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Original Research Article

The Effect of a Homogeneous Combustion Catalyst on Diesel Consumption in South African Engines

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Abstract

Fuel performance catalyst (FPC) is the homogeneous combustion catalysts supplied and distributed by GreenThermo Energy Pty Ltd (GTE) in South Africa. The FPC is a ferrous picrate water butanol solution with additives. These additives are mainly short chained alkali benzenes used to stabilize the catalyst mixture. The influence of fuel performance catalyst in diesel engines is investigated to create seamless 'Green fleet' solutions by reducing fuel consumption within business environments. Fuel economy in internal-combustion engines aim to convert chemical energy is to the maximum amount of useful work. This paper presents experimental results that provide the optimum fuel performance catalyst (FPC) dose in Nissan UD60 diesel direct ignition trucks, rolled out at Premium Packaging Pty Ltd. The fuel consumption was measured as a function of catalyst dosing ratio and distance travelled. The FPC was able to reduce fuel consumption through the field testing method and it was concluded. The FPC integration strategy recommended suggested that an opportunity exists for Premier Packaging, if the trucks were representative of the median population in their truck fleet, an average general fuel consumption of 24L/100Km within 12 months could be achieved. The results were compared to baseline performance of 27L/100Km prevalent at the beginning of FPC dosing implementation, which is within 95% prediction interval. An improvement of up to 3L/100Km represents 11% reduction in fuel cost impact year-on-year.

Keywords: Fuel Performance Catalyst; Diesel engine, Fuel consumption

1. Introduction

The escalating number of cars in some cities has resulted in high demands of fuel. It has been reported that the number of cars on the world's roads surpassed one billion in 2012; this was according to the Huff Post, Canada business news [1]. This has brought about a considerable rise in the global fuel consumption from automobiles and industrialization. In automobiles (in our case, diesel trucks), fuel consumption can be attributed to a number of factors such as payload, weather, grade of fuel, driver behaviour and others [2-3].The consumption of petroleum based fuels has been increasing -with diesel at just under five million litres in 1994 to over ten million litres in 2008[4]. Lately, the focus has shifted to improved fuel-efficient vehicles with reduced carbon dioxide emissions and "lean burn" engines, particularly diesels whose popularity can result to a better fuel economy. Due to increased fuel costs, studies have been conducted over the past few decades in an effort to develop cleaner and more efficient

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diesel engines and their applications [2-9]. Extensive research has been conducted in Western Australia, United States of America, India and Singapore with results showing improved fuel efficiency and reduction in smoke emissions due to additions of catalysts [4-9]. Catalysts are important in the (petro-) chemical industry as these materials are essential for mediating more than 90% of all industrial chemical processes worldwide [10]. The impact of catalysis results not only from its capacity to facilitate chemical reactions, but also its propensity to improve the selectivity of catalysed transformations. Increasing the selectivity reduces by-product formation, resulting in chemical processes of superior environmental performance [11].

Fuel catalysts known to have been researched by scholars include Cerium Oxide which is a rare earth metal with dual valence state existence. It has exceptional catalytic activity due to its oxygen buffing capability, especially in nano-sized form [4]. Some studies investigated the use of an Oil-soluble Organo-metallic Iron Combustion Catalyst developed for use in Siemens-Westinghouse 501 D-5 104 MW combustion turbine engines [5]. Since diesel engines are more efficient and stronger than gasoline engines, they are widely used and due to economic considerations, fuel economy is still pursued [6].

This study investigates and evaluates the influence of Fuel Performance Catalyst (FPC) dose with respect to fuel consumption efficiency in diesel direct ignition trucks for the South African conditions. The FPC is a homogenous combustion catalyst consisting of Ferrous picrate additives with approximately 12% n-butanol, a complex mixture of short chain alkyl benzenes (approx. 1%) of dioctyladipate, a common plasticiser, short-chain alkyl benzenes range from xylenes (C2 alkyl group) to tetra-methylbenzenes (C4 alkyl group). The FPC may be used in the production of gasoline, diesel fuel or any liquid hydrocarbon fuel.

The tests for this work were conducted in Johannesburg which geographically is situated on the Highveld with an altitude of 1753m above sea level. At high altitudes, the local air pressure and oxygen content is low. Reduced atmospheric pressure and oxygen content hinders the engines performance, by lowering its power output and increasing of fuel consumption [12]. The neighbouring regions include Pretoria (west) and Nigel (east) which are 1350m and 1566m above sea level respectively [13].

2. Experimental

2.1. Fuel properties

Before the tests runs were initiated, laboratory tests were conducted for the catalyst dosed and undosed diesel to quantify the effects of the FPC additions into the diesel with respect to viscosity and flashpoints. The flashpoints were determined using the Normalab Analis – Method B. The viscosity was determined using the Cannon Instrument Company viscometer. The above mentioned properties are vital in the quality and combustion rate of the fuel in an automobile engine.

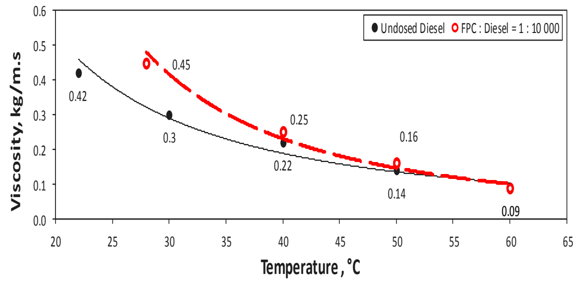

Fig 1. The viscocity profile for the FPC dosed and undosed diesel

The flashpoint accounts for the lowest fuel combustion temperatures when a flame is passed over it, while viscosity accounts for ease of atomization, combustion quality and consequently the resulting potential chemical energy converted to the maximum amount of useful work. The findings obtained for the fuels used are represented in Table 1.

Table 1. Key properties of the fuels used in the tests.

Parameters	Undosed Diesel	FPC : Diesel (1 : 10 000)
Flash point (°C)	63.00	65.00
Density (kg/m³ @ 60°C)	748.75	750.00

2.1. Test procedure and data collection

Two trucks were used during the tests and their details are displayed in table II. The FPC was added into diesel fuel in an ultra-low dosage ratio of Catalyst: Diesel = 1: 10 000 and the mixture was dosed into the trucks at the fuel station. The litres of diesel pumped into two different trucks together with the kilometres travelled by each truck were then logged at each loading point.

Table 2: Test Trucks Description and Tyre Pressure

Truck No	Registration No	Truck Type	Tyre Size	Tyre Pressure
1	VRH060GP	UD60	235 /75 /17.5	600 - 650
2	WXM987GP	UD60	235 /75 /17.5	600 - 650

The experimental data was collected on daily basis recording the distance travelled. The trucks had no designated drivers, the payload and routes varied daily and thus the test conditions were not as controlled as in the laboratory environment. Diesel consumption was interpreted as fuel consumption in litres per 100Km travelled. Inferential statistics, linear and power trend equations were employed for the analysis of the data collected. An independent analyst was also used during the analysis to reduce the level of uncertainty, biasness and to confirm the results obtained.

3. Result and Discussion

Fleet operations are a replete with a myriad of uncontrolled variables that influence the rate of fuel consumption for each individual vehicle. These include change in weather, road, engine and vehicle condition, changes in drivers, routes, equipment, load, road condition, fuel quality and energy content, and idle time. The uses of heaters, lights, wipers, air conditioners, compressors, etc., create parasitic horsepower drain and rob the engine of efficiency. All of these variables combined can give the appearance that the catalyst is ineffective, when the in reality the fuel consumption would be much greater without it [6-7].

3.1. Truck 1: Collective Diesel Consumption

Fig 2b represents the diesel pumped into the truck at the end of the shift. The FPC dosed diesel curve is above the undosed diesel curve as seen on the plot. This confirms the trend observed on fig 2b, which brings about a conclusion that truck 1displayed moderate response to the FPC.

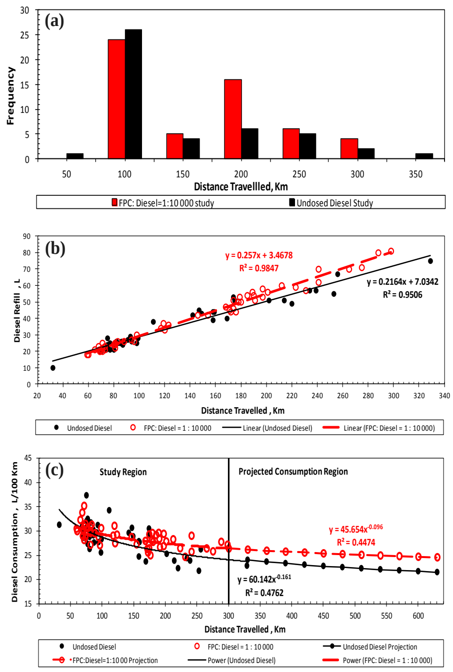

Fig. 2 The collective Truck 1 (VRH 060 GP) data profiles: (a) Destination histogram, (b) The diesel Re-fill per destination, (c) Fuel consumption

According to the results for truck 1, when the collected control data was compared to the experimental data. Truck 1 was mostly used as a short distance delivery truck as seen on fig 2a. Three destination precision points of 50-100km, 150-200km and 250-300km for the destination intervals are also observable. These emphasise that the destination routes during the tests were not fixed and this is one of the variables that pose a challenge in quantifying the FPC performance. Fig 2c indicates that at short distances of 80Km, the dosed and undosed diesel tests have an equivalent fuel consumption of 29L/100Km. Longer distances of 300Km had the dosed diesel study dipping to a consumption to 27L/100Km travelled whereas the undosed diesel showed fuel consumption is seen dropping to 25L/100Km. These variations during the test study were attributed to three variables namely, driver behaviour (since this truck did not have a single designated driver), the inconsistent routes and the daily traffic volume (which created stop and start situations which in turn create discontinuities in peak flame temperatures in the engine, which greatly hamper the FPC performance). Even though the general trend simulated a regression in diesel consumption, the findings show that truck 1 had a moderate response to the FPC. The power trend equations (see trend equations) modelled the truck 1 FPC dosed fuel consumption to be more elevated when compared to the undosed diesel consumption. These major differences between the dosed and undosed diesel tests offer contradiction to the desired fuel consumption trend and this can only be accounted for by the factors that were highlighted at the beginning of this section.

3.2. Truck 2: Collective Diesel Consumption

Fig 3a is the collective diesel consumption for truck 2. The FPC dosed diesel study shows a fuel consumption of 25.8L/100Km and travelling a distance of 80Km. At short distances the dosed test had higher fuel consumption than the undosed diesel consumption study. A steady fuel consumption regression to 24L/100Km is observable at the same rate at a middle distance of 270Km. At longer distances of 360Km the diesel dosed test realised lower fuel consumption of 23L/100Km travelled than the slightly higher undosed diesel consumption test of 23.5L/100Km travelled. The FPC dosed diesel test was projected using the power equation $y = 43.314x^{-0.105}$ at 570Km it is projected to give fuel consumption of 22.2L/100Km travelled whilst the undosed truck will realise 22.8L/100Km travelled at the same distance of 570Km projected by the power equation $y = 33.631x^{-0.061}$. The trend lines projection in fig 3b indicates a 4.3% reduction when a substantial and uninterrupted mileage is accumulated. It can be also be noted from fig 3a that the route for this truck was also not fixed thus, both trucks involved in the tests were subjected to relatively identical test conditions.

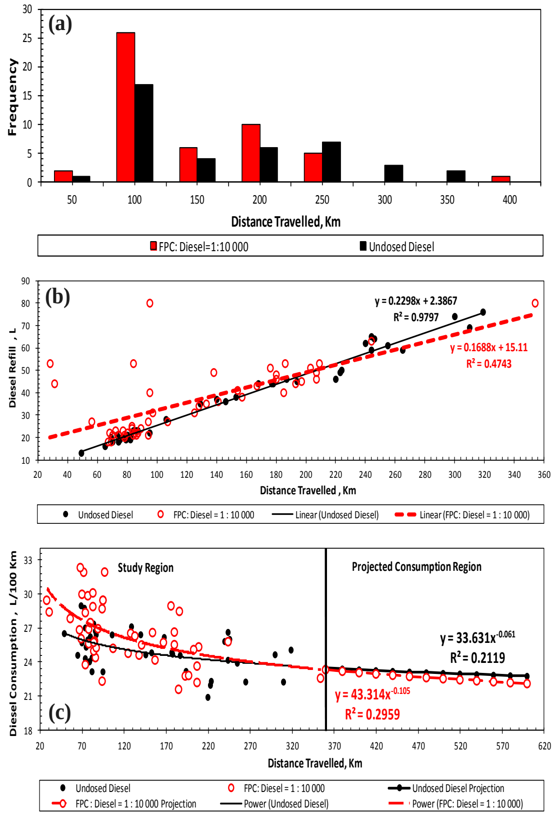

Fig. 3 The collective Truck 2 (WXM 987 GP) data profiles: (a) Distination histogram, (b) The diesel Re-fill per destination, (c) Fuel consumption.

Fig 3b is the diesel fill-up chart and the corresponding FPC for truck WXM 987 GP. This truck is also a middle to long distance delivery truck travelling up to 360Km per day with a longer running time in between the stops. This gives a much better study of the FPC effect on fuel consumption than truck 1.

A considerable variation was noticed when truck 2 was dosed with FPC giving more mileage per same amount of fuel filled up as for truck 1. This effect is observed from destinations of 220Km and onwards on figure 2. The FPC dosed diesel curve is below the undosed diesel curve from 220Km onwards. When applying numerical analysis or basic calculus, the percentage difference between the areas below the curves from an interval of 220-360Km, a 27.86 cumulative reduction in diesel refill litres was obtained during the test period of 5 months.

It can be concluded from the two curves that, truck 2 recorded more mileage when dosed with the FPC while using less diesel as compared to the undosed diesel study. A similar study was carried out by Edward A. Hirs [4] and co-workers for a bus fleet in Bahrain to test in six vehicles over a period of about eight weeks.

In their study, the six vehicles gave a range of 2.9% to +19.7% reductions in fuel consumption [4]. According to the results for truck 2, when the collected control data was compared to the experimental data the following observations could be made:

- For short distances, the dosed diesel test had higher fuel consumption than the undosed diesel test prevalent at the initial stages of the field study and this is a result of the factors discussed in the previous sections of this paper.
- For middle and longer distances, a 27.86 cumulative reduction in diesel refill litres was obtained during the test period of 5 months. This meant that the FPC improved the mileage potential of this truck while consuming less diesel and this is a desired result. The projections in figure 3 indicate a 4.3% fuel consumption reduction when a substantial and uninterrupted mileage is accumulated during operations. In his studies, Valentine et al. [17] studied the effects of bimetallic Pt/Ce catalyst on the engine performance when fuelled with diesel dosed with 4-8 ppm of the active metals and achieved 5-7% improvement in fuel economy. The study done by Keisken et al [14] has shown maximum reduction ratios of 3.1% and 2.0% for fuel consumption when using Mn and Mg based catalysts on the performance of diesel engines at the metal to fuel dosage ratio of 8 μmol/L and 16μmol/L respectively.

4. Conclusion

Due to increased fuel costs in South Africa and all around the globe in general, countless efforts have been made in an attempt to develop cleaner and more efficient diesel applications. Fuel consumption in any automobile is the absolute derivative of countless uncontrolled variables. These were discussed in the previous sections but for this study, variations in driver behaviour, inconsistent loads, changes in routes, runtimes and traffic volume posed a great challenge during the field tests.This study has investigated numerically the influence of a fuel performance catalyst (FPC) through a field test method in two diesel trucks within the business environments of a Johannesburg based company called Premium Packaging Pty Ltd with the aim of creating seamless ‘Green fleet’ solutions by reducing fuel consumption. Power trend equations used to model the diesel consumption relative to accumulated mileage gave useful projections, which played a significant part in the analysis performed. Linear trend equations were used to model the absolute diesel consumption or diesel refill after every shift relative to distance travelled.On overall, the results show that an opportunity exists for Premier Packaging, if truck 2 (WXM 987 GP) is representative of the median population in their truck fleet, to achieve an average general diesel consumption of 24L/100km within 12 months, compared to baseline performance of 27L/100km prevalent at the beginning of FPC dosing implementation as depicted by figure 2 which is within 95% prediction interval. This improvement of 3L/100km represents 11% reduction in fuel cost impact year-on-year. For local trips, there exist an opportunity exists for Premier Packaging, if truck 1 (VRH 060 GP) is representative of the median population in their truck fleet. To achieve an average general diesel consumption of 22L/100km within 12 months compared to baseline performance of 22.1L/100km prevalent at the beginning of FPC dosing implementation as depicted by figure 2, which is within 95% prediction interval. This improvement of 0.1L/100km represents 0.6% reduction in fuel cost impact year-on-year.

A statistical analysis using ANOVA was used by an independent analyst on the same collected data set and it confirmed that the observed differences in fuel reduction when dosing the fuel with FPC and when not dosing FPC were statistically similar though not exact because of the outlier that were either included or omitted, confirming that FPC significantly reduces fuel consumption.

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