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Evaluation of the Economic and environmental benefits of mineral oil used in Bi-fuel engines (Gasoline-compressed natural gas)

Mhd Maher Kallas*[1], Thaer Sallam[1], Younes Saoud[2]

[1]Automobiles & Heavy Machines engineering Department-Faculty of Mechanical & Electrical Engineering - Damascus University- Syria
[2]Higher institute for science & technology- Damascus- Syria

Abstract: Engine oil is very important for engine life and operation. therefore, determining investment period (IP) of oil is useful in minimizing production and harmful wastes cost.
Natural gas (NG) maximizes oil drain intervals (ODI) and reduces toxic gas components caused by internal combustion engine (ICE). In addition, it is available in Syria and could be used as vehicle's fuel.
This research includes laboratory tests and field trails to determine ODI for Syrian mineral oil API SAE 40/ CF used in gasoline engine when operated on compressed natural gas (CNG).
Several used oil samples have been taken from three Bi-fuel vehicles operating at a petroleum field. Each sample was analyzed to monitor change in the physical and chemical properties of the oils, additive depletion and accumulation of contaminants. Used oil analysis (UOA): Kinematic viscosity, total acid number (TAN), total base number (TBN), flash point, antioxidant and anti-wear additives were performed in tribology laboratory.
UOA results were used to determine IP for gasoline engine operated on CNG. ODI of (18000 km) were obtained in comparison with original intervals (7500 km) recommended when oil used in gasoline engines. ODI is extended more than two times. These results will affect economy and environment positively. It reduces the cost of engine oil drain, quantities of new oils and used oils wastes by nearly two times.
Key word: Compressed natural gas (CNG), mineral engine oil, used oil analysis (UOA), oil drain intervals (ODI), internal combustion engine (ICE).

Introduction

The global has been aimed continuously to use alternatives instead of traditional fuels in generators and various combustion engines. That highlighted the gaseous fuel as the most important candidate substitute. It reduces polluting emissions from gaseous fuel in comparison with other types of fuel.

Investment period (IP) for internal combustion engine (ICE) mineral oil means the best oil drain intervals (ODI), which is the longest mileage vehicles passed after using a new oil without noticeable changes in its properties[1].

The operational life and reliability of internal combustion engines are limited by the breakdown of the engine components due to wear under boundary lubricated conditions. It is very advantageous to know the condition of an engine and its components without disassembling the engine for examination. This paper employs the chemical and physical analysis of used API SAE 40/ CF crankcase oil to predict the condition of the lubricant and engine wear components during continuous operation.

Previous research has been conducted on the same mineral oil in an internal combustion engines run on gasoline and diesel fuel, the optimum oil drain interval for a API SAE 40/ CF was found to be 7,500 km [1].

A study by the American oil industry AMSOIL explained that oil drain intervals is 20,800 km of several types of synthetic engine oils recommended by engine manufacturers. we can compare our results with this result [2].

It is worth mentioning that half a gallon of mineral oil can be obtained from a barrel of crude oil which is relatively small quantity compared to other crude's products [3]. That gives great importance to this research.

This research concentrate on using compressed natural gas (CNG) and mineral engine oil to obtain the best oil drain intervals (ODI).

Materials

Compressed natural gas (CNG)

CNG has been used as an internal combustion engines fuel for decades. CNG engines, in most cases, have been used in stationary applications for power generation. More recently, CNG has found its way into mobile applications. Locally operating fleets, such as city bus fleets, have shown a lot of interest in CNG. Bus fleets operate most of the time in urban areas, where lower emission levels are mandated, and the operation allows the busses to return to a central refueling station on a daily basis. It is used as fuel in the transport sector since the thirties of the last century, it spread as natural gas vehicles (NGVS)in about 65 countries around the world. large numbers of vehicles using CNG were estimated around 17.25 million[4].

In this research, Syrian compressed natural gas was used from Jbeseh's petroleum field in Hasakah which is the most recommended for use as fuel in ICE [5].

Mineral engine oil

Recently, oils and lubricants are much better than ones used several years ago. The deterioration of oil are caused by many factors such as heat, friction, chemical contamination, and oxidation. In recent years the petroleum companies, working hand-in-hand with carmakers, have developed stronger additive packages to produce new types and categories of oils which extended Oil drain intervals, so oil can withstand tougher conditions.

The chemical additives are added with certain proportions into base oils to improve properties or impart new properties which were not present there. The proportion of these chemical additions is about (15 – 25) %.

In this research, we adopted Syrian engine oil API SAE 40/ CF. It is recommended when the engine operated with compressed natural gas [6].

Experimental

Research methods

This research depended on the experimental method of field trials vehicles and laboratory processes by travel vehicles thousands mileage. Oil samples were taken from engines which operated on mineral oil API SAE 40/ CF and compressed natural gas. Then, laboratory tests performed to obtain the oil drain intervals (ODI). Each sample was analyzed to monitor additives depletion, accumulation of contaminants, and change in the physical and chemical properties of the oils. The resulted values were compared with previously scheduled (7500 km) when engine operates on gasoline and diesel [1].

Tests' Research & Equipment

Oil analysis is a set of laboratory tests performed to evaluate the condition of oil and engine's parts. Primarily, this is possible because of the cause-and-effect relationship may be known by studying the samples.

Engine oil tests

1- Kinematic viscosity

Viscosity is one of the most important properties of lubricating oil. Viscosity is a measurement of resistance to flow at a specific temperature in relation to time. The two most common temperatures for lubricating oil viscosity are 40°C and 100°C. Viscosity is normally evaluated with a kinematic method and reported in centistokes(cSt). It is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. In used oil analysis, the used oil's viscosity is compared to that of the new oil to determine whether excessive thinning or thickening has occurred.

2- Total Base Number TBN

The total base number is an expression of the amount of alkaline additives in the oil that are capable of neutralizing the acid products of combustion. A new oil starts with the highest TBN it will possess. During the time, the TBN decreases as the alkaline additives neutralize acids. TBN is an essential element in the establishment of oil drain intervals since it indicates whether the additives are still capable of providing sufficient engine protection.

3- Total Acid Number TAN

The total acid number is the quantity of acid or acid-like constituents in the oil. An increase in TAN from that of the new oil should be monitored. The TAN of a new oil is not necessarily zero since oil additives can be acidic in nature. Increases in TAN usually indicate lube oxidation or contamination with water or an acidic product. TAN is an indicator of oil serviceability.

4- Flash point

Flash point is an important property for any oil. It is the temperature at which it will ignite when exposed to a flame or a spark. Flash point varies inversely with the 0ill's volatility.

During this experiment, the degree of flash and ignition for each petroleum products that have a twinkle above the 79 °C and under 400 °C, using a manual-Cleveland open-cup.

5 - Antioxidant and anti-wear

Lubricating oil in engines and other Components combines with available Oxygen under certain conditions to Form harmful by-products. Heat, pressure, and catalyst materials accelerate the oxidation process. By products of oxidation form varnish and sludge deposits, corrode metal parts and thicken oil beyond disability to lubricate. Most lubricants contain additives that retard the oxidation process. Infrared analysis offers a direct mean of measuring the level of oxidation in oil. Note: Anew oil reference is required for accurate measurement of oxidation. Zinc Dialkyl Dithiophosphate (ZDDP) is an important engine oil additive, which is an indicator of the level of anti-oxidant and anti-wear additives in the oil. ZDDP decomposes into constituents which have better properties to reduce friction, wear and oxidation [7].

Equipment

Table 1. below contains information about instruments used in this study:

Table1.Tests instruments

Equipment	Type	Manufacturer	Tests	Method
Viscometer	Manual/ Ostwald	Cannon/Fenske	Kinematic viscosity at 40◦C & 100◦C	ASTM D445
Potentiometer	Automatic	Metrohm	Total Base Number (TBN)	ASTM D 2896
			Total Acid Number (TAN)	ASTM D664
infrared spectrometer	Galaxy series 5000	Unicam	Anti-wear and anti-oxidant additive percentage (ZDDP)	instrument manufacturer's instructions
Cleveland open cup flash point test meter	Manual/Cleveland Open Cup	SUR-Berlin	flash point	ASTM D 92

Field trials plan

we adopted the following procedure:

1. Selection and preparation of research vehicles in good technical engine condition operating on compressed natural gas CNG, namely:

   Wagon Nissan
   Wagon Toyota Land cruiser
   Wagon Isuzu

2. Selection of mineral engine oil API SAE 40/ CF, which is the one recommended oil when engines operate on compressed natural gas CNG under heavy duty conditions.
3. performing laboratory analysis of the new oil (zero sample).
4. taking oil samples from the field vehicles after frequent distances.
5. Making six laboratory analyzes for each oil sample (kinetic viscosity at 40 °C and 100 °C, TBN,TAN, anti-wear and anti-oxidant (ZDDP) and flash point).
6. engine oil samples were tested periodically every few thousands kilometers.

Adopted allowed precautionary limits of oil analysis to evaluate results are illustrated in table 2 [8].

Table 2. precautionary values adopted criterion for the validity of oil

Series	Specifications	allowed precautionary limits
1	Kinematic viscosity at two degrees 40◦C & 100◦C	± 35%
2	Total Base Number (TBN)	< (2)
3	Total Acid Number (TAN)	> (7)
4	Anti-wear and oxidation (ZDDP)	decrease until peak disappearance

Results and discussion

1- kinetic viscosity curves:

The curves above illustrate that viscosity fluctuate towards increasing for all field trail vehicles and remain within accepted precautionary limits. The reason for this behavior that viscosity change is a result of many different factors and conditions of engine. Alkaline and antioxidant additives deplete in oil with time allowing the oxidation, polymerization and the disintegration of oil and formation of acids so viscosity increases, oil thicken. On the other hand, polymeric additives expose to shearing as a result of stress, thereby viscosity decrease. Therefore, The resultant viscosity may increase, decrease or may cancel out.

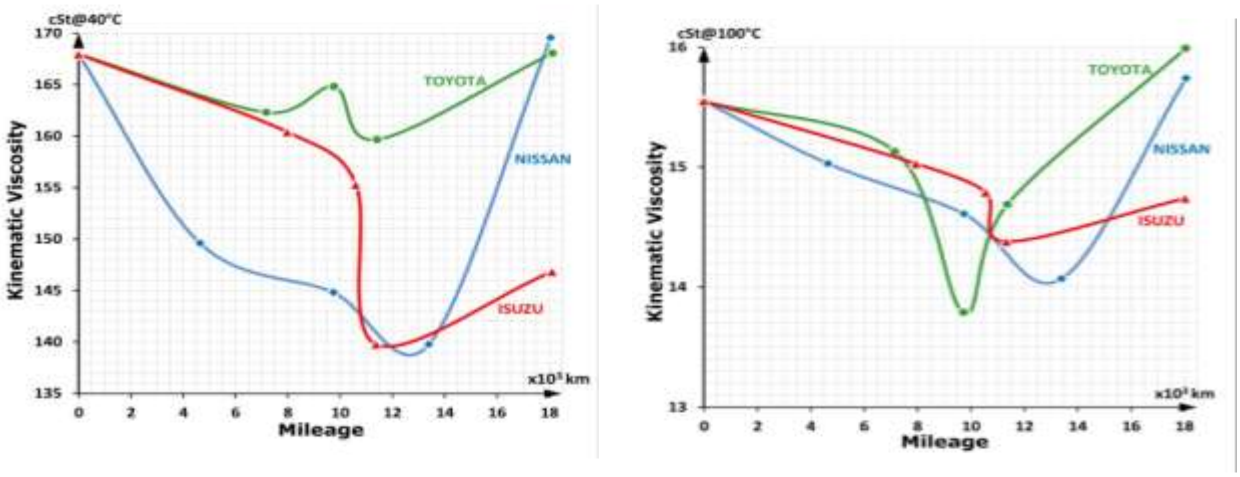

Figure 1. The variation of kinematic viscosity(cSt) with traveled distance (Km)

2-Total Base Number (TBN) curves:

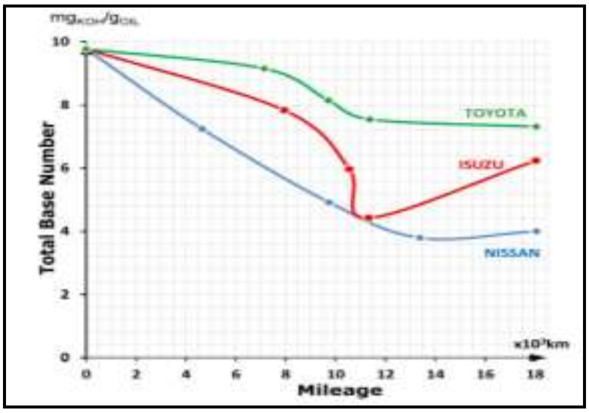

Figure 2. The variation of total base number (mgkoh / goil) with traveled distance (Km)

The figure shows decreasing total base number TBN with traveled distance, which starts at high value of the new oil at (9.66 mgkoh / goil) which expresses the amount of alkaline additives in the oil to neutralize the acidic products formed during operation, These products will reduce the alkalinity additives percentage in the oil as indicated by decrease of TBN to (4mgkoh / goil). It remains at the allowed precautionary values.

3- Total Acid Number (TAN) curves:

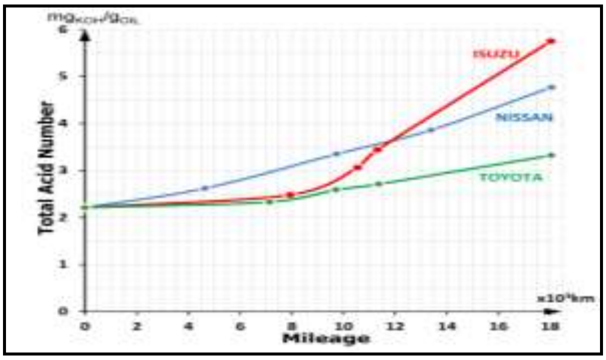

Figure 3. The variation of total acid number (mgkoh / goil) with traveled distance (Km)

We note from curves increasing in the total acid number (TAN) for all analysis results. It starts from low value of the new oil (sample zero) which is estimated (2.21 mgkoh/ goil), then gradual rise with traveled distance to reach the highest value (5.83 mgkoh/ goil). These values remain less than the precautionary value of total acid number. This increasing occurs from formed acids in the oil by engine heat, pollution of oil through the ventilation crankcase, exhaust gas and sulfur leaks into combustion chamber. These would lead to oxidation, wear and corrosion of metal parts and oil thickness.

4- Flash point curves:

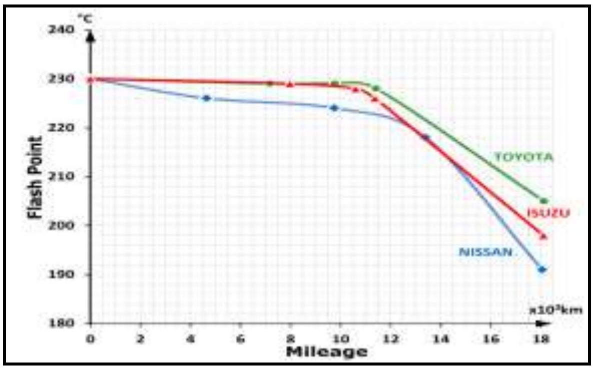

Figure 4. The variation of flash point (˚C) with traveled distance (Km)

Flash point gradually decreases slightly and within acceptable limits which indicates there is no fuel leakage into engine lubricant.

5- Antioxidant and anti-wear additives curves:

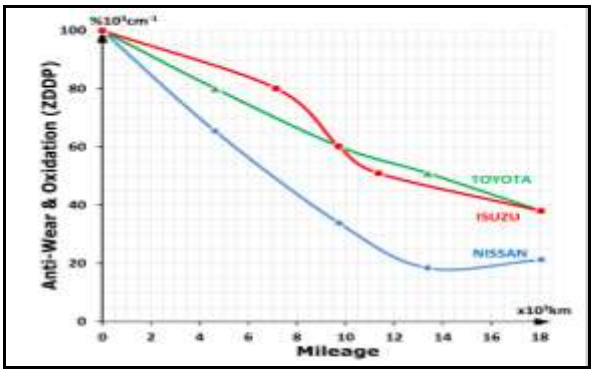

Figure 5. The depletion of antioxidant and anti-wear additives (%) with traveled distance (Km)

The results of infrared spectroscopy refers to the depletion of oxidation and anti-wear additives ZDDP in oil. But it is acceptable, permitted and normal for all field trail vehicles and allowed precautionary adopted value. The new zero-oil sample is the primary reference to compare the oil oxidation. The decline and depletion of anti-oxidant and anti-wear additives lead to increase in oil oxidation and increases the viscosity, form the varnish, mud and resins on the engine parts such as piston rings ,crankshaft, camshaft and axes bearings.

Conclusion

1. Used oil analysis (UOA) results were used for API SAE 40/ CF to determine investment period (IP) for gasoline engine when operated with compressed natural gas (CNG). IP of (18000 km) were obtained in comparison with original intervals (7500 km) recommended when oil used in gasoline engines.
2. Oil drain intervals (ODI) is extended more than two times. These results will affect economy and environment positively.
3. It reduces less than two times the cost of engine oil change, quantities of new oils and used oils wastes.
4. Natural gas (NG) maximizes ODI and reduces toxic gas components caused by internal combustion engine (ICE).

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Abbreviations

API : The American petroleum institute, ASTM: American society for testing and materials,
Bi-fue l: Bivalent fuel, CNG: compressed natural gas, ICE: internal combustion engine,
IP : investment period, NG: Natural gas, NGVS: Natural gas vehicles, ODI: Oil drain intervals,
SAE : Society automobile engineers, TAN: Total acid number, TBN: Total base number,
UOA : Used oil analysis, ZDDP: Zinc Dialkyl Dithiophosphate.

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