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CONDITION MONITORING THROUGH OIL ANALYSIS

Dirty Diesel

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The quality of the diesel in South Africa has been making headlines more and more in recent years. One of the first things to identify is what we mean by quality diesel; let us not confuse quality with dirty, wet or adulterated. It is extremely unlikely that a single drop of diesel leaving SA's refineries does not conform to the SABS standard for the quality of SA diesel, however wide or omissive that standard may be. It is from this point that the problems start, with poor transport methods, poor handling, sloppy storage and corruption.

In this bulletin I have attempted to briefly cover the various issues with diesel that have detrimental effects, showing that a wide variety of engine problems can be traced directly back to the cleanliness of the diesel used.

SULPHUR

Although not an issue in terms of contamination, sulphur is an area of concern. There is a range of valid reasons for the removal of sulphur from our diesel supplies. The first most pressing reason is that high sulphur diesels produce sulphur oxides on combustion which, when dissolved in the other by-product of combustion – water - form strong acids. When these acids condense they attack the metal surfaces of valve guides, cylinder liners and bearings. The acids produced are neutralised by the engine lubricant and, in doing so, reduce the working life of the lubricant necessitating shorter drain intervals.

Secondly, sulphur is also known to influence the emission of fine particulate matter through the formation of sulphates. These particulates are considered a health hazard and their reduction is desirable. However, the presence of sulphur must not be confused with dirty diesel; it is a vital component of diesel in that it imparts a natural lubricity, protecting fuel pumps and injectors. When this is removed during refining, it has to be replaced with additives to perform the same function.

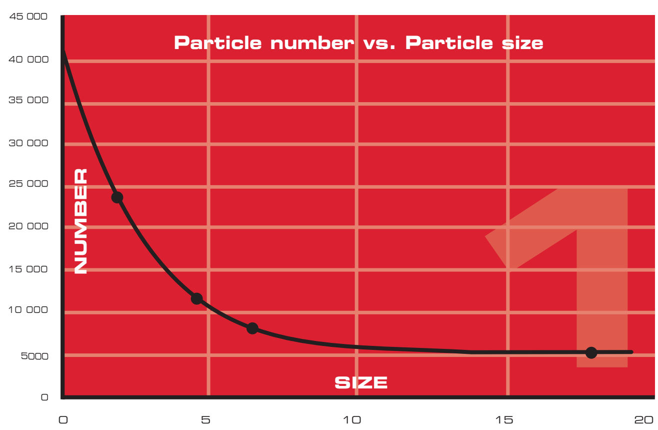
There are, however, steps that can be taken to reduce the damage that can be caused by burning high sulphur fuel.

- Know the sulphur content of your fuel. It is recommended that every bulk delivery is checked, especially if fuel quality is questionable.

- Keep the normal operating temperature of the cooling system above 80°C, this will limit condensation of sulphuric acids on cylinder liner walls.
- Select oils with a sufficient starting TBN (Total Base Number).
- Follow standard oil change regimes unless oil sampling indicates differently.
- Maintain the crankcase breather system to prevent condensation in the crankcase oil, which will cause rapid TBN depletion.

CONTAMINATION AND ADULTERATION

Particulate contamination is one of the most common problems associated with SA fuel. Particulates found in typical fuels come from a range of sources including but not limited to: dust and dirt, pump wear debris, corrosion debris from bulk tanks, filler caps and pipe work, resins, fiberglass and plastics from bulk tanks, paper and cotton from filter media, bacteria, yeasts and fungi and the fuel's own degradation products, gums and sediment. As these larger particles are removed from the fuel by the filter, they can cause loss of efficiency and blocking, leading to a host of problems, discussed in greater detail later. As shown in Figure 1 the number of particles found in a given



batch of fuel increases exponentially as the size drops. Consequently the filtering efficiency of a typical fuel filter falls away to nothing as the particle size gets smaller.

Particulate contamination is common

Modern diesel engines are more susceptible to fuel contamination than ever before. Injection pressures can be as high as 50,000psi with dynamic clearances in injectors of 2.5 micron and getting smaller. What this in effect means is vast numbers of particles are passing through pumps and injector tips causing erosive wear and increasing nozzle hole size. This leads to larger fuel drop sizes and dirt particles becoming trapped in the mating surfaces of the sealing areas of the injector tips, keeping them apart. Leaking and dribbling subsequently occur. Wear between barrel and piston occurs sometimes, resulting in seizure or reduced injection pressure and poor atomisation. Gums and resins in the fuel will coat fuel injector lines, pumps and injectors and will interfere with the close tolerances of the fuel system's moving parts. The effects of these various problems are highlighted below.

Another contaminant that finds its way into diesel is petrol. This has several adverse effects that the cleanest diesel and best filters cannot prevent, such as loss of lubrication, viscosity and cetane number, manifesting itself in leaking plungers and seals, premature ignition, engine knock and pump and injector wear. All lead to inevitable failure of valves, turbochargers, pistons, rings and bearings.

Financial incentives arising from differential taxes are the primary causes of adulteration, but are by no means the only ones. Other forms of adulteration also occur:

- Blending diesel with varying amounts of used lubricants or transformer oils contaminated with PCBs - which would be costly to dispose of in an environmentally approved manner.

- Blending heavier fuel oils into diesel.

The main adulterant of diesel is illuminating paraffin (IP) which, having a tax benefit, is often introduced illegally to increase fuel volume at low cost. IP is chemically very similar to diesel. However, when it is added to diesel, it results in a range of problems such as a drop in viscosity, a drop in cetane number and the most damaging of all, loss of lubricity. As discussed previously, the inherent lubricity of diesel is essential for the lubrication of the fuel pumps and injectors, without which wear and seizure are very real possibilities.

The main adulterant of diesel is IP

As demonstrated above, both contamination and adulteration have a detrimental effect on pumps and injectors. Subsequent damage caused can therefore be very similar. Eroded and damaged injectors produce needle dribble or poor spray patterns. Needle dribble is the main cause of piston crown meltdowns as the raw fuel burns directly on the piston itself at a much higher temperature than the melting point of the crown (see Figure 2).

Figure 2: Piston crown meltdown

Poor spray patterns lead to loss of power, sooting, increased fuel consumption and smoke as the bigger fuel droplets fail to burn cleanly. Another effect is that these larger droplets reach the cylinder liner and thin out the lubrication film there, resulting in piston scoring and wear. This also results in dilution of the oil as the thinner oil is pushed past the rings into the sump. This causes a drop in the overall viscosity and subsequent load bearing properties of the oil, resulting in big end bearing wear.

WATER

There are three types of moisture in fuel:

- dissolved moisture
- free, but dispersed
- free and settled

Most diesels will contain some dissolved water. However, the fuel can only dissolve a certain amount of water at any one temperature so, as the temperature changes, the amount of water dissolved will vary. Free and dispersed water takes the form of droplets of moisture suspended in the fuel, which over time will settle. Water gets into diesel fuel storage and vehicle tanks in a range of ways:

- Storage tanks “breathing” in humid air during use or as the temperature drops.
- Condensation of humid air in storage tanks or dissolved water separating out as the temperature drops.
- Leakage through faulty fill pipes or vents during transportation from refineries to service stations.
- Careless handling.
- Adding water to bulk tanks to reach the fuel in the “dead zone”.

Excess water breaks down the film strength of the fuel. Since the fuel itself is used to lubricate injector and pump assemblies, excessive water will also cause injector nozzle and pump wear as well as corrosion of storage tanks and microorganism growth (see figure 3 overleaf), resulting in fuel filter plugging. The effects of water accumulation can be minimised by keeping tanks as full as possible, careful handling, fitting the correct breather and filters to storage tanks and, where possible, using water separators.

MICROBIAL GROWTH

As a result of the presence of water, another common problem of diesel is microbial contamination. Bacteria and fungi are always present in the air and soil around us, and consequently are found in diesel. Under normal circumstances this presents no real problems. However, given additional water and the right conditions, they multiply rapidly, growing in the interface layer between the fuel and the water.

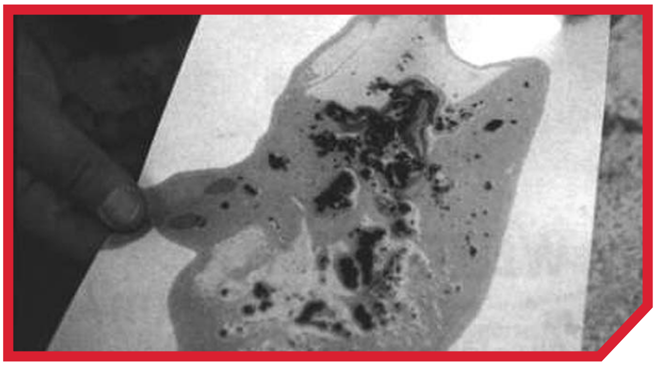


Figure 3: Slime

Along with South Africa's conducive climate, many new diesel engines return hot uncombusted fuel to the tank, keeping the contents warm and creating the ideal environment for bacterial growth. As they grow and multiply, the colour of the fuel becomes darker and turbid and black slimy mats are formed (see Figure 3). These block filters and produce a pungent smell like rotting eggs. Their by-products are often acidic, reducing the pH of the water and promoting corrosion of the fuel system.

Steps should therefore be taken to minimise the problems of bacterial growth:

- Avoid periods of long fuel storage, this also prevents the natural degradation that will inevitably take place.
- Keep the fuel dry.
- Use a fuel biocide, followed by filtering, to kill bacteria present or at least slow their growth.

So, as demonstrated above, dirt and bacterial contamination may both lead to fuel filter blockage. Any malfunction in the fuel filter adversely affects the engine's performance, generally by fuel starvation and reduced performance. When this happens, drivers resort to several trial and error practices: driving at high RPM or holding the engine at high idling speeds to avoid stalling, adjusting the fuel pump, and using cheaper or less effective filters. These practices in turn cause a host of additional problems:

- Increased smoke
- Increased oil and fuel consumption
- Failure of filters, fuel pump and injectors
- Increased engine wear due to non uniform fuel flow caused by blocked filters
- Corrosion of the fuel tank

Wearcheck has opened a fuels testing facility at Isando

Wearcheck has recently opened a fuels testing facility at its Isando offices to complement its oils and coolant analysis services. A major advantage of the new petrol and diesel testing service is that it offers piece of mind that the fuel in use is of a suitable condition. This allays the very real concerns of operators, particularly because of the problems currently experienced with diesel and the high cost of replacement equipment and downtime.

SIGNIFICANCE OF THE MAIN LAB TESTS

1. Flashpoint

The flashpoint temperature of diesel is the minimum temperature at which the fuel will ignite on application of an ignition source.

Flashpoint varies inversely with the fuel's volatility. This helps identify petrol adulteration because, for every 1/2 per cent addition of petrol, we would see an approximate 8°C drop in the flashpoint. The SABS requirement is a minimum flashpoint of 55°C.

2. Viscosity

Viscosity is a measure of a fluid's resistance to flow. It therefore affects injector lubrication and fuel atomisation. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps or injector plungers, resulting in increased wear or leakage. High viscosity fuels on the other hand will increase gear train, cam and follower wear on the fuel pump assembly due to the higher injection pressures. Diesel fuels with high viscosity also tend to form larger droplets on injection, causing poor combustion and increased smoke and emissions. Fuels that do not meet viscosity requirements lead to loss of performance. Again this test would help identify both thin (petrol) and thick (oil) adulterants. The SABS requirement is 2.2-5.3 cSt.

Fuels that do not meet viscosity requirements lead to loss of performance

3. Sulphur

This measurement helps identify what a diesel sample is *not* rather than what it *is*. Low sulphur diesel is specified as 0.05% (500ppm) or less while normal diesel is 0.3% (3000ppm). However, due to the cross 'contamination' of low sulphur diesels with regular diesel, most analyses come back anywhere between the two, unless the sample comes directly from a bulk supplier. As discussed earlier, the level of sulphur may also help an operator determine which oil would be best suited to the available fuel supply.

4. Distillation

This test measures the temperature range over which a fuel turns to vapour. Volatility is one of the primary methods which distinguish various fuels from one another. They also give an indication of the fuels ability to start the engine, its power, fuel economy, emissions and deposit formation. In the laboratory, we measure the point at which the diesel starts to boil (IBT), the temperature at which the first 10% has distilled over (T10), the temperature at which 50% of the fuel has distilled over (T50), and the temperature at which 90% of the fuel has distilled over (T90). This is specified at a maximum of 362°C. If the percentage distilled is plotted against the temperature, a characteristic distillation curve is produced. Any deviations suggest contamination.

5. Density

This is a measure of the specific gravity of the fuel. It essentially determines the energy content. The denser the fuel, the more power the engine can generate, and vice versa. Diesel is specified at a minimum of 0.800kg/l at 20°C. This again helps us identify adulterants such as IP which has a density of 0.790kg/l.

6. Cetane number (index)

The cetane number is a measure of the ignition quality of the diesel. It represents the time delay between injection and ignition. If the cetane number is too high, the fuel will ignite too close to the injector. This forms a fuel rich region whilst the rest of the chamber has a weak fuel to air ratio. Incomplete combustion and soot formation will be the result. Low cetane fuels cause knock, difficult starting, rougher running and increased exhaust emissions.

For typical on and off highway engines a cetane number of 45-50 is considered ideal, and is specified at a minimum of 45 in SABS 342 (but is generally found to be around 48). IP has a cetane index of around 40 and will therefore affect the cetane performance of the diesel. Cetane number is determined by expensive testing in an engine laboratory; therefore Wearcheck determines the cetane index of the fuel using an ASTM method utilising the distillation values T10, T50, T90 and the density of the fuel at 15°C and 20°C.

7. Illuminating paraffin contamination

All IP produced in SA must, by law have a marker added. This is a colourless chemical, usually added at about 20ppm. If IP should be illegally added to diesel, then a test can be carried out. This involves mixing the suspect diesel with a special reagent mix and observing any colour change. Adulterated diesel will turn magenta, indicating the presence of the marker and hence IP.

8. Particulate contamination

This test is used to determine the amount of 'dirt' in the diesel. Although this is not specified in South Africa, it is specified at less than 27mg/kg in Europe. Testing involves filtering 100ml of sample through a pre-weighed 0.45 micron filter. The difference in weight before and after is an indication of the amount of solid particulate contamination in the sample.

9. Water

As water and diesel do not mix, most of the water contamination will be found at the bottom of a tank. However, as discussed earlier, some water will dissolve, or will exist as extremely small droplets in the bulk liquid. This can be determined by a test known as Karl Fischer. This is an electrochemical method for detecting water in the parts per million range and can give an indication of the overall water content of the diesel.

10. Bacterial testing

As the name suggests, a sample of diesel is tested for the presence of a range of bacteria and fungi. This is a time-consuming process and involves adding a portion of the diesel to a special testing strip containing media ideal for the growth of 'bugs'. This is then incubated for about 72 hours. The growth of bugs over this period of time is rated against a chart and given a slight, medium or heavy concentration of bacteria. Essentially this may allow us to identify problem areas; it would then be up to the operator to take corrective action such as dosing the bulk tanks with a biocide.

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