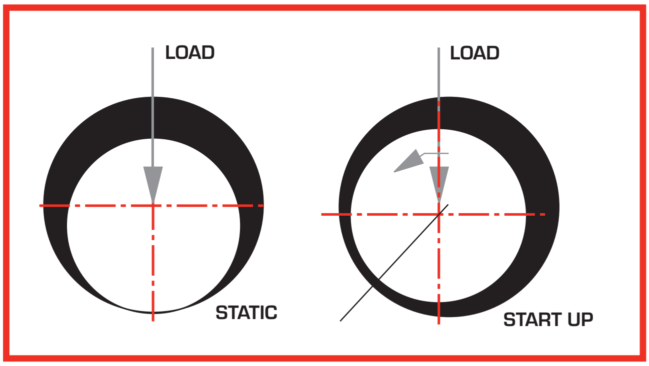


Figure 5: Oil supply from oil pump

As rotation commences oil pressure which is built up between the bearing and the crankshaft journal creates an oil wedge (see Figure 6).

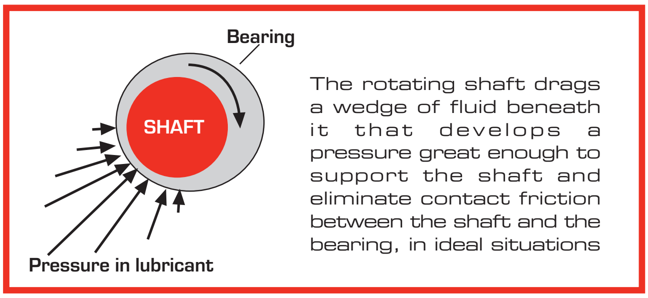


Figure 6

In a cold start-up situation the same occurs except that the oil is substantially thicker due to the fact that it is cold and therefore cannot pass through the filter media efficiently. This means that the filter goes into bypass, allowing the oil to move through the system in a partially or totally unfiltered state. The filter or filter housing is designed in such a way as to allow this to happen. There is either a bypass valve in the filter itself or one is built into the filter housing. This bypass valve also works as a safety mechanism in the event that the filter was to block, allowing oil supply to continue to all the engine components. As the operating temperature of the oil and the engine increases, the viscosity of the oil decreases and the bypass valves reseat themselves, allowing the oil to move through the filter media.

BOUNDARY LUBRICATION

A boundary lubrication regime lubricates all additional components within the engine that are not lubricated under pressure. The components that fall into this category are pistons, piston rings, camshaft lobes, cam followers, rockers, valves, timing drive train, etc. (see Figure 7).

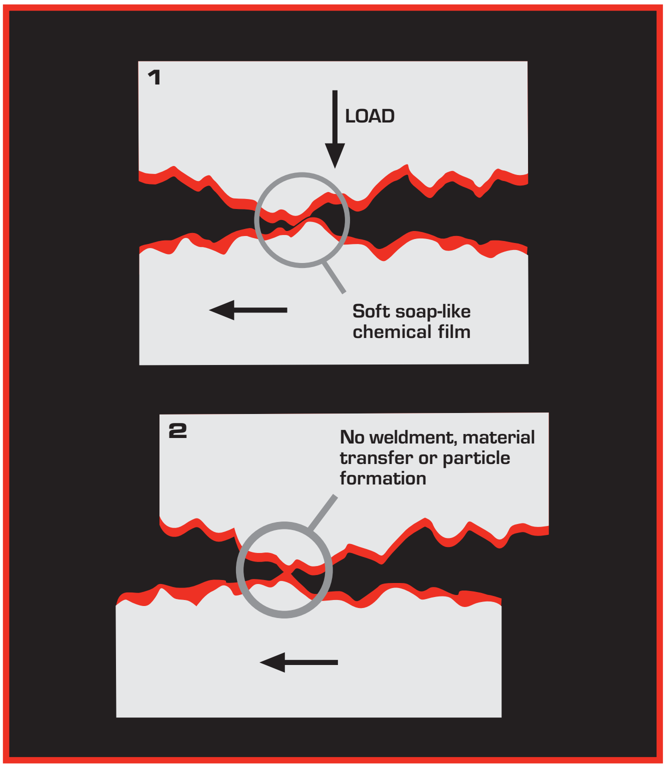


Figure 7

Boundary lubrication is reliant on high-volume replenishment for lubrication to work efficiently and the fact that engine oils contain anti-wear additives that reduce friction and wear even when a full hydrodynamic film of oil is not present. High-volume replenishment can be achieved by means of spray nozzles or splash-feed. All new generation engines are fitted with piston cooling spray nozzles to ensure proper piston cooling and lubrication to the piston skirts. This oil then coats the components during movement in order to reduce friction, at which time the lubrication is generally forced away from the components but continuously replaced with a fresh supply of oil being splashed or sprayed into the affected area (see Figures 7.1 and 7.2).

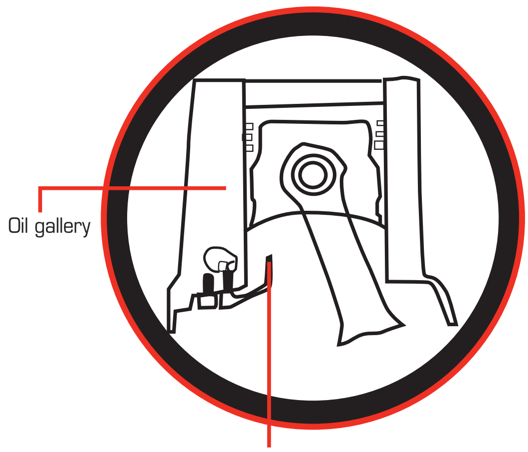


Figure 7.1: Oil sprayed into piston through spray nozzle

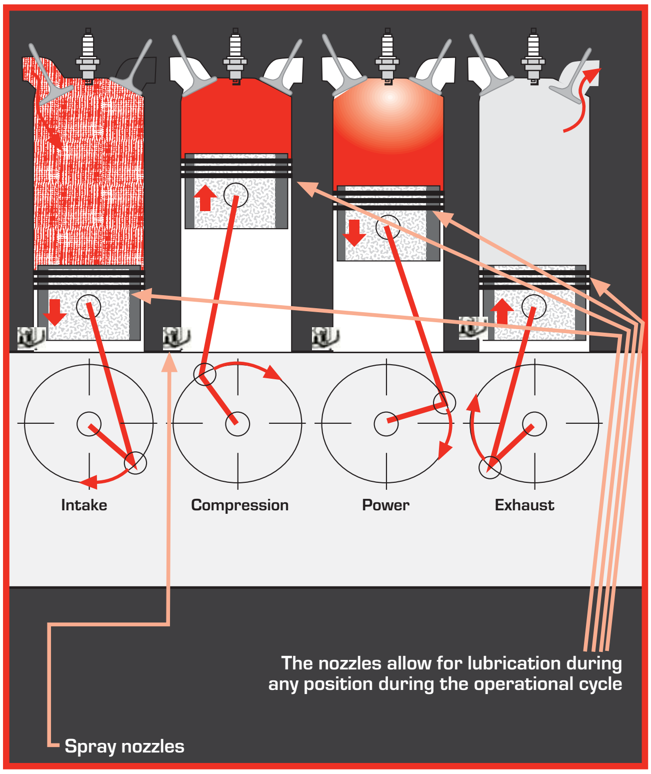


Figure 7.2

LOW OIL OPERATING TEMPERATURE

Keeping all of this information in mind, if the optimal oil operating temperature is not achieved, the engine will be in an inefficient running and lubrication state.

If the oil operating temperature in the sump is below 90°C when the water cooling system is at optimum temperature then there will be additional cooling of the oil cooled components such as the piston skirts and crank shaft. This will interfere with the expansion rate and extension size as well as operating clearances between these components. For example, the cylinder liner will expand due to combustion heat but the piston will then be cooled excessively due to the low oil temperature. The clearance between the piston rings, piston skirt and the cylinder liner will not be optimal, allowing for inefficient combustion which will, in turn, aggravate situations such as fuel dilution, soot generation and fuel consumption efficiencies.

An additional problem that is a lot less visible is the build up of acids in the oil. In a cold engine there is condensation from atmospheric moisture in the air, and water is a normal combustion by-product. As fuel is burned there are combustion by-products deposited in the oil and in the presence of water these combine, forming harmful acids. If the oil temperature is too low, it creates an ideal environment for this to take place. Under normal operating temperatures, most of the water evaporates and the acids cannot be formed so easily. In the low oil temperature situation they are created and can cause chemical acid attack of the soft metals, which can also decrease the life expectancy of the engine.

This problem will also be aggravated by the fact that at low temperatures the oil will be too thick to be filtered efficiently and therefore the filter bypass valve will be in the semi-open position, almost continuously allowing a percentage of unfiltered oil to move through the lubricated areas. This could quite easily lead to an accelerated wear situation. Due to over-cooling, shaft seals and sealing efficiencies will be compromised possibly causing oil leaks and/or contamination ingress. All of these factors can result in a reduced life expectancy of the engine. A safe oil temperature and viscosity range is illustrated in Figure 8.

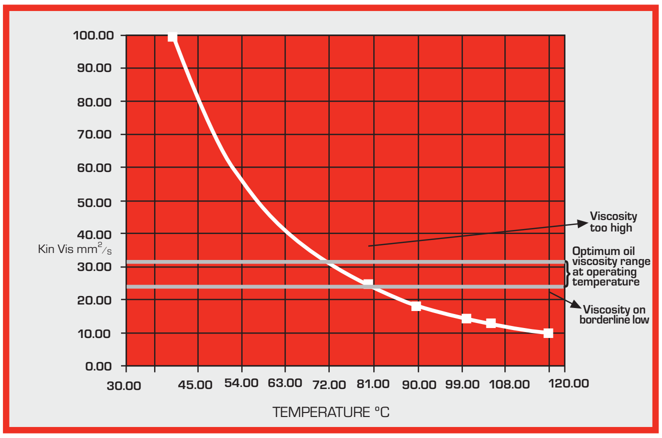


Figure 8

HIGH OIL OPERATING TEMPERATURE

High oil temperature operation can be a lot more detrimental to the wellbeing of an engine. Although it is common knowledge that the higher the temperature the more efficiently the engine runs, it also has its optimal operating ranges and limitations; exceeding these can end in catastrophic failures. High oil temperature affects the pressurised hydrodynamic lubrication regime more significantly than the components lubricated by boundary lubrication.

As the oil operating temperature increases, the viscosity decreases and the oil pressure also decreases. At normal operating temperatures the oil is more than capable of carrying out the lubrication function expected of it but as the operating temperature increases beyond the normal range, the oil viscosity becomes too thin to lubricate the components adequately especially when additional load is applied, as in the case of a big end and connecting rod journals. As the heat increases the metal components expand and the clearances between these components decrease.

The oil also decreases in viscosity, allowing contact between the connecting rod bearings and the crankshaft journal especially during the compression and power stroke (see Figure 9).

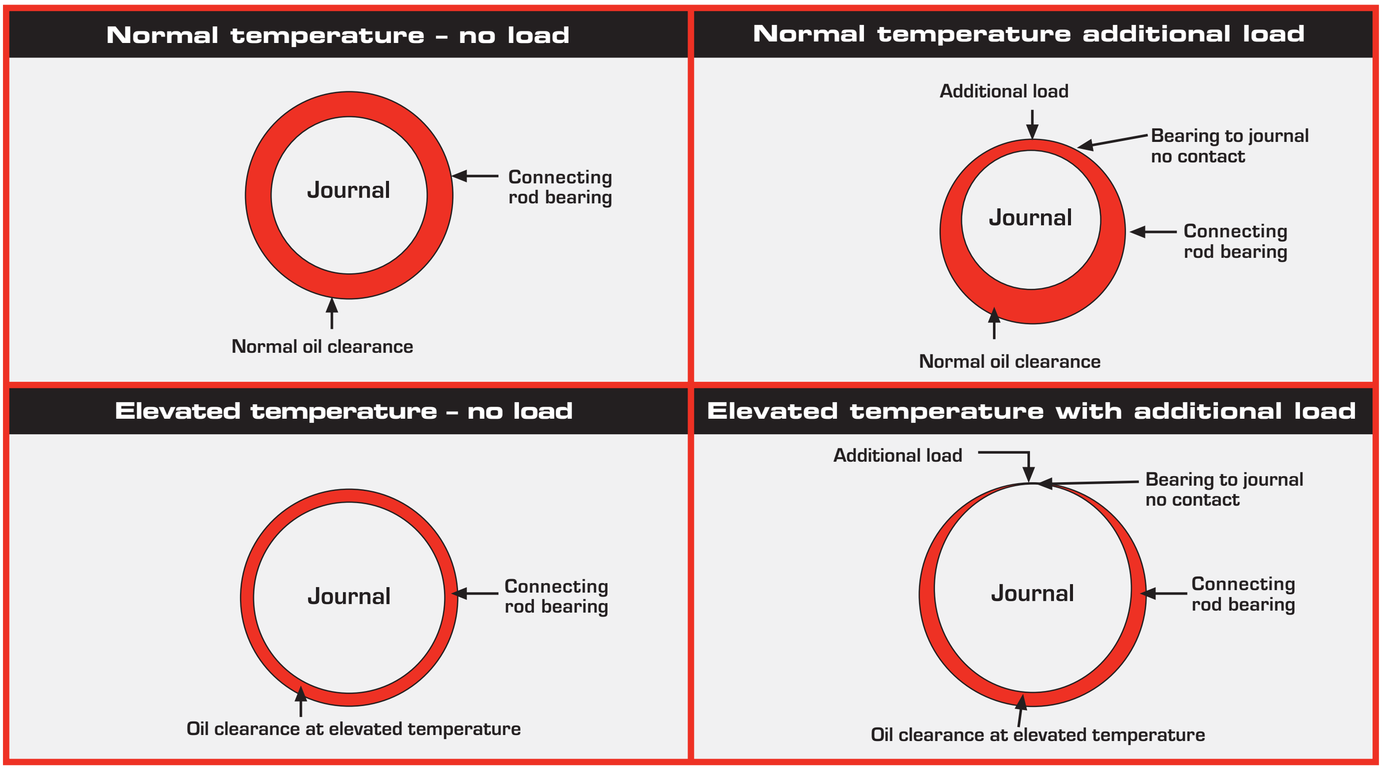
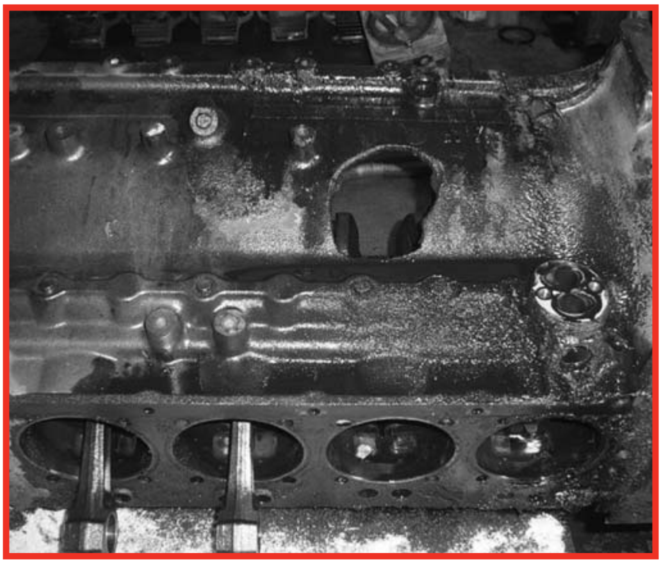


Figure 9

This situation can result in excessive bearing wear in the contact area. If operation continues under these conditions it will eventually result in catastrophic engine failure as illustrated in the photographs below:



The high oil temperature problem is aggravated even further by the constant journal to bearing contact as this increases the friction and therefore generates more heat. As the oil temperature goes up, the oil starts to oxidise which can be identified by means of an oil analysis programme. Once the oil temperature goes over 125ºC the oil is so thin that it starts to bypass the rings and gets burned in the combustion process. The oil is in a very low concentration compared to the fuel and generally is not visible as combustion smoke. In a situation such as this, oil consumption will increase and frequent top-ups will be made to keep the oil level constant. By topping up the oil in the sump there is new oil introduced which sweetens the oil additive package and dilutes the contaminants and degradation by-products. This means that oxidation of the old oil is also diluted, often making it difficult to detect when it is analysed. The same problem occurs with wear debris as accelerated wear levels are diluted with fresh oil to make them appear normal. Figure 10 illustrates the effect that dirt entry can have on wear readings, then shows how abnormal wear levels will start to look normal as oil consumption increases.

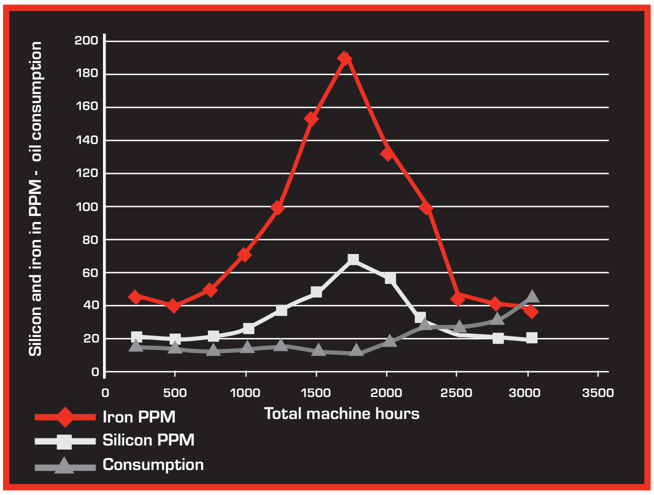


Figure 10: Dirty entry, abnormal wear and effect of oil consumption on wear readings

These problems often go undetected until there is a series of failures. Very often the problem is not identified immediately and failures are put down to lack of lubrication, as the failure modes appear very similar. The connecting rods turn blue, bearings seize onto the journal and bearings rotate in the bearing caps, with deformation failures of the bearings and housing. This all happens when the oil pump is still intact and there is still adequate oil in the sump.

A telltale sign of this type of failure that makes it identifiable from a lack of oil is the condition of the oil pump and piston skirts. If you have a lack of oil failure where there was no oil in the sump, most commonly the oil pump will either be broken or the pump gears will be blue and the piston skirt will have signs of seizing on it. In the case of overheating, the oil pump may discolour but will not turn blue and would not have broken in any way. The piston skirt is usually undamaged.

This tends to be a common problem found on new or recently overhauled engines, as a new unit's clearance is much tighter than that of an older unit. The smaller clearance allows for less expansion and therefore the failures occur faster. These failures will also commonly occur on the journal with the smallest assembly clearance.

In conclusion, when operating engines there must be careful consideration given to the following before sending expensive machinery into work, particularly in a hostile environment:

- Correct OEM approved oil must be used
- The work area must be adequately ventilated
- The unit cooling system must be adequate for the application and environment
- Oil levels must be recorded and properly maintained
- A professional oil analysis programme must be implemented and strictly enforced.

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