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A briefing on the evaluation of the effectiveness of the FTC/FPC additives in diesel fuels

Project Background

I was commissioned by BHPBilliton Iron Ore Pty Ltd to undertake a desk-top study and independent evaluation of the effectiveness of the FTC/FPC additives in diesel fuels used in mining operations including trucks, light vehicles, mobile equipment and locos in April 2007. The evaluation examined a large volume of data from various historical laboratory tests and field trials and applied statistical assessment of the results. It was realised that, while the fuel savings by using the FPC catalysts were real and significant, the widespread applications have been hampered, in part, by the lack of systematic science-based understanding and proof of the efficacy of these catalysts. Therefore, an ARC Linkage Project entitled "*Homogeneous Combustion Catalysts for Efficiency Improvements and Emission Reduction in Diesel Engines*" was enacted, funded by the ARC and carried out at the Centre for Energy in UWA. The research has been completed successfully with a number of peer-reviewed papers published in international scholarly journals.

The Chemistry of Fuel Technology's Diesel Additives

The FPC diesel combustion catalysts manufactured by FTPL contain iron picrate salt in the form of ferrous picrate, n-butanol (approx. 12%) and a complex mixture of short-chain alkyl benzenes (approx. 87%).

Metal picrates are particularly sensitive and can be formed with metals such as copper, nickel, lead, iron and zinc. Ferrous picrate is the ideal choice among these as it delivers the ferrous ions as the combustion catalyst and decomposes at an extremely high rate upon heating while only being required at very low concentrations.

As far as the fundamental chemistry goes, ferrous picrate needs to be dissolved in a sorbent that will not result in phase separation when added to diesel. Alcohols are the obvious choice as they can readily dissolve with all hydrocarbons, and butanol is perhaps the best of all. Based on the chemical make-up, the use of FTC/FPC combustion catalyst as a diesel additive to improve engine efficiency has a sound scientific basis.

Testing Process and Results

In real-world applications, there are many factors affecting the "on-road" performance of a diesel engine, including (1) fuel related variables (2) engine type, age and maintenance (3) road conditions, (4) weather conditions and, not the least, (5) the different operator (driver) habits, just to name a few. The advantage of laboratory engine testing is that we can vary one factor at a time while with all others under controlled so that the efficacy of the use of the catalysts can be measured more precisely and in a scientific manner.

During the laboratory testing, the engine was run primarily under two sets of conditions: (1) fixing the engine speed while changing the load from none to 100%, and (2) maintaining the engine at full load and varying the speed. Under each of the test conditions, the engine was allowed to operate at the specified speed and load for about 30min until the characteristic parameters of the engine stabilised. Then the fuel consumption was measured using an electronic weighing scale at certain time intervals. Similarly, the exhaust emissions (CO, UHC, NOx, Soot) were also measured under each engine condition. In particular, soot particles were collected from the engine exhausts and subjected to a group of advanced analytical techniques to reveal the changes in soot physical and chemical properties under the effect of the catalyst. When feeding the engine with a different fuel, the engine was purged with the new fuel for 30min to eliminate the effect of the fuel in the previous test.

To further understand the effect of the FPC catalyst on the combustion characteristics of diesel, a single droplet study was also performed to examine the changes in key parameters such as flame temperature, burning rate and combustion duration.

Results from the laboratory study have shown that the addition of the FPC catalyst has significantly improved diesel combustion, with the following benefits ascertained:

1. Diesel fuel consumption was reduced from 2.4%-4.2%.

2. Smoke emission from diesel combustion was reduced by up to 39%, with CO and UHC reduced by up to 22% and 15%, respectively.

3. The use of the catalyst promoted the combustion process by shortening the burnout time and increasing the burning rate and flame temperature of diesel fuel droplets, which means the catalyst provides faster and more complete combustion of the fuel.

4. As a result of improved fuel combustion with the use of the catalyst, soot particles from diesel engine exhausts were found to be smaller and of higher reactivity, which can be more easily burned off and lead to less soot emissions and less engine wearing.

Implications for Large Fuel Consumers

The efficacy of the FPC catalyst in promoting fuel combustion and reducing exhaust emissions has important practical implications, especially for large fuel consumers in terms of the significant economic and environmental benefits. Based on a careful calculation using an achievable fuel saving of 2.5% with the use of the catalyst (our laboratory tests and field trials have consistently demonstrated up to 4.2% and 5.6% fuel savings), it is clear that fuel consumers can expect to see savings as shown in the following examples:

- For operations with an annual fuel consumption at 5 million litres such as medium transportation companies, local councils and remote power generations, the use of the catalyst can reduce 335 tonnes of greenhouse gas (GHG) emissions and save $100,000 of fuel costs per annum.

- For medium – scale fuel users with 50 million litres fuel consumptions per annum, e.g. medium mine site operations and shipping companies, the application of the FPC catalyst can lead to 3,353 tonnes of GHG emission reduction and $1 million of fuel cost savings.
- The benefits are even more profound if the catalyst is applied by large fuel users with 300 million litres or more fuel consumptions per annum, for example BHP Billiton or Rio Tinto's iron ore mining operations in Western Australia, a substantial reduction of 20,120 tonnes in GHG emissions and $6.1 million in fuel cost savings can be achieved by the use of FPC.

Responses to Frequent Concerns

1. Peak pressure/temperature

The combustion process in diesel engines consists of two phases: pre-mixed combustion phase and diffusion controlled combustion phase. The fuel injected into the engine evaporates and pre-mixes with air during the ignition delay period and then the fuel/air mixture ignites and burns where the peak combustion pressure usually occurs. The use of the FPC catalyst has very little effect on the peak pressure of the engine. In fact, the working mechanisms of the catalyst in the combustion process of diesel is that it reduces the combustion duration and enhances the heat release rate in the diffusion controlled phase, resulting in higher **average** pressure and combustion temperature and therefore higher fuel combustion efficiency and lower exhaust emissions.

2. Fuel specifications

We have systematically tested the changes in fuel specifications associated with the use of the FPC catalyst, including viscosity, density, flash point, pour point, distillation temperature and Cetane index. Results have shown that there are no noticeable differences in terms of these key properties between the baseline diesel and the catalyst treated fuels. This is, naturally, due to the extremely low catalyst dosages used (at parts per million). This follows that no modifications to the engine systems are required to accommodate the catalyst treated fuels, nor any adverse effects associated with the use of the catalyst would occur to the engine system.

3. Engine wear

It is considered that the use of the catalyst can ease and reduce the engine wear. As the catalyst promotes fuel combustion and reduces soot formation and coking in the engines, this leads to reduced carbon residue build-up on the interior engine parts, and therefore, the combustion is much cleaner with reduced maintenance and downtime required and less occurrence of engine wear.

4. Soot in oil

It has been consistently demonstrated in our tests that the addition of the catalyst always leads to less soot precursors formed in the engine as a result of the improved combustion, therefore reducing the overall soot emissions. Furthermore, our study has also proven that the iron element in the catalyst can subsequently promote soot oxidation once the soot is formed. The reduction in soot in lubricant oil in engines is therefore expected.

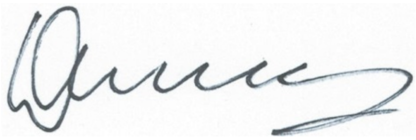
5. Compatibility with other fuels

An important part of our laboratory study was carried out with biodiesel, which proved that similar beneficial effects of the FPC catalyst can be achieved. Evidence has shown that during biodiesel combustion, the smoke, CO and UHC emissions were reduced by up to 24%, 17% and 4% respectively, with up to 2.8% fuel savings achieved by the addition of the catalyst.

Based on its chemical make-up of the catalysts, it is reasonable to deduce that the catalyst is compatible with most hydrocarbon fuels. Our future work will examine the effect of the catalyst in improving the combustion of kerosene, heavy fuel oil and renewable fuels.

6. Comparison between small and large engines

The testing program in our research has involved a single cylinder laboratory diesel engine and a large industrial-scale diesel engine and we have accessed data from tests elsewhere. The results have consistently demonstrated fuel savings and reduced exhaust emissions regardless of the engine type and size. The fuel consumption was reduced by up to 4.2% with the use of the catalyst in the small laboratory diesel engine and up to 5.6% in the large industrial diesel engine. Interestingly, the tests have also shown that the fuel savings are greater under light load conditions and inefficient engine operation modes.



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