

Preliminary results on nano-diamond and nano-graphite testing as additive for an engine lubrication oil

D Moldovanu¹, A Molea¹ and I Barabás¹

¹Technical University of Cluj-Napoca, Automotive Engineering and Transports Department, Bd. Muncii 103-105, Cluj-Napoca, Romania
Corresponding author: andrea.molea@auto.utcluj.ro

Abstract. An important amount of the fuel energy burned in an internal combustion engine is used to overcome the friction losses inside the engine. Developing advanced lubricants is one of the ways to improve the fuel efficiency and reducing the pollution caused by internal combustion engines. This paper presents tests done with 1% v/v nano-diamond and nano-graphite additives in engine oils, with bench tests on an air-cooled spark ignition engine (Honda GX 160) with a displacement of 118 cubic centimeters. Using the raw lubrication oil laboratory, tests were done to determine the viscosity, density and viscosity index using an Anton Paar SVM 3000 viscometer in comparison to the oil with nano-diamond and nano-graphite additives. The tests also revealed an average reduction in fuel consumption of 21% for the single cylinder engine in case of the oil with additives, for the entire speed range of the engine, showing a decrease of the fuel efficiency as the speed increases. The temperature of the exhaust manifold, outer side of the cylinder and the temperature of the oil pan were measured. By adding nano-diamond and nano-graphite additives to the lubricant oil, tests have revealed a reduction of the temperature of the exhaust manifold (with 11%), temperature on the outer side of the cylinder was reduced with 21% showing a clear friction reduction within the cylinder and piston-rings assembly. The temperature of the oil pan was reduced with 20%, showing a general reduction of the lubricating oil temperature which means a substantial reduction of the friction losses.

1. Introduction

An important amount of 33% of the fuel energy is used to overcome the friction losses in the car from which 35% is used to overcome the friction in the engine system. From this 12% of fuel energy, 45% is consumed in the piston assembly, 30% is consumed in bearings, seals, etc. (hydrodynamic lubrication), 15% is consumed in the valve train (mixed lubrication), and 10% is consumed by pumping and hydraulic viscous losses [1]. The less friction in the internal combustion engine the better fuel efficiency and less pollutant emission. The friction can be reduced using high performance engine oils.

Modern oils for internal combustion engines consist of a base oil (synthetic or semisynthetic) and an additive pack which could have a concentration up to 30-35% vol and it contains surface protective additives (anti-wear, corrosion and rust inhibitor, detergent, dispersant, friction modifier agents), oil performance improver additives (pour point depressant, seal swell agent, viscosity improver agents) and lubricant protective additives (anti-foaming, anti-oxidant, metal deactivator agents) [2].

During the past few years, various nano-materials have been studied as a new additive for lubricant oils, including polymers, metals, organic and inorganic materials [3].

In [4] the authors have studied the anti-scuffing property of lubricating oil and diamond nano-particles additive. They found out that 3% vol concentration of the diamond nano-particles had the most favourable effect on reducing the wear loss and the friction coefficient. Raina and Anand [5] have investigated the nano-diamond in combination with copper oxide and hexagonal boron nitride particles



as an additive for poly-alpha-olefin. They observed a significant improvement in the lubrication properties of the base oil, the decrease of the friction coefficient was 15-25%.

Su et al. [6] have investigated the tribological properties of multi-walled carbon nanotubes with different sizes and volume fractions as an oil additive using a pin-on-disk friction and wear tester. They found that at 0.05% vol fraction the thin and short multi-walled carbon nanotubes could improve both friction-reducing and anti-wear properties of the oil more effectively than the thick and long multi-walled carbon nanotubes. Martorana et al. [7] have investigated the use of the dispersed fine graphite flake and carbon nanofiber in ethanol as a potential replacer of low pressure conventional hydraulic fluids in gear pump-driven hydraulic circuits. They found that both graphite and carbon nanofiber dispersions in ethanol within a concentration range of 195–1500 ppm can sustain hydraulic circuits with increases in pump efficiency.

Liu et al. [8] have conducted an investigation regarding the effects of nano-diamond additives in lubricating oil not only in a friction tester but also in a diesel engine. The authors ascertained a significant reduction of the friction coefficient of 30% and a slight increase on engine performances.

In our best knowledge the effect of the mixture of nano-diamond and nano-graphite as an additive for engine oil on the engine performances have not been investigated yet. The main goal of this article is to investigate the effect of this mixture on an internal combustion engine fuel consumption and friction.

2. Methodology

The test bench is presented in figure 1 and it consists of the internal combustion engine (I.C.E.) fitted with an external fuel tank, placed on an electronic scale (Gibertini Euromatic) to measure the fuel consumption. The speed of the engine was measured using an infrared tachometer (Lutron-DT 1236L), and the temperatures were measured with a digital infrared thermometer (ANENG AN550). For the Lutron-DT 1236L tachometer, the measurement range is 10 to 99999 rpm [9].

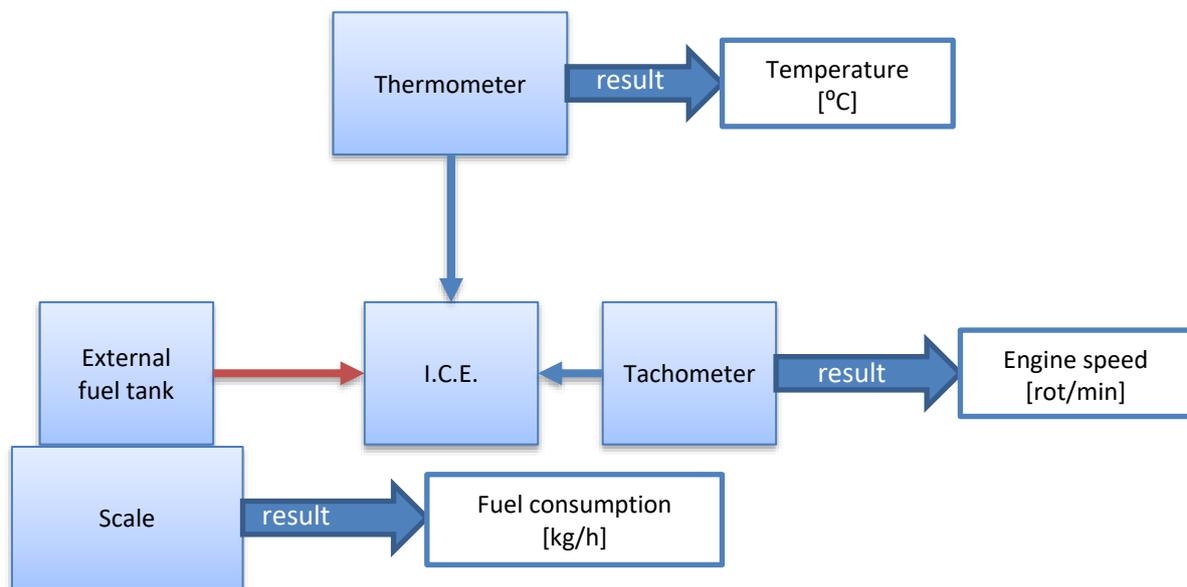


Figure 1. Used test bench sketch

The engine used for the tests was a Honda GX 160 single cylinder engine with the specifications presented in table 1.

Table 1. Honda GX 160 engine specifications.

Type	Single cylinder, 4 stroke
Displacement	163 cm ³
Bore x Stroke	68 x 45 mm
Max Power	3.6 kW @ 3600 rot/min
Max Torque	10.3 Nm @ 2500 rot/min
Cooling	Air cooled
Oil capacity	0.6 L
Fuel consumption	1.4 L/h @ 3600 rot/min

The used lubrication oil is Motul 5100 4T 10W-30, because it fulfils the API SL/SM standards. The standard properties of the lubrication oil are presented in table 2.

Table 2. Properties of Motul 5100 4T 10W-30.

Viscosity grade	SAE J 300	10W-30
Density at 20°C	ASTM D1298	0.871 g/cm ³
Viscosity at 40°C	ASTM D445	74.6 mm ² /s
Viscosity at 100°C	ASTM D445	11.5 mm ² /s
Viscosity index	ASTM D2270	147
Pour point limit	ASTM D97	-36°C
Flash point	ASTM D92	226°C
Total Base Number (TBN)	ASTM D2896	7.5 mg KOH/g

A commercially available ADDO nano-diamonds and nano-graphite particles, purchase from Plasma Chem, was used as additive. The additive contains 90% v/v motor oil and 10% v/v carbon nanoparticles, with an average of nano-particles size of 4-6 nm and this fulfils DIN EN ISO 6245 and DIN EN ISO 2160 standards. In order to prepare the oil with nano-diamonds and nano-graphite particles, a volume of 60 mL nano-additive was dispersed into 540 mL lubricant oil and the final concentration of the lubricant oil with additive was 1% v/v. The viscosity at 40°C and 100°C, viscosity index and density recorded with Stabinger viscometer SVM 3000 for the oil with nano-additive and the oil with nano-additives after used are presented in table 3.

Table 3. Properties of oil lubricant with nano-additives before and after use in engine.

Physicochemical properties	Oil with nano-additives before use	Oil with nano-additives after use
Density at 15°C	0.868 g/cm ³	0.867 g/cm ³
Viscosity at 40°C	62.175 mm ² /s	69.159 mm ² /s
Viscosity at 100°C	10.389 mm ² /s	11.178 mm ² /s
Viscosity index	156	154

The first test was done using as lubricant, only the Motul 5100 4T 10W-30 oil, with the engine speed variation from 1000 to 2500 rot/min in 100 rot/min steps, at zero load. The temperatures of the exhaust pipe (T_1 was chosen to monitor the temperature of the exhaust and therefore the fuel burn temperature loss), outer side of the cylinder (T_2 was chosen to evaluate the friction between the cylinder and the piston-rings assembly), exterior of the oil pan (T_3 was chosen to estimate the temperature of the lubricant itself) and the starter (T_4 was chosen as a reference temperature for the start of measurements) were measured, as seen in figure 2.

The second test was made using the same Motul 5100 4T 10W-30 oil, but with added nanomaterial additive (5 mL, the equivalent of 1%).

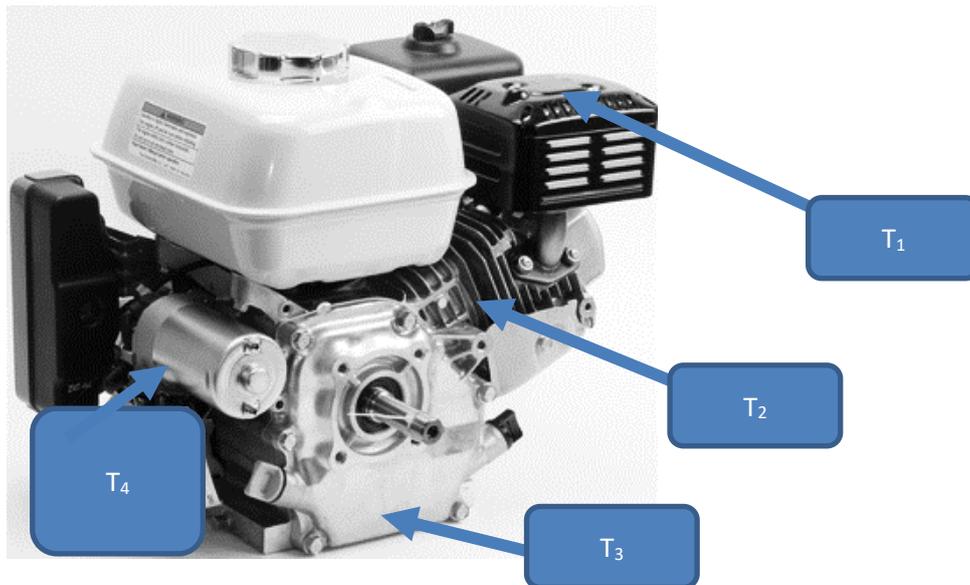


Figure 2. Measurements points for all temperatures

3. Results

First results that were extracted are the fuel consumptions for both tests, determined using the external fuel tank and scale. According with measurements, the variation of fuel consumption with speed presents a second order polynomial regression. The fuel consumption average (Fig. 3) when the oil lubricant with nano-additives was used (5.03 [kg/h]), decrease by 21% in comparison with the average of fuel consumption when the standard oil lubricant was used (7.11 [kg/h]). This reduction is extremely high, but it is logical due to the fact that the engine was tested at zero load, where the engine only has to overcome the internal frictions, and no outer load is applied. This leaves more room for further investigations using the same additive but with an engine that can be loaded accordingly.

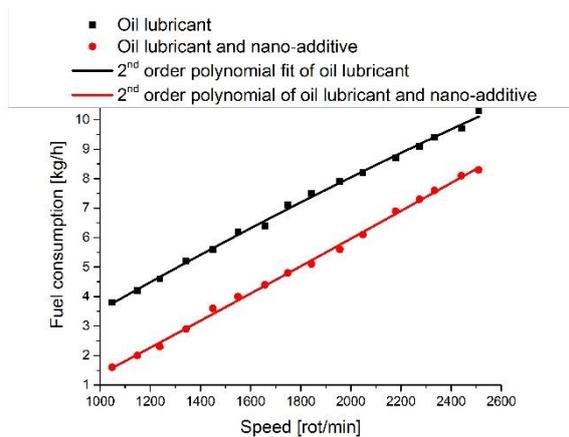


Figure 3. Fuel consumption versus speed

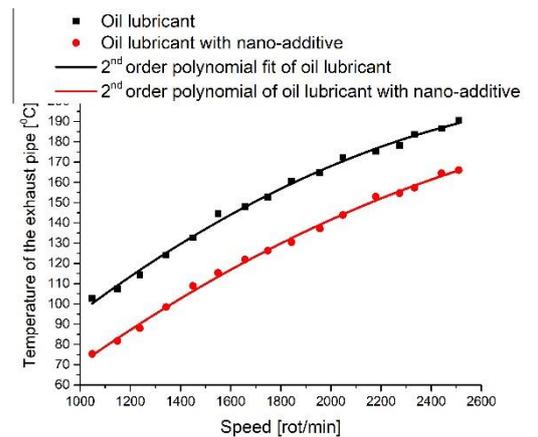


Figure 4. Temperature of the exhaust pipe versus speed

On the other hand, a reduction when nano-additives were used is explained through the viscosity index. The results showed that the viscosity index of the oil lubricant increases with 6% when nano-additives are used (Tab. 3), which influences the fluid friction due to the formation of a better viscous film on the surface, leading to a reduction of the frictional losses. This reduction of power losses further enhances the automotive engine efficiency and our results are in agreement with [10] and [11].

The results shown in figure 4 indicate the variation of the temperature of the exhaust pipe (T_1) with speed. An increase in temperature was observed for the oil lubricant with nano-additives. For the temperature of the exhaust pipe, an average value of 150°C was recorded for the standard lubricant oil while using the nano-additives, the average value of the temperature decreases to only 124°C , which indicates a better evolution of the temperature for the same testing time, i.e. better efficiency over time due to a lower friction coefficient.

The temperature of the outer side of the cylinder (T_2) also has second order polynomial variation, but the start temperature is around 45°C for the standard lubrication oil, and only around 37°C for the oil with nano-additive (Fig. 5). Due to the reduction of the frictions, the temperature of the outer side of the cylinder is reduced with 11% on the entire speed spectrum, when using nano-additives.

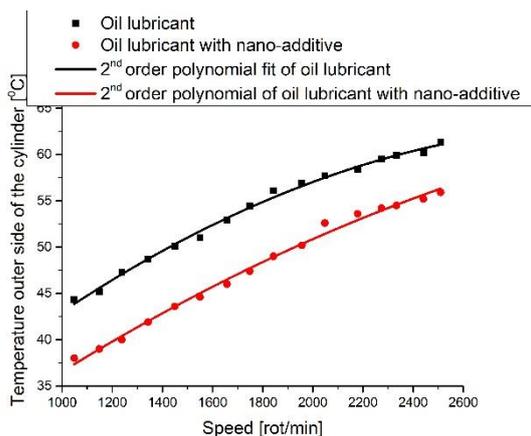


Figure 5. Temperature of the outer side of the cylinder versus speed

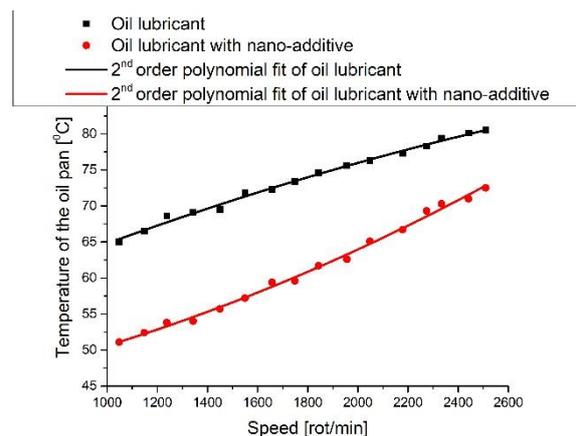


Figure 6. Temperature of the oil pan versus speed

Outside the oil pan (T_3), the temperature was monitored to understand the variation of the lubrication oil for both cases. By using the nano-additives instead of reaching an average value of 71°C , a value of 59°C was reached (Fig. 6) underlining the friction reduction with 20%.

4. Conclusions

The measurements were done with the increase of the speed at precise time intervals, with the same starting temperature of 25°C for the starter (neutral reference temperature zone).

Based on the present experimental investigations, the following conclusions can be drawn:

- ✓ by using nano-additives in the lubrication oil, an improvement of the physicochemical properties was observed, especially because of the decreasing of the viscosity and increasing of the viscosity index which lead to the formation of a better viscous film capable to reduce the frictions between the lubricated components;
- ✓ due to the reduced frictions, the fuel consumption was reduced by 21% at zero load;
- ✓ all the measured temperatures were reduced for the same exploitations of the engine.

Further investigations will be focused on loading the engine using a test bench, and the stabilization of the working temperature of the engine.

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