

Engine emission compliance

Emissions regulations in Australia will soon change and demand massive cuts to NOx and particulate matter. To make sure that its new generation of engines meet specified targets and deliver better performance, Perkins Engines have combined a number of technologies and components.

Previously, emissions' tiers were managed successfully with in-cylinder technologies, changing the dynamics of the combustion process to achieve a cleaner burn. This alone, however, wouldn't be enough to achieve the reductions in NOx and Particulates required to meet Tier 4 Interim/Stage IIIb.

Perkins decided that there were two ways around this – one, to use exhaust gases to cool the combustion process; and two, to use a system called Selective Catalytic Reduction (SCR).

NOx reduction system

NOx is formed at very high temperatures in the engine's cylinder. One way to cool the combustion process is to introduce a small amount of exhaust gas into the cylinder.

It can be packaged tightly onto the engine; it's relatively cost effective and improves fuel consumption by about 3% on current Tier 3 product.

In the past, Perkins was reluctant to use these technologies because there was a chance that soot and even sulphuric acid would collect on intake components and affect engine durability.

Today, sulphur fuels and levels of particulate output are lower. And now that it's become a viable option, Perkins has decided to use this technology for its new engine platforms.

Selective Catalytic Reduction

The Selective Catalytic Reduction (SCR) technology is being used on on-highway equipment, especially in Europe.

The main difference between this and other technologies is that a second fluid is needed in addition to the diesel fuel. Typically, a second tank is fitted on the machine and filled regularly, usually after the main tank has been filled with diesel three or four times. The second fluid, known as Adblue in Europe or Diesel Emissions Fluid in North America, contains a chemical called urea.

The urea is injected in small quantities (typically 4 to 5% of diesel fuel) into the exhaust system, where it's mixed with the exhaust gases. The hydrolysis catalyst converts the urea into ammonia, which reacts with the NOx in the SCR catalyst to produce nitrogen, water and carbon dioxide. A final stage of catalyst (oxidation catalyst) is then needed to clean up any ammonia left in the output gases, as it's potentially harmful and has an unpleasant odour.

SCR improves diesel fuel consumption by about 5% over other technologies, but the main cost saving will depend on the relative cost of urea and diesel fuel. For example, in the UK, Adblue is slightly more expensive than the red diesel used by many operators of off-highway equipment, but cheaper than on-highway fuel.

The production of urea uses a lot of energy, so it's likely that in the future it will closely follow diesel fuel prices.

SCR's fuel consumption advantage is also restricted to certain operating conditions. According to Perkins' research, these conditions don't correlate well with the operating conditions of most off-highway machines.

At this point, Perkins has chosen not to use this technology for Tier 4 Interim / Stage 3b for two main reasons:

1. The inconvenience of handling urea – purchasing, transporting, storing and filling. There's a chance that some territories won't have well-developed distribution infrastructure in time for the 2011 introduction of new emissions legislation.
2. The complexity – additional components are needed to make the system work. Urea freezes at about -9°C, so pipes and tanks must be fitted with special heating mechanisms.

However, because this technology is an effective method of NOx reduction, Perkins may consider it as an option to meet tighter NOx requirements at Tier 4 Final and beyond. More

technology would be needed though for complete NO_x management and additional after-treatment would be needed to manage particulate matter.

The Diesel Particulate Filter

All engine manufacturers will also need to introduce some form of exhaust after-treatment to meet the particulate matter levels at Tier 4 Interim/Stage IIIb.

Perkins will use a cordierite diesel particulate filter (DPF). This porous ceramic material is highly efficient at removing particulate matter – 90% as a minimum, and often, much higher. The exhaust gases flow through the porous walls of the material, depositing the particulate and leaving the exhaust gases clean.

Diesel Oxidation Catalyst

The diesel particulate filter removes most legislated gases, but Hydrocarbons, carbon monoxide and the 'soluble organic fraction' are left behind. That's why the DPF is used in combination with another device called a diesel oxidation catalyst (DOC).

The DOC is a similar cordierite material but uses a through flow principle. The gases pass straight through the device rather than through the walls. The DPF and DOC are combined together in the same canister in the machine.

As the diesel particulate filter cleans the particulate matter from the exhaust gases, soot will start to accumulate in the filter. This needs to be cleaned out through a process called regeneration. The rate at which the filter fills depends on how clean the engine is and it's certainly desirable to make the particulate output of the engine as low as possible. The operating cycle of the machine also has some effect on the rate of soot accumulation.

DPF regeneration

There are two forms of regeneration that can clean the soot from filters – a continuous process called low temperature regeneration or a periodic process called high temperature regeneration. For low temperature regeneration, a catalyst of precious metal helps create NO₂ in the exhaust gas, which oxidises carbon at temperatures of around 250 °C or higher.

One limitation of this technology is that it requires some NO_x to make the process work; usually a minimum ratio of 25:1 NO_x to particulates is required, with 40:1 being desirable.

Even though the particulate output of the engine is very low, it's only really viable in engines up to 130kW, where a little more NOx is allowed by the legislation.

This process occurs continuously, so the operator won't normally notice anything different during the duty cycle, and won't need to take any exceptional actions.

After extensive field research, which measured the operating cycles of a large number of different off-highway machines, Perkins is confident that for the majority of machines there'll be sufficient working periods where the exhaust temperature will be higher than 250 °C for the filter to regenerate effectively by this method.

However, there'll be some applications, notably in cold temperatures or very light duty cycles, where some additional help will be needed to raise the exhaust temperature. A simple mechanical device will be fitted to Perkins engines to assist regeneration in these special circumstances.

High temperature regeneration is a periodic process that's used to burn off the accumulated soot after a few hours of operation. There are several different methods, but the one preferred by Perkins, for engines over 130kW, is to use a burner in the exhaust stream. The burner heats the exhaust gases to over 600 °C, directly oxidising the accumulated soot in a well-controlled manner.

This system is robust and highly controllable compared to some competitors' systems, because it's possible to start and stop the regeneration at any time. The process is most fuel-efficient at lower speeds, and based on the measurement of machine duty cycles, it's clear that there'll be plenty of opportunities in almost all machine types for this to occur without operator intervention.

Ash service

Although most of the particulate matter in the filter will oxidise completely during regeneration, there are tiny quantities of minerals (e.g. phosphates) in engine lube oil that don't combust. Over many hours of operation, these result in the accumulation of ash in the channels of the diesel particulate filter. Eventually, they reduce the volume of the filter and increase the backpressure, resulting in deterioration in fuel economy and performance.

Ash doesn't regenerate, so it needs to be cleaned out using a special machine. In North America, the Environmental Protection Agency (EPA) specifies that the first ash service

shouldn't occur before 3000 hours for engines less than 130kW, and 4500 hours for engines above 130kW.

In Europe, ash service isn't specified by legislation. Perkins feels that ash service is an inconvenience to machine owners and should be avoided for as long as possible. With a small increase in filter size at the lower power end, Perkins has managed to avoid ash service altogether for some of its engine range.

Sulphur

Sulphur in fuel is a problem not only for Perkins, but for the whole industry. Sulphur reacts with precious metal catalysts and prevents them from working correctly. The legislators recognise this and new "Ultra Low Sulphur Diesel" standards are being introduced for off-highway fuel. Typically, this will mean sulphur levels of less than 15 parts per million, similar to those of modern on-highway fuels.

But there are issues with this change in fuel. For example, will storage tanks really be completely empty before new ultra low sulphur diesel is added? With this in mind, Perkins is making sure that its technologies are designed to be robust in the face of occasional misfueling.