Energy Efficiency and Engine Oils

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Summary

The need to reduce greenhouse gases (GHG) such as CO2, as well as other environmental contaminants caused by vehicle tailpipes, become fundamental for humanity. The combinations that driver to a significant fuel economy in the automotive segment are too complex and based on several physical, economical and technological factors, however in this work we tried to isolate the variables aiming to demonstrate only the influence of the viscosity grade from the lubricant used in the internal combustion engine (ICE). We performed tests on a popular vehicle, which is representative in the Brazilian market, powered by an 1,000 cm^3 Otto engine, installed in a chassis dynamometer in an independent laboratory certified by INMETRO using the NBR 6601 and 7024 standards as reference, in urban and highway cycles, with engine oil in three different viscosities grades: SAE 5W-40, SAE 5W-30 and SAE 0W-20. To ensure only the viscosity change, these three fluids were blended with the same basic oil type and the same additive package, adjusting only the amount of viscosity modifier and the fractions of the base oils to meet the desired viscosity grade. The result showed that thinner oils reduce friction in the engine among its moving parts, reduce the pump losses and, therefore, an improvement on the fuel efficiency, as well as reduction in exhaust gas emissions. The results obtained in this study show that the fuel economy changing from a SAE 5W-40 oil to a SAE 5W-30 in this vehicle operating in this cycle was 0.91% and using the SAE 0W-20 fluid under the same conditions the reduction was 2.11%. The SAE 0W-20 viscosity grade proved a real benefit on hardware efficiency, helping on new environmental challenges and reducing the vehicle's operating cost to the end customer.

Introduction

To reduce the greenhouse gases, industry and the scientific community have been concerned to develop more efficient ways to obtain and to use the energy generated in the internal combustion engine, in addition to improve vehicle´s fuel efficiency. In those cases, considering both engine types Diesel and Otto, several studies show that by reducing friction between metal parts and using lower viscosity lubricants, fuel savings of up to 3% are possible, which is very significant considering the global fuel demand. According to the studies [1,2], in Japan since 2000 thinner viscosities become officially recognized like SAE 0W-20, SAE 0W-16 and currently SAE 0W-8. However, to qualify and recommend the use of products in these new viscosity grades, the durability of the equipment must not be compromised in detriment of fuel consumption. The lubricant film is physically the component that avoid and protect the metal to metal contact between the piston from the ring as well the piston ring against the cylinder wall, therefore, it is necessary in this component an in-depth research of the physicochemical elements that influence the tribological conditions of metallic friction that occurs in the combustion engines as done in the works [3,4,5].

1. Engine oil breakdown

Figure 1 below, shows the components that are used to produce an engines oil. The goal is to break the finish fluid into base oils that can be mineral and/or synthetic, additives and viscosity modifiers. The base oil proprieties are related to oxidation, evaporation loss, amount of saturates, sulphur content, solvency and viscosity index. The additives complement the base oil proprieties adding proprieties to meet the finish fluid requirements. These additional roles are related to wear protection, cleanness, improve or enhance the base oil performance, assuring the hardware durability neutralizing acids generated during the combustion process, keeping contaminants in suspension preventing sludge and deposits. The viscosity modifier helps on the lubricant flow, maintain the film and support the shear stress and minimize the viscosity changes with respect to temperature.

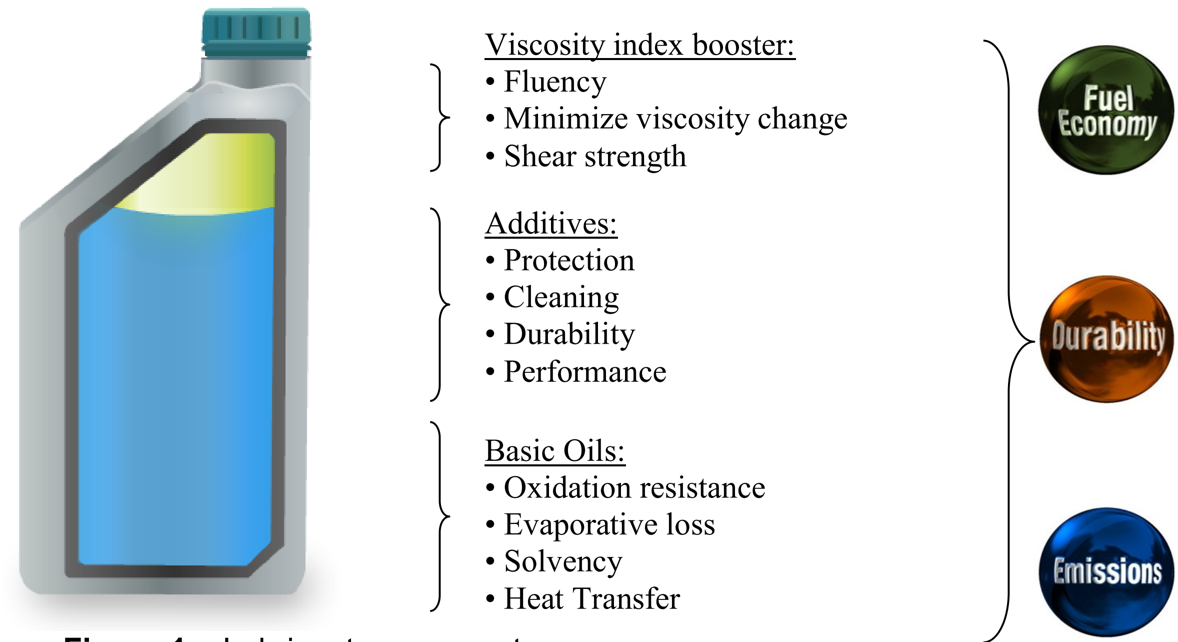


Figure 1 – Lubricant components

2. HTHS - High Temperature High Shear

Studies [3,4,5,6] carried out to evaluate fuel economy with the use of low-viscosity lubricants show that it is important to evaluate the capacity of this lubricant to avoid the momentary loss of viscosity when it is subjected to high temperatures and high shear rate. The result indicates the resistance that the fluid has to pass through regions with very strict tolerances, such as the moving and hot parts of an engine. The lower the HTHS number, the lower the lubricant viscosity grade. HTHS is measured according to ASTM D5481 or ASTM D4683.

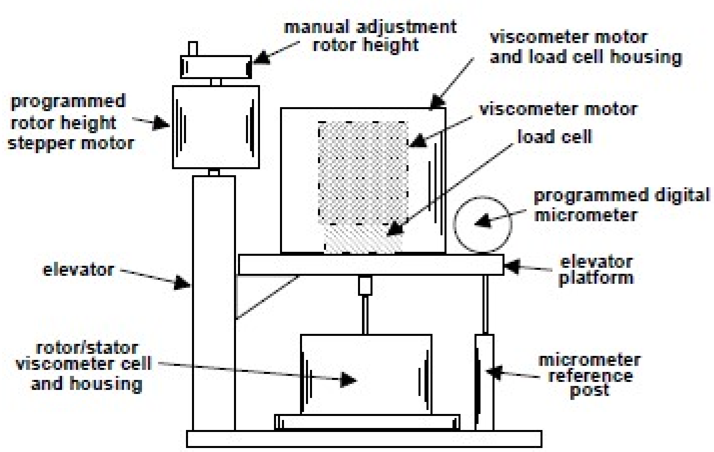


Figure 2 - Schematic sketch of ATBS Viscometer setup showing arrangement of stepper motor, elevator, rotor drive motor, in-line load cell, viscometer cell, and programmed digital micron [7,8]

3. Evaluation of fuel economy benefit with a low viscosity engine oil.

In this study it was used a vehicle powered by an Otto engine, 3 cylinders and 1,000 cm^3 displacement, submitted to a fuel consumption tests according to ABNT NBR 6601 and 7024 standards, using three different viscosity grades, in an independent and certified laboratory by INMETRO.
The tests were repeated three times with each lubricant to determine its influence on the fuel economy and emissions levels. Lubricant samples were collected for laboratory analysis before and after the tests. To avoid lubricant contamination, before each viscosity grade change, two flushes process were performed. The first process was based on a high detergent oil and the second was using the same lubricant that will be used in following tests. To improve even more the cleanness process, the oil filters were changed. The same batch of fuel was used as the reference gasoline E22 according to the ABNT NBR 8689 standard.

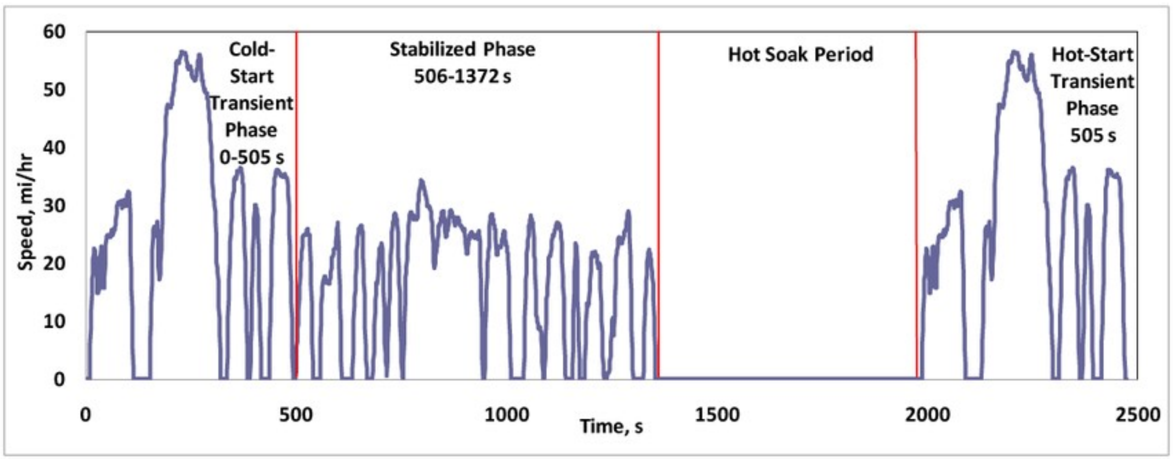


Figure 3 - Cycle pattern according to ABNT NBR 6601 and 7024 standards

The lubricants used in this study were formulated focusing only to achieve the viscosity grades, using the same base oils source, the same additive package and the same treatment rate. Despite using the same viscosity modifier, it was necessary to adjust the treatment rate as well the base oil balance to meet these different viscosities. It is important to mention that no friction modifier was added in these prototype fluids and it can be checked via infrared analysis by the Fourier transform technique as shown in figure 4.

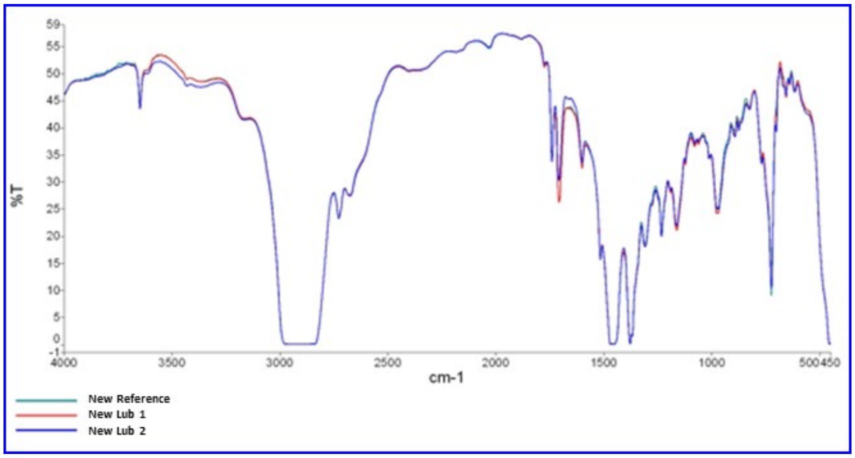


Figure 4 - Fourier transform infrared (FTIR) of the lubricants used in the XXW40 test reference sample, XXW30 Lub 1 sample and XXW20 Lub 2 sample.

The lubricants were named by Lub 1, Lub 2 and Reference. The base line lubricant or reference oil is a SAE 5W-40 which is officially qualified on API specification SN and ACEA A3/B4. The lubricants named by Lub 1 is a SAE 5W-30 and Lub 2 is a SAE 0W-20. Both are prototypes and they do not have any approval because they were blended only for this study.

Results and Discussions

During the test, it was not observed significant changes or impacts on the kinematic viscosity at 100ºC and/or in the HTHS before versus after test cycles according to ABNT NBR 6601 and NBR 7024. The samples analysis of new and used oil, as shown in figures 5 and 6 respectively.

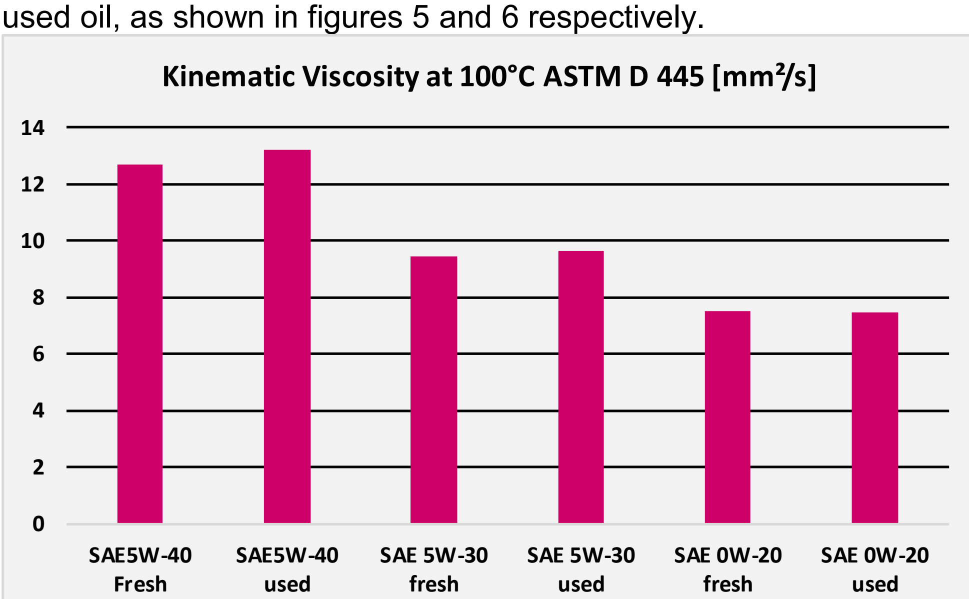
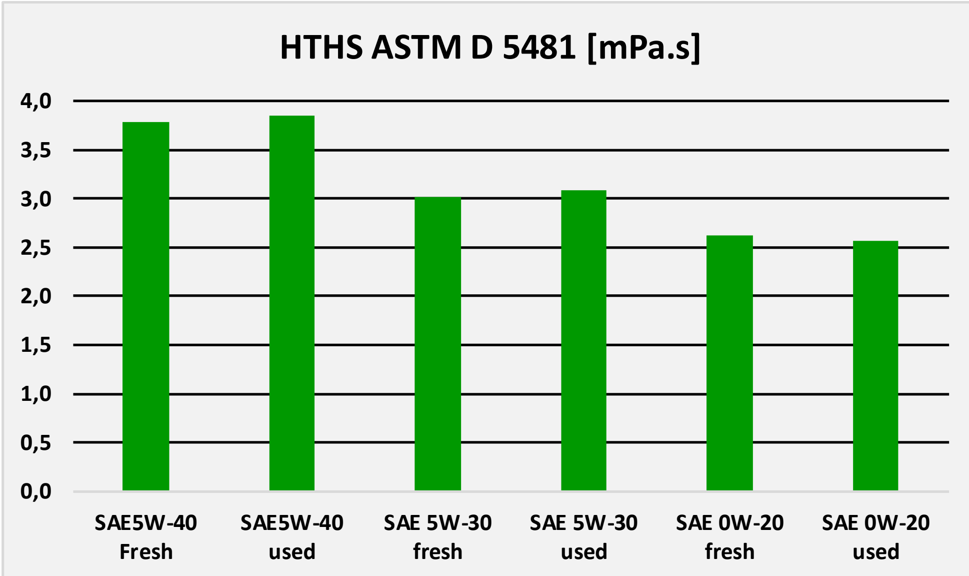


Figure 5 – Kinematic viscosity at 100°C in mm²/s obtained in the new samples and used in the ABNT NBR 6601 and NBR 7024 tests.



Figur6 – HTHS in mPa.s obtained from the new samples and used in the ABNT NBR 6601 and NBR 7024.

According to the fuel consumption method, city and highway cycles values are expressed in liters per 100 km (l/100 km), but considering the local (Brazil) practices these values were converted to kilometer per liter (km/l).
In the urban cycle according to figure 7, it is possible to see that thicker lubricant, base line or SAE 5W-40 showed the highest fuel consumption with an average of 16.62 km/l. The lubricant SAE 5W-30 got an average fuel consumption of 16.81 km/l and the thinner fluid, SAE 0W-20 showed the best fuel efficient with an average of 17.08 km/l

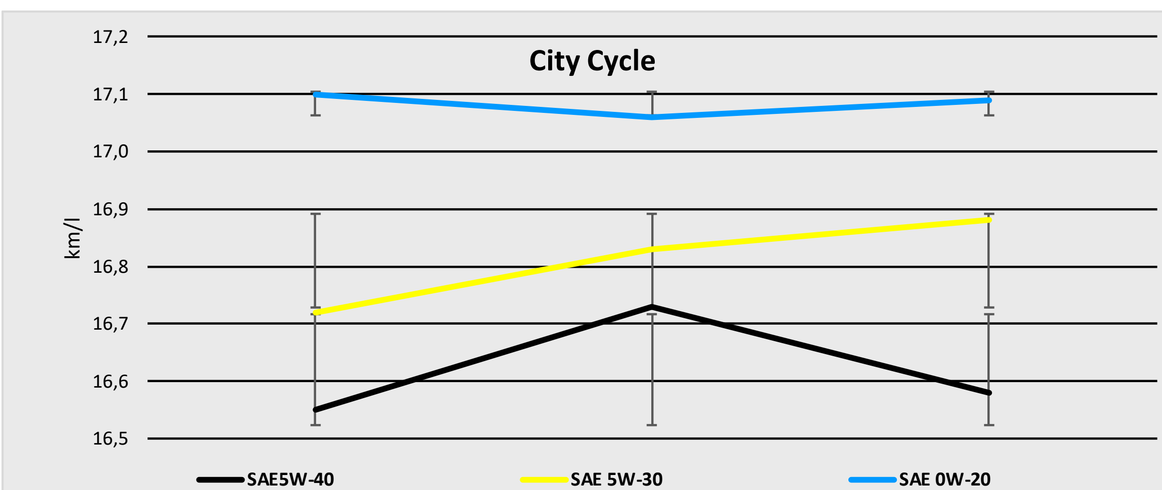


Figure 7 – Test of urban cycle.

Moving to highway cycle, figure 8, it is possible to observer the same behavior of fuel consumption versus viscosity grade. The thicker lubricant, SAE 5W-40, repeated the highest consumption with an average of 19.99 km/l; The mid viscosity fluid or SAE 5W-30 obtained an average fuel consumption of 20.01 km/l and the thinner fluid SAE 0W-20 showed again the lowest fuel consumption with an average of 20.21 km/l.

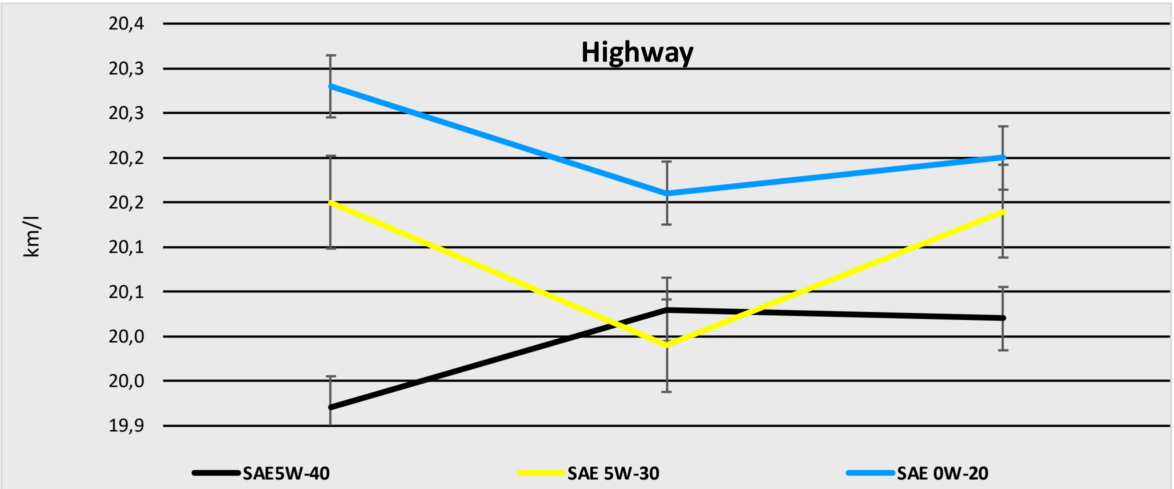


Figure 7 - Highway cycle test.

The final fuel consumption number is a weight average based on urban and highway cycle (55%) and urban cycle (45%). On to figure 9, it is possible to see the previous behavior from the lubricant viscosity and fuel efficiency.

The high viscosity fluid, SAE 5W-40, presented the worst fuel efficiency, with an average of 17.98 km/l. The SAE 5W-30 fluid got a fuel consumption of 18.15 km/l and the SAE 0W-20 showed the best fuel consumption with the average of 18.36 km/l.

Evaluating the percentage of fuel consumption among the three viscosities studied according to figure 10, we can verify that the change from a SAE 5W-40 to a SAE 5W-30 it was possible to save 0.91% or 0.17km/l and moving to a SAE 0W-20 the improvement on fuel consumption was 2.11% or 0.38 l/km. The fuel saving from a SAE 5W-30 to a SAE 0W-20, the saving was 1.19% or 0.21 km/l.

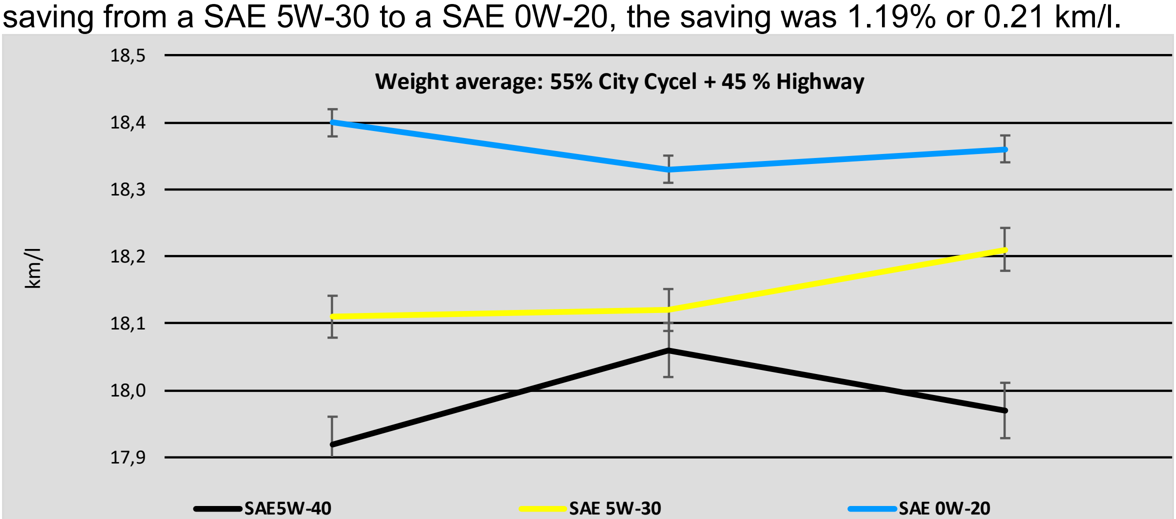


Figure 9 - Combined cycle 55% urban cycle and 45% cycle road (Highway).

	Fuel Consumption [km/l]		
Lubricant	**City**	**Highway**	**Weight Average**
SAE 5W-40	16,55	19,92	17,92
	16.73	20.03	18.06
	16.58	20.02	17.97
Average	**16.62**	**19.99**	**17.98**

	Fuel Consumption [km/l]		
Lubricant	**City**	**Highway**	**Weight Average**
SAE 5W-30	16.72	20.15	18.11
	16.83	19.99	18.12
	16.88	20.14	18.21
Average	**16.81**	**20.09**	**18.15**

	Fuel Consumption [km/l]		
Lubricant	**City**	**Highway**	**Weight Average**
SAE 0W-20	17.1	20.28	18.4
	17.06	20.16	18.33
	17.09	20.2	18.36
Average	**17.08**	**20.21**	**18.36**

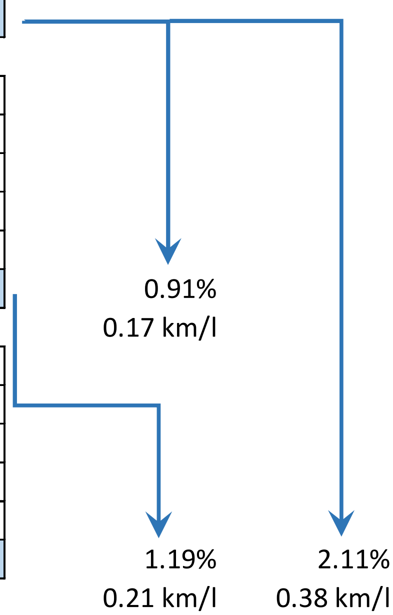


Figure 10 - Comparison of consumption in the urban and road cycle.

Conclusion

In this work, it was possible to confirm the influence of viscosity on fuel economy and that the change from SAE 5W-40 lubricant to SAE 0W-20 product, delivers 2.11% (0.38 km/l) or fuel saving. Considering that the average performance obtained for SAE 5W-40 oil in the combined urban and highway cycle of 17.98 km/l with a change in viscosity, this performance increases to 18.36 km/l.
Reducing the viscosity grade from SAE 5W-40 to SAE 5W-30 fluid, the benefit was 0.91% (0.17 km/l) of fuel economy with represent an intermediate step if considered to SAE 0W-20 lubricant.

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