On road experience with neat GTL Diesel

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Gas-to-Liquids (GTL) diesel from the Low Temperature Fischer-Tropsch (FT) process has been available from pilot and demonstration plants of various scales for nearly two decades now. It has been subject to various research efforts to quantify the performance and exhaust emissions benefits. Much of this development has focused on test-bench engine evaluation, supported by in-vehicle verification.

Although GTL diesel has found its way as a blend component into the European niche diesel market and even motorsport applications, the use of neat GTL diesel as an automotive fuel remains an area of interest, especially in light of the European (CEN) and United States (ASTM) specification authorities’ efforts to allow neat GTL diesel to be marketed as a final product. The commercial scale operations of Oryx-GTL and the imminent commissioning of Shell’s Pearl GTL plant will increase the levels of GTL diesel in the market, making the application of neat GTL diesel a reality. This requires confidence in understanding the impact on engine durability and maintenance. Although much of this confidence has been gleaned by bench durability testing, the ultimate test of a fuel remains real-life application.

This paper gives an overview of the various on-road experiences with neat GTL diesel, not only in the form of controlled, comparative fleet tests, but also in real-life vehicle applications. Controlled trials include bus fleet and passenger car fleet tests, whilst other experiences include a trans-Africa vehicle expedition using neat GTL diesel and a two vehicle wildlife census project covering more than 350,000 kilometres. Although real-life, on-road tests benefit from exposure to real operating conditions, including fuel handling and dispensing, the extent of detailed engine evaluations are limited by operational, logistical and time constraints. The continuous monitoring of lubricant condition and regular evaluation of vehicle performance are indicators of gross component impact, while detailed, post-trial evaluation of various components allowed for a more in-depth understanding of long-term effects of neat GTL diesel on engines and fuel systems. All of these on-road evaluations showed GTL diesel to be a superior fuel from a performance, emissions and engine durability point of view.
Forward-looking statements

In this document we make certain statements that are not historical facts and relate to analyses and other information which are based on forecasts of future results and estimates of amounts not yet determinable. These statements may also relate to our future prospects, developments and business strategies. Examples of such forward-looking statements include, but are not limited to, statements regarding exchange rate fluctuations, volume growth, increases in market share, total shareholder return and cost reductions. Words such as "believe", "anticipate", “expect”, "intend", "seek", "will", "plan", "could", "may", "endeavour" and "project" and similar expressions are intended to identify such forward-looking statements, but are not the exclusive means of identifying such statements. By their very nature, forward-looking statements involve inherent risks and uncertainties, both general and specific, and there are risks that the predictions, forecasts, projections and other forward-looking statements will not be achieved. If one or more of these risks materialise, or should underlying assumptions prove incorrect, our actual results may differ materially from those anticipated. You should understand that a number of important factors could cause actual results to differ materially from the plans, objectives, expectations, estimates and intentions expressed in such forward-looking statements. These factors are discussed more fully in our most recent annual report under the Securities Exchange Act of 1934 on Form 20-F filed on 28 September 2010 and in other filings with the United States Securities and Exchange Commission. The list of factors discussed therein is not exhaustive; when relying on forward-looking statements to make investment decisions, you should carefully consider both these factors and other uncertainties and events. Forward-looking statements apply only as of the date on which they are made, and we do not undertake any obligation to update or revise any of them, whether as a result of new information, future events or otherwise.
About Sasol

Sasol is an integrated oil and gas company

• world leader in gas-to-liquids (GTL) and coal-to-liquids (CTL) technology
• world’s largest producer of synthetic fuels
• joint venture partner in ORYX GTL – 32,400 bpd GTL plant
• present in 38 countries
• ~ 34000 employees worldwide
• turnover of about USD18bn

(for the year ended 30 June 2011)
The Sasol Slurry Phase Distillate™ (SPD™) Process

A three step process:

• reforming natural gas with oxygen and steam over a nickel catalyst to produce syngas

• converting syngas into long-chain waxy hydrocarbons in a Sasol Slurry Phase Fischer-Tropsch (FT) reactor

• selectively cracking the waxy hydrocarbons to produce GTL diesel, kerosene and GTL naphtha
SPD™ GTL diesel

SPD™ GTL diesel is:
- nominally zero sulphur (<1 ppm) and total aromatics (<1 %)
- low density (~0.77 kg/l) and very high cetane (> 75)
- colourless and odourless, with excellent long-term storage stability
- generally lower tailpipe emissions, especially of particulate matter
- superior thermal stability, resulting in reduced engine deposit formation
- can be blended with conventional and bio-derived diesel fuels
- complies with CWA 15940 “Automotive fuels – paraffinic diesel from synthesis or hydrotreatment – requirements and test methods”
Introduction

Sasol was the first to bring large scale commercial GTL diesel to market and thus required:

- absolute confidence in performance & fit-for-purpose nature of the product
- large number of evaluations have been completed:
  - engine bench & vehicle evaluations – emissions & performance
  - engine bench durability
  - **ultimate test is on road application**

The Sasol Chevron name and the associated symbol are proprietary to Sasol Chevron Holdings Limited, and use herein does not necessarily imply any endorsement by Sasol Chevron.
On road applications trials with neat GTL diesel

- 2 cars
  - >35,000 km
  - ~3,200 litres

- 10 busses
  - >295,000 km
  - >126,000 litres

- 14 busses
  - ~173,000 km
  - ~54,000 litres

- 1 car
  - >40,000 km
  - >2,400 litres

- 2 SUV’s
  - >350,000 km
  - >40,000 litres

- 1 SUV
  - ~11,000 km
  - ~1,400 litres

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  - ~11,000 km
  - ~1,400 litres

Totals

- 30 vehicles
- ~905,000 km
- ~226,000 litres
Passenger Car 1

3 car comparative fleet test
• 2 cars on GTL – 1 on European EN590
• SPD™ GTL ex pilot plant
• routine oil condition monitoring
• internal engine visual inspections
• visual injector inspections
• emissions tests on completion
• Conclusions
• no fuel related issues
• visible chamber and injector deposits comparable
• significant oil condition monitoring benefits noted with GTL diesel (discussed below)
• emissions at completion continue to show GTL diesel use resulting in emissions benefits

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<th>Timing</th>
<th>Initiation</th>
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Bus Fleet Trial 1

20 bus comparative fleet test

- 10 buses on GTL – 10 on European EN590
- SPD™ GTL ex pilot plant
- all buses 15,000 km normalisation on EN590
- test group – 2 x 15,000 km oil drain intervals
- control group – 1 x 15,000 km drain interval
- fuel consumption monitored
- routine oil condition monitoring
- internal engine visual inspections - borescope
- visual injector inspections
- driveability and performance measurements
- free acceleration smoke tests
- driver perceptions

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</table>

| Fuel Quantities (l) | Reference | 180,830 |
|                    | GTL       | 126,373 |

| Vehicle Info. | Number | 20 |
|              | Type    | MAN Explorer Engine: FOC 18.262 |
|              | Model Year | 2001 & 2002 |
|              | Emissions Level | EU II |

| Total Distance (km) | Reference | 452,733 |
|                     | GTL       | 295,785 |

Bus Fleet Trial 1

Conclusions

• no fuel related concerns
• significant oil condition and wear benefits (discussed later)
• slight measured power reduction – not perceptible to regular drivers
• exhaust smoke benefit maintained throughout trial
• injector tip deposits reduced
• \( \sim 3.3\% \) increase in volumetric fuel consumption – less than expected from density & energy content differences
Long term trial – Wild Cheetah Project

2 SUV’s utilised in Wild Cheetah Conservation Project

- 3 year duration
- SPD™ GTL ex pilot plant
- harsh conditions including significant off road operation
- vehicles with advanced emissions control including diesel particulate filters
- routine oil condition monitoring
- regular vehicle performance monitoring
- post trial retention of exhaust system components for inspection and evaluation
- extensive post trial evaluations of critical fuel injection equipment

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Long term trial – Wild Cheetah Project

Conclusions
• no fuel related concerns
• oil condition monitoring:
  • lubricant soot loading very low
  • no indication of excessive wear
  • oil condition remained well within limits for every drain interval
• no negative visible affects to exhaust aftertreatment devices
• post trial component evaluations:
  • high pressure fuel pumps & injectors successfully passed functional testing, no significant wear
  • fuel injectors flow rates within tolerance, fouling as expected for mileage completed
Trans African Expedition – the GTL Challenge

SUV operated on GTL diesel
- SPD™ GTL ex pilot plant
- 46 days
- from Sasolburg, South Africa to Doha, Qatar
- 11,000 km
- 1,400 litres GTL diesel
- no fuel related concerns
- noticeably less oil sooting relative to accompanying vehicles operated on conventional diesel fuel

“a symbolic passage of the technology across Africa, where it was developed, to Qatar, where it has been taken to the next stage of commercial development”
Passenger Car 2

2 car comparative fleet test
- project only one part of first ever comprehensive evaluation of SPD™ GTL diesel from large scale commercial plant – Oryx GTL
- new vehicles first pre-conditioned - 5,000 km on conventional EN590 specification diesel
- 1 vehicle dedicated to GTL diesel, other remained on EN590
- 2 x 20,000 km oil drain intervals each
- routine oil condition monitoring
- regular vehicle performance measurements
- internal engine visual inspections - borescope
- detailed imaging of injectors – scanning electron microscope

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Passenger Car 2

Conclusions

• no fuel related concerns
• internal engine visual inspections indicated both engines in good condition
• oil condition monitoring:
  • lower oil soot loading
  • reduced wear
• commercially produced Oryx GTL diesel declared as fit-for-purpose (in combination with larger project which included engine durability, injector fouling, fuel pump wear etc)
Bus Fleet Trial 2

16 bus comparative fleet test

- project conducted by Chevron, AC Transit and Cummins
- utilised Sasol SPD™ GTL pilot plant diesel
- 12 buses used both fuels, as well as a 20% bio-diesel blend, switching fuels every 9,600 km, for 28,800 km
- 2 buses each exclusively used GTL diesel and CARB diesel for 28,800 km
- measurement made for: fuel economy, smoke, filter clogging, injector fouling, lubricant condition, diesel particulate filter, power

Timing

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Vehicle Info.

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Bus Fleet Trial 2

Conclusion

• “none of the fuels experienced adverse effect with respect to: smoke, material compatibility, filter clogging, injector fouling, lubricant, diesel particulate filter”
• “all post-injector testing and evaluation indicated that parameters were within the acceptable range defined by the manufacturer”
• “GTL diesel had significantly lower fuel economy than CARB diesel” (approximately 4.3%)

Oil Condition Monitoring

Significant benefits for engine wear have been found with SPD™ GTL diesel
- consistent oil condition monitoring trends across several projects (including engine bench tests)
- SPD™ GTL’s near zero levels of sulphur and aromatics result in:
  - reduced soot loading and possibly smaller particulate size
  - reduced acidic products entering lubricant
  - improved combustion properties may further reduce wear
GTL diesel leads to reduced wear

- Oil soot loading reduced with GTL
- Iron wear rates reduced with GTL

*Iron wear rates* reduced with GTL diesel leads to reduced wear.
Injector fouling

SPD™ GTL diesel exhibits superior injector fouling properties
- has been demonstrated in industry standard tests
- on road experience has supported those results
- in no cases did SPD™ GTL diesel result in excessive fouling
- where direct comparisons with crude diesel were possible, equivalent or better performance noted

SPD™ GTL diesel has been thoroughly evaluated in actual on road applications as a neat fuel

- in 30 vehicles ranging from passenger cars to heavy duty buses
- > 900,000 km on neat GTL and many more on blended fuels and comparative reference fuels
- > 225,000 litres of neat GTL consumed
- thorough and detailed investigations have shown the generally superior properties of SPD™ GTL diesel
Arthur Bell
Principal Engineer
Sasol Technology, South Africa

Author Biography

Arthur has worked in the automotive powertrain research and testing industry since 1993 when he joined the automotive engineering research centre at Stellenbosch University in South Africa. Arthur remained part of this group as it privatised to become a major automotive engineering service provider in South Africa, specialising in engine development and testing services. During this time, Arthur completed his PhD from Stellenbosch University studying the effects of fuel formulation on spark ignition engine emissions.

Arthur joined Sasol Technology Fuels Research in 2007 where he is currently principal engineer in the mechanical research department where he has been involved in various fuels evaluation projects, acting as project manager in many of these.