

Effect of Fischer-Tropsch Diesel on Fuel Supply System

Masachika Masuko, Yoriko Sakamoto, Nobuhiro Okabe
Showa Shell Sekiyu K.K.

Noboru Uchida
Hino Motors,Ltd

Koji Kitano, Ichiro Sakata
TOYOTA MOTOR CORPORATION

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ABSTRACT

This paper investigates the effects of Fischer-Tropsch Diesel (FTD) (a completely a paraffinic fuel) on the fuel supply system in automotive applications. In particular, the effects of Gas to Liquid (GTL) (an FTD synthesized from natural gas) on the elastomer components has been investigated by laboratory scale tests and field trials. In the field trials, GTL was supplied to a commercial vehicle operator and the effect of real running conditions was observed. Also, the laboratory scale testing to simulate the actual condition of usage of a commercial vehicle was conducted under stringent conditions, and a correlation with the field trials was investigated. As a result, no negative effects related to GTL were found.

INTRODUCTION

With the globally increasing energy demand and the need for energy security, many kinds of energy and fuel need to be considered. In the case of diesel fuel for automotive engines, many alternative fuels are being discussed as possibly commercially viable. Fischer-Tropsch Diesel (FTD) is one commercially viable option. FTD is the fuel synthesized from synthesis gas (CO, H₂) by the Fischer-Tropsch (F-T) process. Through F-T process, similar fuel characteristics can be made from various feedstocks, including Gas (GTL) and Biomass (BTL). In this work, GTL synthesized from synthesis gas that was derived from natural gas was used as a test fuel. FTD including GTL is a clean fuel because of its many advantages including high cetane number, and no sulfur or polycyclic aromatic hydrocarbon (PAH) content, which contribute to the formation of particulate matter. Therefore, because GTL fuel is seen as one option to reducing the exhaust emissions from diesel engines, considerable research related to GTL has been carried out. Examples include, how the characteristics of GTL effect exhaust emissions, and the development of diesel engines and their

after-treatment systems that can utilize the benefits of GTL. [1-8]

As GTL is a completely paraffinic fuel as previously explained, it contains no aromatics or sulfur, this is the key difference from conventional Automotive Gas Oil (AGO). So when it is used as an automotive fuel there is a possibility it may have an impact on components in the fuel system in the vehicle.

Recently, high-pressure fuel injection systems have been introduced to diesel engines to reduce the exhaust emissions. High injection pressures are now around 200MPa, forcing fuel temperatures higher to around 100deg-C. Therefore, especially in the returning fuel hose from the injector, the difference between GTL and conventional gas oil needs to be understood under these more severe conditions. The lack of aromatic content in GTL fuels raises particular concern for elastomer compatibility in the minds of OEMs and fuel injector equipment manufacturers.

The object of the present study is to investigate the effect of GTL on elastomer components in the vehicle. In this study, fundamental compatibility tests were conducted initially. Then, field trials with two types of commercial vehicle, trucks and buses were carried out. These vehicles types were selected as they have their engines located at the front and rear respectively, providing two vehicles with different fuel temperature conditions. Finally, the accelerated laboratory scale testing to simulate the actual vehicle environment was conducted to investigate a correlation with the field trials.

TEST FUEL PROPERTIES

Table 1 shows the typical properties of GTL and AGO used in this test programme. GTL has a lower density and higher cetane number than AGO due to its paraffinic nature.

Table 1. Typical properties of GTL and conventional gas oil (AGO) used in this test

		GTL	AGO
Density@15deg-C	g/cm ³	0.776	0.835
Viscosity@30deg-C	mm ² /s	2.949	3.926
Flash point	deg-C	89.5	68.5
Pour point	deg-C	-22.5	-12.5
CFPP	deg-C	-21.0	-8.0
Distillation			
IBP	deg-C	205.0	168.5
T10	deg-C	224.5	217.0
T50	deg-C	260.0	286.5
T90	deg-C	299.0	341.0
EP	deg-C	310.5	368.5
Cetane number		83.7	56.4
Sulfur	mg/kg	<1	6
Aromatics	Vol%	<1	19.7
Gross heating value	MJ/kg	46.62	45.79

FUNDAMENTAL STUDY OF ELASTOMER COMPATIBILITY

For the first step, to investigate the effects of GTL on the physical properties of elastomer components used in vehicles, a simple material soak test was conducted. The tested materials were as follows: nitrile-butadiene rubber (NBR), hydrogenated nitrile-butadiene rubber (HNBR) and fluorine-containing rubber (FKM). These were selected as they are commonly used for the components in the fuel system, mainly fuel hoses and O-rings.

TEST METHOD

The test was conducted in reference to JIS K 6251. The elastomer components were shaped into a standard dumbbell (Figure 1) and were soaked in GTL and AGO. The three elastomer components (NBR, HNBR, FKM) were soaked as per the test conditions shown in Table 2. After soaking for 1008 hours, the 5 properties shown below were measured.

- Change ratio in tensile strength
- Change ratio in elongation
- Change ratio in hardness
- Volume change
- Weight change

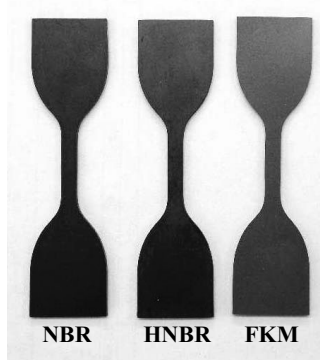


Figure1. Dumbbells for elastomer test

Table 2. Test condition for elastomer compatibility test

Type of elastomer		NBR	HNBR	FKM
Temperature	55 deg-C	○	-	-
	85 deg-C	○	○	○
	120 deg-C	-	○	○

TEST RESULTS

Figure 2 shows for all of the samples, the change ratio of the 5 properties after soaking for 1008 hours compared with before soaking. The hardness measure indicates that the rubber is hardened when it increases and softened when it decreases.

FKM shows small differences between GTL and AGO in each of the properties, even when it was soaked at a higher temperatures.

NBR also shows small differences in tensile strength and elongation. However, greater differences were observed in volume and weight. With AGO, both volume and weight increased, but when soaked in GTL there was not so much a difference in volume, though a decrease in weight was observed. Also, NBR became hardened when it was soaked in GTL at relatively higher temperatures.

The tendency for HNBR to decrease volume and weight and increase hardness when soaked in GTL was demonstrated, but these effects were reduced when soaked in AGO.

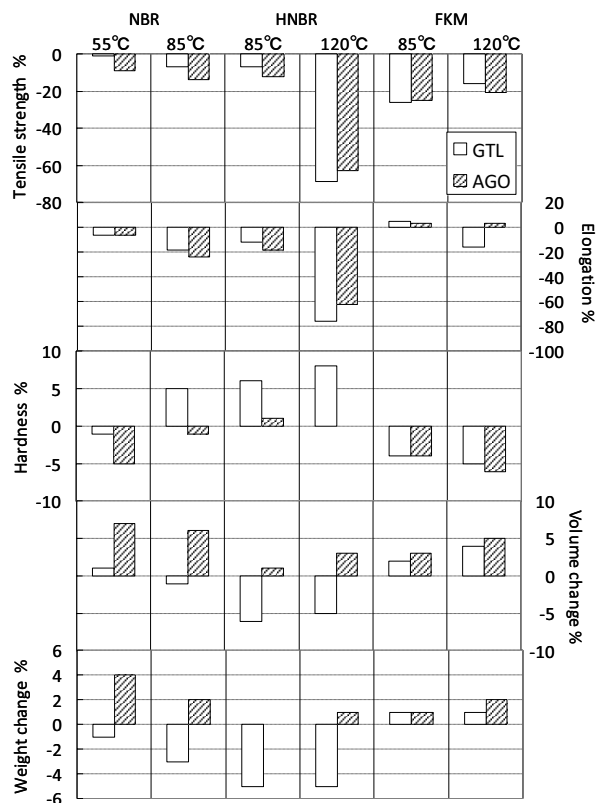


Figure 2. Results of material compatibility test soaked in GTL and AGO for 1008h

From these results it is clear that the changes in volume and hardness have the potential to affect the practical performance of sealing components such as O-rings and the flexibility of fuel hoses. To investigate whether these potential issues occur in practice, field trials and laboratory scale tests with real vehicle components were conducted.

FIELD TRIAL TEST

To see the effect in an actual operation environment, a field trial was conducted. In this trial, two types of test commercial vehicle (truck and bus) were used to see the effect of their different fuel temperature conditions due to engine configuration as described previously. Generally, trucks and some minibuses have their engines located in the front of the vehicle, when using common-rail injection systems the fuel return temperature can increase up to 80deg-C if the fuel is injected under high pressure. On the other hand, city-buses have their engines located on the rear of the vehicle where the fuel temperature can rise to around 100deg-C, as it is difficult to be cooled by airflow from the forward movement of the vehicle.

TRUCK FIELD TRIAL

In the truck field trial, two vehicles were prepared to run under different operating conditions. Test vehicle A ran on the highway for 450 to 500 km per day to see the effect of high duty operations. Test vehicle B ran under city traffic conditions, connecting 6 points for 100 to 300 km per day to see the effect of operating under partial load conditions, due to the stop and start operation. At the start of this trial, the GTL filling station was installed, providing only GTL. This trial was conducted for 3 months. Figure 3 shows the driving routes of the field trial.

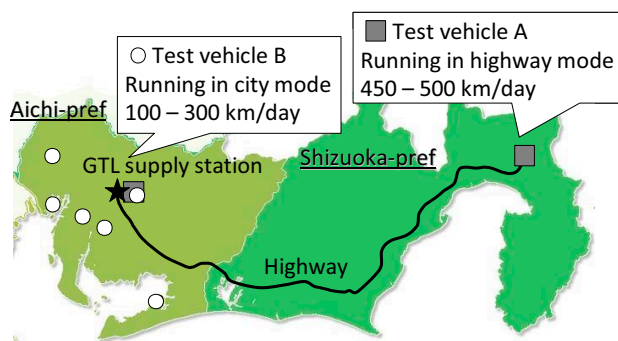


Figure 3. Driving routes of field trial

The specifications of the test vehicles are shown in Table 3, the trucks were manufactured by Hino. The test vehicles had 7 and 8 years of use before this trial; all components of the fuel system on the test vehicles were changed to new ones before the trial. After the trial the properties of fuel hoses were investigated.

As a result, the total running distance of each vehicle was 22797km (Test vehicle A) and 10036km (Test Vehicle B). Through this trial, no problems derived from the fuel, such as fuel leakage was found. Also

there were no changes in the surface of the hoses or condition of the injectors.

Table 3. Specification of test vehicle

	Test Vehicle A	Test Vehicle B
Test car	Hino Ranger	
Registered year	2001	2000
Engine type	J08C	
Displacement	7.96 L	
Intake system	Turbocharger with intercooler	
Fuel injection system	Common rail system	
Fuel tank volume	400 L	
Emission regulation	Long term regulation	
Total running distance	22797 km	10036 km

BUS FIELD TRIAL

The city-bus field trial was conducted to see the difference in effects between GTL and AGO on the fuel system. Figure 4 shows one of the buses used in this trial, the bus is a new hybrid bus made by Hino with a 7.7L engine. Four buses were prepared for this trial, in which two buses ran on GTL and the other two ran on AGO. To see the long-term effect on fuel hoses this trial was conducted for one year. Also, by conducting through one year, it was possible to see any changes due to seasonal effects. The four test vehicles were inspected every six months. At the first 6 month inspection the fuel hose elongation of one GTL and one AGO bus was analyzed; after 12 months the fuel hoses of the remaining buses were inspected. Through this trial, the total running distance of the test vehicles reached over 30000km. At the end of the one-year field trial no problems in the fuel systems occurred, especially the O-rings and fuel injectors. This trial also showed that whilst operating under relatively high temperatures, no detrimental effects due to GTL on the fuel system were observed.



Figure 4. The picture of tested city-bus

Figure 5 shows the elongation of the fuel hoses analyzed at the 6 month and 12 month inspections. The elongation at the 6 month inspection showed no difference between GTL and AGO. At the 12 month