COBEM 2021
26th International Congress of Mechanical Engineering
ABCM
Associação Brasileira de Engenharia e Ciências Mecânicas
November 22-26, 2021, Virtual Congress, Brazil

COB-2021-0011
INFLUENCE OF LUBRICATING OIL VISCOSITY AND CHEMICAL PROPERTIES IN THE VIBRATION LEVEL OF AN INTERNAL COMBUSTION ENGINE

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Abstract. *In the automobile industry, the production technology of lubricating oils follows the technological evolution of internal combustion engines. The new technologies incorporated in the production of automotive oils ensures greater cleaning of the engine, greater protection against wear, better performance with less fuel consumption, helps to reduce the vehicle emission in addition to ensuring a longer oil change interval. The objective of this study is to investigated the vibrational behavior of a modern internal combustion engine in function of fuel and the type of technologies incorporated into automotive oils. The study consisted of instrumenting the engine at specific points with accelerometers to measure the vibration level intensity of the engine during the experiment and operating the engine on a bench dynamometer in a test cycle with a specific fuel (ethanol or gasoline) and specific oil (mineral, semi-synthetic or synthetic). Each experiment lasted 600 hours of testing and every 50 hours an engine vibration level were measured and 100ml sample of lubricating oil was collected for chemical analysis of the lubricant's properties. The results show that the vibration level of the engine increases with the time of use of the lubricating oil and that this increase is very significant when the oil viscosity reaches the minimum value stipulated by the manufacturer. Semi-synthetic and synthetic lubricating oils have similar engine protection characteristics, but synthetic oil protects the engine for a longer period of time due to less degradation of chemical properties compared to semi-synthetic. Mineral lubricating oil presented protection for a very short test period, due to the rapid degradation of chemical properties and measurements showed an average increase of 20% of vibration engine running with mineral lubricating oil in relation synthetic and semi-synthetic oils. This research is important because it correlates the degradation of the lubricating oil with the engine vibration level and vibration problems in internal combustion engines produce premature wear on the internal components of the engine, which contributes to reduce the lifespan of the engine. This study also shows how is important to observe the correct application of automotive oils.*

Keywords: *Internal combustion engine, Engine vibration, Mineral oil, semi-synthetic oil, synthetic oil*

1. INTRODUCTION

The objective of this study is to investigated the vibrational behavior of a modern internal combustion engine in function of fuel and the type of technologies incorporated into automotive oils. The contribution of this work in relation to previous works is that the present research analyzes and correlates the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration of engine as a function of viscosity and TBN of the lubricating oil.

(Khuong *et al.*, 2017) investigated the oil degradation, and lubricating efficiency of fully-synthetic oil diluted with various bioethanol–gasoline blends. A fully synthetic oil was homogenously mixed with five formulated fuels such as pure gasoline, gasoline with 10% ethanol, gasoline with 20% ethanol, gasoline with 30% ethanol and gasoline with 85% ethanol. This experimental study shows that the assess the impact of bioethanol–gasoline blends, on the tribological performance of engine oil under selected conditions using four-ball wear tester. The 6% addition of all bioethanol–gasoline blends to fully-synthetic oil significantly decreased the viscosity of the fresh oil to about 30%, compared to fresh synthetic oil. The decrease in viscosity from ethanol dilution may result in the thinner boundary film and higher wear because viscosity reduction causes more contact between asperities of the surface. Bioethanol–gasoline diluted oils show slightly higher the acid number, compared to fresh synthetic oil. The engine oil needs to be more alkaline to prevent the metal surface from corrosion. However, bioethanol is more chemically reactive compared to gasoline, which enhances the degradation of the fuel–oil mixture. Therefore, the fuel diluted lubricants contain more acidity making the surface more susceptible to corrosion, thus increasing wear losses. The addition of ethanol–gasoline fuels to synthetic oil shows that there is no clear trend or conclusive indication of each fuel–oil mixture is worse for friction at both loads, but during the test, it was shown that the ethanol rapidly and fully evaporated from the lubricant at the temperature of 75°C. This minimal effect on the friction behavior is also due to the fact that the tests were conducted under boundary lubrication regime. Although bioethanol fuels have slight impact on the frictional characteristic of the oil, it has significant differences in the amount of wear. At both 40 and 80 kg loads, fuel–oil mixtures increase wear losses more or less with the increased amount of bioethanol, compared to their fresh oil. Gasoline with 30% ethanol and gasoline with 85% ethanol have higher wear losses but low friction because acid corrodes the surface and causes additional corrosive wear. In overall, 6% of bioethanol fuel dilution can degrade properties performance and tribological behaviors of the synthetic oil. Ethanol fuel dilution may reduce friction, compared to pure gasoline due to its polarity and acidity. However, high acid in the oil causes high wear due to its corrosion on the surface, suggesting that ethanol-resistant engine oil should be produced in order to avoid serious wear from bioethanol. (Kurre *et al.,* 2017) performed a review study of engine oil degradation mechanism of diesel engines and its association with engine component wear. This review study shows that the high load and long run of an engine produces higher engine wear due engine oil degradation. Degradation occurs mainly by soot formation, exhaust gas mixed with engine oil, engine blow-by, water contamination and wear particles. Soot formation in engine oil is increased with load. Biofuels are able to restrict soot loading. Metal contamination causes engine oil degradation. Metal contamination advances engine component wear. A biodiesel fueled engine shows less wear than a diesel fueled engine. Abrasive wear occurred in the engine component due to metallic and soot contamination. Degradation of engine oil decreases engine efficiency and increases friction and metal to metal contact. (Besser *et al.,* 2014) investigated the impact of acetic acid as partial combustion product of ethanol, a bio-derived component in gasoline, on the performance of two engine oils regarding their stability and corrosion potential towards engine parts was assessed. Oils evaluated in laboratory for their stability were subjected to a chassis dynamometer bench test for examination under more realistic conditions. In addition to reference runs, bench tests were performed with addition of acetic acid to the oil. Oil condition monitoring enabled the differentiation between runs with and without addition of acid concerning the oil parameters Total Base Number and Neutralization Number. The results of the study prove that a good differentiation between bench test runs with and without addition of acetic acid can be found by evaluation of the conventional oil parameters, namely Total Base Number and Neutralization Number. No conventional oil parameter reached critical values to recommend an oil change. In the present study, a corrosion potential towards iron and copper was found for oil samples from runs with the addition of acetic acid whereas in reference runs no built-up of these elements was observed in the oils. Stoichiometric consideration of the addition of acetic acid showed that this acid is largely evaporated during engine operation, concluding that in common vehicle operation a rather low corrosion potential in the oil and consequently low risk of damage in the engine can be expected. Failure assessment was carried out of used parts demounted from the passenger car after operation on the chassis dynamometer bench test. The viscosity of oil is the most important property of lubricant oils for internal combustion engines and it also indicates the degree of resistance a lubricant oil allows on two surfaces in relative motion and the main property that influences the viscosity is the temperature, (Haycock *et al.,* 2004). (Gravalos *et al.,* 2003) investigated the effects of vibrations on spark ignition engine fueled with gasoline and gasoline blend with ethanol and methanol at concentrations of 10%, 20% and 30%. per volume. The experiments were realized a single cylinder spark ignition engine and were performed at rotational speed of 1000, 1300, 1600 and 1900 rpm onto a hydraulic dynamometer. The results demonstrate that vibration amplitude of the fundamental harmonics decrease with increase of load or decrease of engine speeds. The vibration values of gasoline had higher amplitudes at 1300 rpm, gasoline blend with 10% of methanol fuel had higher amplitudes at 1900 rpm. Gasoline blend with 10% of ethanol gave more stable vibration intensity, in comparison with others fuels. The results are due the changing of the process combustion, which was caused by combustion characteristics of bend fuels. (Santana *et al.,* 2013) demonstrated through the frequency spectrum, that the dynamics of the opening and closing movement of the valves in the cylinder head is an important source of vibration generation in the engine. (Santana *et al.,* 2020) demonstrated that the mobile components of the engine have a low degree of freedom in the longitudinal direction and this limited movement produces low intensity vibration in the longitudinal direction in both tests with gasoline and ethanol fuel. In the vertical direction, the results showed that the vibration intensity of the engine increased with increasing speed and was more intense in the tests with ethanol. The factors that most influenced the vibration in this direction were the dynamics of the opening and closing of the valves in the cylinder head and the engine combustion process. (Santana *et al.,* 2019) correlated the combustion process with the vibration intensity in the 1st and 5th crankshaft bearings of an Otto cycle internal combustion engine. In the transverse direction, the results showed that the intensity vibration engine also increased with increasing speed and was also more intense in the tests with ethanol. The factor that most influenced the vibration in this direction was the ignition advance of the engine.

2. METHODOLOGY

The experimental procedure involved the instrumentation of the engine with an accelerometer on the side wall of the engine block and on the 1st and 5th main bearing of the crankshaft in order to measure the level of vibration of the engine during testing. The accelerometers used for testing were a piezoelectric accelerometer model Kistler K Shear 8704B100. A hydraulic dynamometer, passive FE model 150s, was used in order to measure engine speed, torque and power engine generated during testing. The measured engine vibration data are acquired in LMS Test Lab Software by SIEMENS. All other experimental data are acquired in test bench acquisition system. The analysis of the vibration data was an average mean of the engine block vibration intensity and the 1st and 5th main bearing of the crankshaft. This was done using the Root Mean Square (*RMS*) of the accelerometer signal amplitudes during the time acquired during each test condition. The RMS value is the root mean square of the signal and is used to represent the energy in the signal and it is the most relevant measure of vibration intensity in internal combustion engine since it gives an amplitude value by considering time history of the signal vibration measured. The *RMS* acceleration value can be calculated by the following Eq. (1):

$$RMS = \sqrt{\frac{1}{T}\int_{0}^{T} a_w^2(t)dt} \qquad (1)$$

Were, ([a_w]) (m/s^2) represents the weighted accelerations and ([t]) (s) represents measurement time. The Figure 1 shows the accelerometer position in the engine block and on the 1st and 5th main bearing of the crankshaft and the orientation of measurement vibration. The direction Y, X and Z represents the longitudinal, transversal and vertical vibration in the engine block and the 1st and 5th main bearing of the crankshaft.

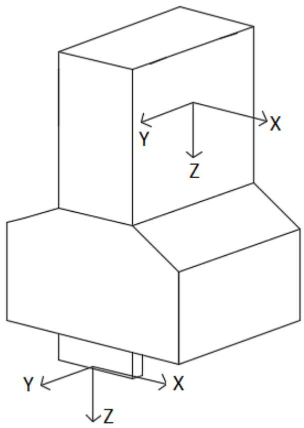

Figure 1 - Orientation of accelerometers measurement to measuring the engine block and the 1st and 5th main bearing of the crankshaft vibration.

The tests were carried out on a four-cylinder flex-fuel spark-ignition engine with the follow specification presented in Table 1.

Table 1 – Specification of spark ignition engine.

Parameter	**Type or value**
Cycle	Four strokes
Compression ratio	10.35: 1
Bore × stroke	72.00 × 84.00 mm
Number of cylinders	4, in line
Total displacement	1368 cm³;
Intake system	Naturally aspirated
Maximum torque	112,80 Nm at 4500 rpm with gasoline 114.60 Nm at 4500 rpm with ethanol

The experimental procedure involves test in engine with a specific fuel (ethanol or gasoline) and a specific lubricating oil (SAE 5W30, SAE 15W40 or SAE20W50) operated for 600 hours in a specific cycle of tests. Every 50 hours of testing, vibration level measurements were made at the extremities of the crankshaft and engine block, and a 100 ml sample of the lubricating oil was collected for analysis of the physical and chemical properties and besides the employment of testing procedures and the analysis of the experiment data. The test was conducted with full load condition and at maximum engine torque rotation (4500 rpm). Data were acquired under the following conditions: water average temperature at around 95 °C and oil at 135 °C. A synthetic SAE 5W30 lubricant oil with gasoline fuel and ethanol fuel were used during the first part of test. The experiment was repeated with semi-synthetic SAE 15W40 and mineral SAE 20W50 lubricant oil, the same fuel (gasoline and ethanol) and under the same conditions of first part. The test consisted of running the engine dynamometer at specific speed (4500 rpm) and full load (maximum throttle opening). After stabilizing the conditions of the temperatures of both water and oil, the acquisition of the vibration signal in accelerometers and other parameters were processed and stored in the Software LMS Test Lab and Software Indicom and data were acquired under the following conditions: water average temperature at around 95°C and oil at 135°C. At each test speed, data was acquired for 2 minutes at a rate of 100 Hz. The Fig. 2 shows the experimental setup scheme.

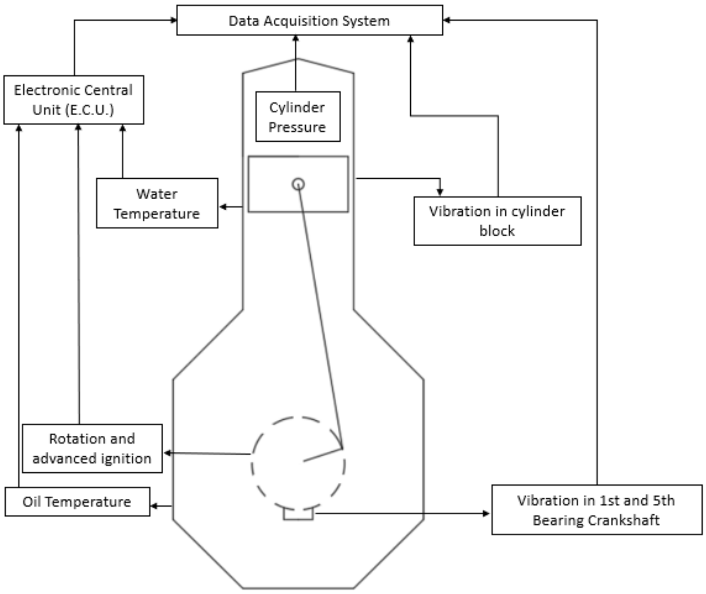

Figure 2 - Experimental setup scheme.

The analysis of the results consisted in correlating the data of vibrations measured on the engine block and the1st and 5th main bearing of the crankshaft of engine operated with gasoline and ethanol fuel as analyzed as a function of viscosity oil lubricant and TBN (Total Base Number).

3. RESULTS AND DISCUSSION

This section will be present and discuss the measurements results of vibration in the engine block and the1st and 5th main bearing of the crankshaft of engine installed in the dynamometer working in full load condition (maximum throttle opening) at specific speed (4500 rpm) as a function of viscosity and TBN of the lubricating oil used in the test. The Table 2 shows classification of lubricants oil viscosity and TBN according to standards (SAE J300_201304, 2013) and (ASTM D 2896, 2001).

Table 2 - Classification of lubricants according to standards (SAE J300_201304, 2013) and (ASTM D 2896, 2001).
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	Specification 5W30 Synthetic Oil	**Specification 15W40 Semi-Synthetic Oil**	**Specification 20W50 Mineral Oil**
Viscosity at 100°C cts	9.30 a 12.50	12.50 a 16.30	16.30 a 21.90
TBN mgKOH/g	9.00	10.00	11.50

The Figure 3 shows oil viscosity measurement during test, a minimum reference value of viscosity, oil TBN measurement during test, a minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements as a function of the engine speed 4500 rpm using SAE 5W30 lubricant oil and gasoline fuel.

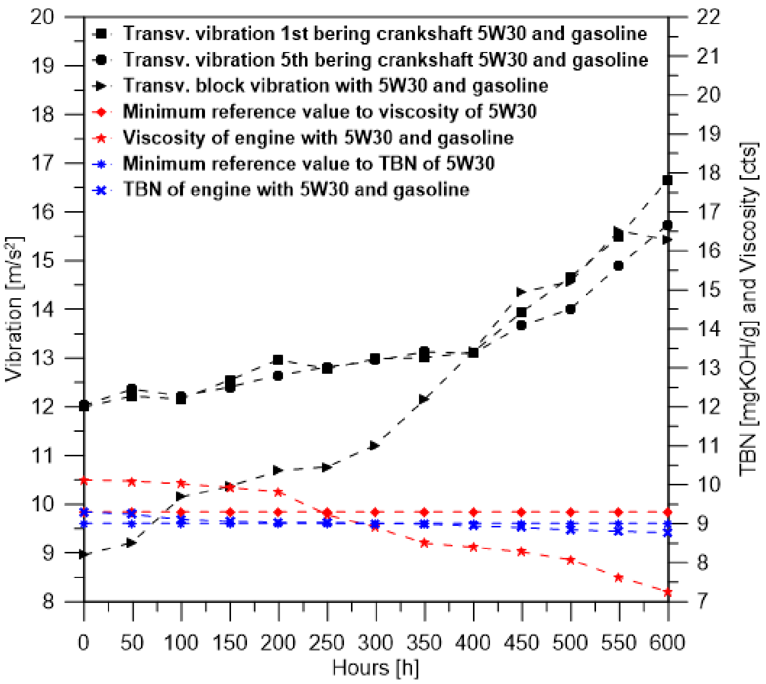

Figure 3 - Oil viscosity measurement, the minimum reference value of viscosity, oil TBN measurement, the minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements using SAE 5W30 lubricant oil and gasoline fuel.

With SAE 5W30 lubricant oil and gasoline fuel the transverse vibration measured in engine block varied from 8.95 m/s^2 at beginning test to approximately 15.42 m/s^2 at end test, the main transverse vibration measured in the 1st and 5th main bearing of the crankshaft vibration varied from 12.00 m/s^2 at beginning test to approximately 16.50 m/s^2 at end test. The 5w30 oil viscosity reference value is 9.30 cts (SAE J300_201304, 2013 and Table 2) and the viscosity of the 5W30 oil with gasoline fuel decreased from 10.45 cts at beginning test to approximately 7.30 cts at the end test. The 5w30 oil TBN reference value is 9.00 mgKOH/g (ASTM D 2896, 2001) and the TBN of the 5W30 oil decreased from 9.20 mgKOH/g at beginning test to approximately 8.80 mgKOH/g at the end test. The results of tests with SAE 5W30 lubricant oil and gasoline fuel show that vibration in the engine increased with the engines test hours and after 400 hours of testing the increase in vibration level in the engine was more intense. The viscosity of the oil 5W30 with gasoline fuel decreased with the engines test hours and the minimum reference value was reached with approximately 250 hours of testing. The TBN oil also decreased with the engines test hours and the minimum reference value was reached with approximately 300 hours of testing. Analyses of results show that, after approximately 400 hours of test, the vibration intensity is more significant because the oil was degraded with viscosity and TBN presented values below the minimum recommended by the (SAE J300_201304, 2013) and (ASTM D 2896, 2001).

The Figure 4 shows oil viscosity measurement during test, a minimum reference value of viscosity, oil TBN measurement during test, a minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements as a function of the engine speed 4500 rpm using SAE 5W30 lubricant oil and ethanol fuel.

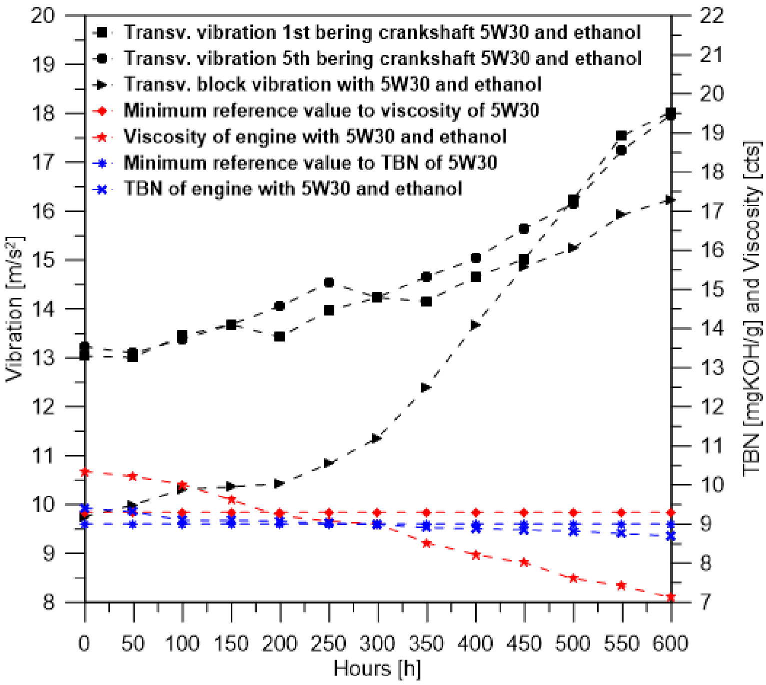

Figure 4 - Oil viscosity measurement, the minimum reference value of viscosity, oil TBN measurement, the minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements using SAE 5W30 lubricant oil and ethanol fuel.

With SAE 5W30 lubricant oil and ethanol fuel the transverse vibration measured in engine block varied from 9.75 m/s^2 at beginning test to approximately 18.25 m/s^2 at end test, the main transverse vibration measured in the 1st and 5th main bearing of the crankshaft vibration varied from 13.20 m/s^2 at beginning test to approximately 18.50 m/s^2 at end test. The viscosity of the 5W30 oil with ethanol decreased from 10.50 cts at beginning test to approximately 7.20 cts at the end test and the TBN oil decreased from 9.25 mgKOH/g at beginning test to approximately 8.75 mgKOH/g at the end test. The results of tests with SAE 5W30 lubricant oil and ethanol fuel show that vibration in the engine increased with the engines test hours and after 300 hours of testing the increase in vibration level in the engine was more intense. The viscosity of the oil 5W30 with ethanol fuel decreased with the engines test hours and the minimum reference value was reached with approximately 200 hours of testing. The oil TBN also decreased with the engines test hours and the minimum reference value was reached with approximately 300 hours of testing. Analyses of results show that, after approximately 250 hours of test, the vibration intensity is more significant because the oil was degraded with viscosity and TBN.

The Figure 5 shows oil viscosity measurement during test, a minimum reference value of viscosity, oil TBN measurement during test, a minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements as a function of the engine speed 4500 rpm using SAE 15W40 lubricant oil and gasoline fuel. With SAE 15W40 lubricant oil and gasoline fuel the transverse vibration measured in engine block varied from 8.00 m/s^2 at beginning test to approximately 14.00 m/s^2 at end test, the main transverse vibration measured in the 1st and 5th main bearing of the crankshaft vibration varied from 11.60 m/s^2 at beginning test to approximately 17.50 m/s^2 at end test. The 15W40 oil viscosity reference value is 12.50 cts (SAE J300_201304, 2013 and Table 2) and the viscosity of the 15W40 oil with gasoline fuel decreased from 13.65 cts at beginning test to approximately 10.80 cts at the end test. The 15W40 oil TBN reference value is 10.00 mgKOH/g (ASTM D 2896, 2001) and the TBN of the 15W40 oil decreased from 10.25 mgKOH/g at beginning test to approximately 9.80 mgKOH/g at the end test. The results of tests with SAE 15W40 lubricant oil and gasoline fuel show that vibration in the engine increased with the engines test hours and after 250 hours of testing the increase in vibration level in the engine was more intense. The viscosity of the oil 15W40 with gasoline fuel decreased with the engines test hours and the minimum reference value was reached with approximately 250 hours of testing. The TBN oil also decreased with the engines test hours and the minimum reference value was reached with approximately 300 hours of testing. Analyses of results show that, after approximately 300 hours of test, the vibration intensity is more significant because the oil was degraded with viscosity and TBN presented values below the minimum recommended by the (SAE J300_201304, 2013) and (ASTM D 2896, 2001).

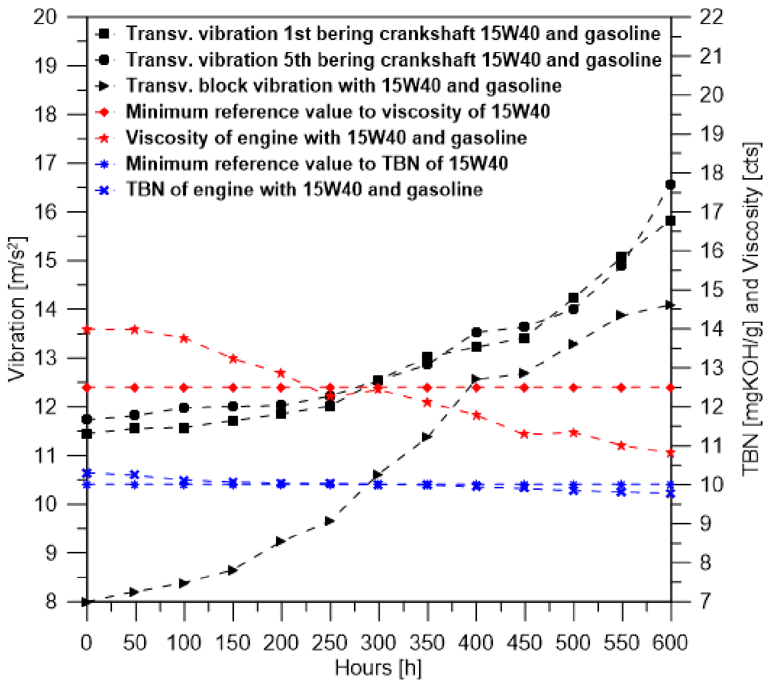

Figure 5 - Oil viscosity measurement, the minimum reference value of viscosity, oil TBN measurement, the minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements using SAE 15W40 lubricant oil and gasoline fuel.

The Figure 6 shows oil viscosity measurement during test, a minimum reference value of viscosity, oil TBN measurement during test, a minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements as a function of the engine speed 4500 rpm using SAE 15W40 lubricant oil and ethanol fuel.

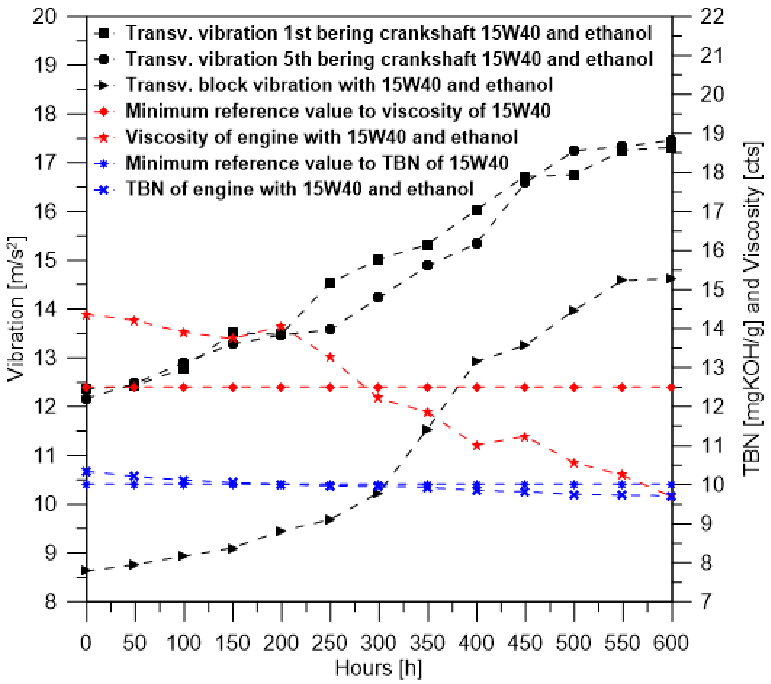

Figure 6 - Oil viscosity measurement, the minimum reference value of viscosity, oil TBN measurement, the minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements using SAE 15W40 lubricant oil and ethanol fuel.

With SAE 15W40 lubricant oil and ethanol fuel the transverse vibration measured in engine block varied from 8.60 m/s^2 at beginning test to approximately 14.75 m/s^2 at end test, the main transverse vibration measured in the 1st and 5th main bearing of the crankshaft vibration varied from 12.20 m/s^2 at beginning test to approximately 17.50 m/s^2 at end test. The viscosity of the 15W40 oil with ethanol decreased from 14.30 cts at beginning test to approximately 9.75 cts at the end test and the TBN oil decreased from 10.20 mgKOH/g at beginning test to approximately 9.75 mgKOH/g at the end test. The results of tests with SAE 15W40 lubricant oil and ethanol fuel show that vibration in the engine increased with the engines test hours and after 250 hours of testing the increase in vibration level in the engine was more intense. The viscosity of the oil 15W40 with ethanol fuel decreased with the engines test hours and the minimum reference value was reached with approximately 250 hours of testing. The oil TBN also decreased with the engines test hours and the minimum reference value was reached with approximately 300 hours of testing. Analyses of results show that, after approximately 250 hours of test, the vibration intensity is more significant because the oil was degraded with viscosity and TBN.

The Figure 7 shows oil viscosity measurement during test, a minimum reference value of viscosity, oil TBN measurement during test, a minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements as a function of the engine speed 4500 rpm using SAE 20W50 lubricant oil and gasoline fuel.

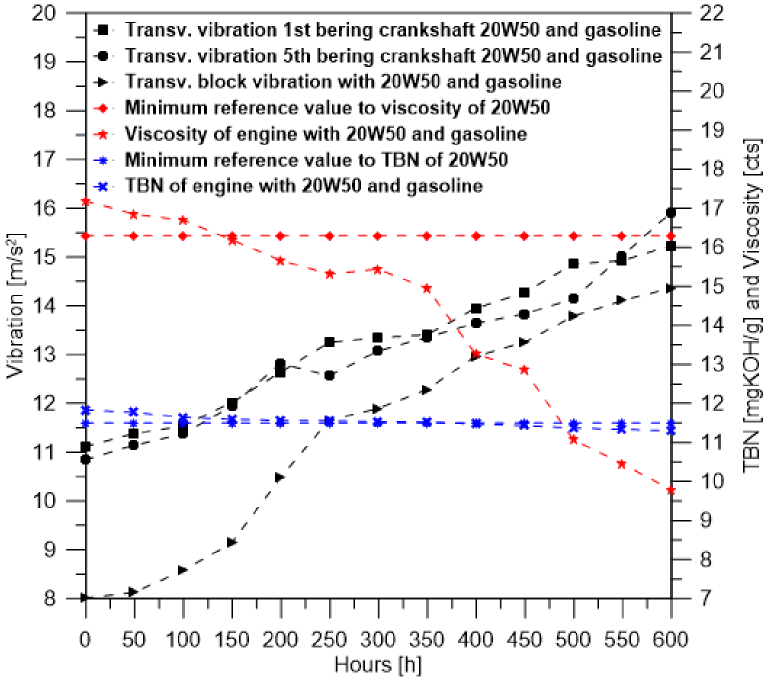

Figure 7 - Oil viscosity measurement, the minimum reference value of viscosity, oil TBN measurement, the minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements using SAE 20W50 lubricant oil and gasoline fuel.

With SAE 20W50 lubricant oil and gasoline fuel the transverse vibration measured in engine block varied from 8.00 m/s^2 at beginning test to approximately 14.20 m/s^2 at end test, the main transverse vibration measured in the 1st and 5th main bearing of the crankshaft vibration varied from 11.00 m/s^2 at beginning test to approximately 15.50 m/s^2 at end test. The 20w50 oil viscosity reference value is 16.30 cts (SAE J300_201304, 2013 and Table 2) and the viscosity of the 20W50 oil with gasoline fuel decreased from 17.15 cts at beginning test to approximately 9.80 cts at the end test. The 20w50 oil TBN reference value is 11.50 mgKOH/g (ASTM D 2896, 2001) and the TBN of the 20W50 oil decreased from 11.75 mgKOH/g at beginning test to approximately 11.80 mgKOH/g at the end test. The results of tests with SAE 20W50 lubricant oil and gasoline fuel show that vibration in the engine increased with the engines test hours and after 125 hours of testing the increase in vibration level in the engine was more intense. The viscosity of the oil 20W50 with gasoline fuel decreased with the engines test hours and the minimum reference value was reached with approximately 150 hours of testing. The TBN oil also decreased with the engines test hours and the minimum reference value was reached with approximately 250 hours of testing. Analyses of results show that, after approximately 150 hours of test, the vibration intensity is more significant because the oil was degraded with viscosity and TBN presented values below the minimum recommended by the (SAE J300_201304, 2013) and (ASTM D 2896, 2001).

The Figure 8 shows oil viscosity measurement during test, a minimum reference value of viscosity, oil TBN measurement during test, a minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements as a function of the engine speed 4500 rpm using SAE 20W50 lubricant oil and ethanol fuel.

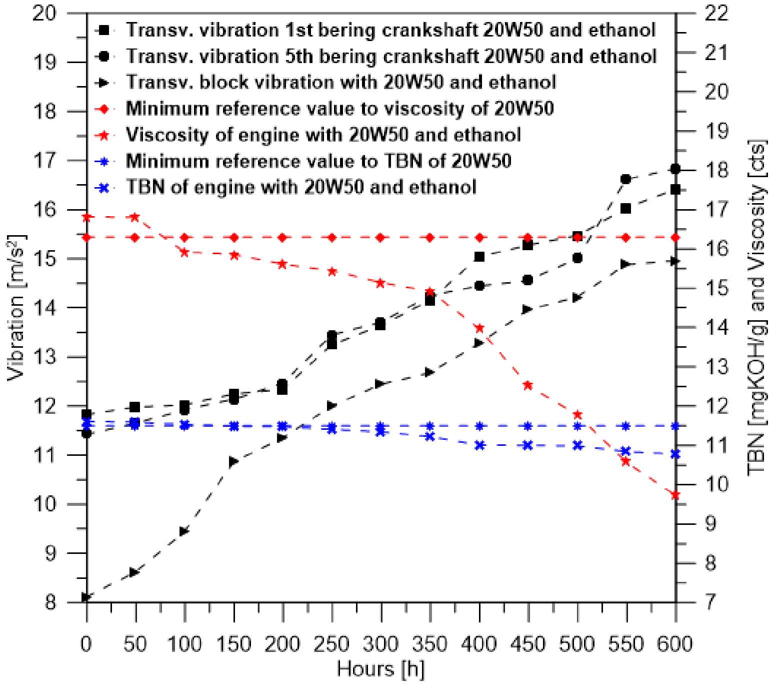

Figure 8 - Oil viscosity measurement, the minimum reference value of viscosity, oil TBN measurement, the minimum reference value of TBN, the1st and 5th main bearing transverse vibration on the crankshaft and transverse block vibration measurements using SAE 20W50 lubricant oil and ethanol fuel.

With SAE 20W50 lubricant oil and ethanol fuel the transverse vibration measured in engine block varied from 8.20 m/s^2 at beginning test to approximately 15.00 m/s^2 at end test, the main transverse vibration measured in the 1st and 5th main bearing of the crankshaft vibration varied from 11.60 m/s^2 at beginning test to approximately 16.80 m/s^2 at end test. The viscosity of the 20W50 oil with ethanol decreased from 16.60 cts at beginning test to approximately 9.85 cts at the end test and the TBN oil decreased from 11.60 mgKOH/g at beginning test to approximately 10.80 mgKOH/g at the end test. The results of tests with SAE 20W50 lubricant oil and ethanol fuel show that vibration in the engine increased with the engines test hours and after 50 hours of testing the increase in vibration level in the engine was more intense. The viscosity of the oil 20W50 with ethanol fuel decreased with the engines test hours and the minimum reference value was reached with approximately 75 hours of testing. The oil TBN also decreased with the engines test hours and the minimum reference value was reached with approximately 200 hours of testing. Analyses of results show that, after approximately 50 hours of test, the vibration intensity is more significant because the oil was degraded with viscosity and TBN.

The comparison of the tests performed with the SAE 5W30 synthetic oil, SAE 15W40 semi-synthetic oil and SAE 20W50 mineral oil lubricant with gasoline and ethanol shows an average increase of vibration of the engine run on ethanol in comparison to gasoline. Such increase in vibration intensity in the tests performed with ethanol is related greater degradation of lubricating oil properties in engines fueled with ethanol than with gasoline. This degradation of the oil is characterized by the reduction of viscosity and TBN which is related to workload, temperature and dilution of fuel. The 5W30 synthetic oil and 15W40 semi-synthetic oil lubricants has the same degradation characteristics, but 15W40 protects better the engine against 5W30 since the vibration level is smaller. The 20W50 mineral oil lubricant which is a mineral oil degrades faster working in same conditions as 5W30 and 15W40 lubricants which are synthetic and semi-synthetic oil respectively, which rapidly increases the engine's vibration level.

(Chiavola *et al.*, 2010) also demonstrated that the combustion pressure in an engine influences the vibration level in the engine block. This study confirms that the vibration level of an internal combustion engine depends on the type of fuel used in the engine. (Keskin, 2010) investigated vibration effect of ethanol and gasoline blends on two stokes spark ignition engine. The experiments were at 1500, 2000 and 2500 rpm engine rotational speed. The results demonstrate that vibration characteristics of engine changed significantly at 1500 and 2000 rpm with gasoline blend with ethanol fuels and the vibration amplitude of the engine with ethanol showed a trend of increasing.

4. CONCLUSIONS

This study confirms that the vibration level of an internal combustion engine depends on the type of fuel used in the engine. In the present work, the vibration level of the engine running with ethanol was more intense than the engine running with gasoline in all operating conditions. The intensity of vibration in an internal combustion engine increase as the oil degrades. The degradation of the oil is characterized by the reduction of viscosity which is related to workload, temperature and dilution of fuel. In all operating conditions, the ethanol-run engine has higher vibration intensities than the gasoline-run engine. For the same type of fuel, an oil of higher viscosity attenuates the level of vibration of the engine. The 5W30 and 15W40 lubricants has the same degradation characteristics, but 15W40 protects better the engine against 5W30 since the vibration level is smaller. The 20W50 lubricant which is a mineral oil degrades faster working in same conditions as 5W30 and 15W40 lubricants which are synthetic and semi-synthetic oil respectively.

5. ACKNOWLEDGEMENTS

Federal University of Ouro Preto, Department of Mechanical Engineering.
PROPEM – UFOP - Master's program in Mechanical Engineering.
Federal University of Minas Gerais, Department of Mechanical Engineering.
CPGMEC – UFMG – Collegiate of Post-graduation in Mechanical Engineering.

6. REFERENCES

Chiavola, O., Arnone, L., Chiatti, G. and Manelli, S., “Combustion Characterization in Diesel Engine via Block Vibration Analysis”, SAE Technical Papers, April 2010, doi: 10.4271/2010-01-0168.

Besser, C., Steinschütz, K., Dorr, N., Farkas, F. N. and Allmaier, G., Impact of engine oil degradation on wear and corrosion caused by acetic acid evaluated by chassis dynamometer bench tests, Wear, 317 (2014) 64 – 76, doi:10.1016/j.wear.2014.05.005.

Gravalos, I., Moshou, D., Gialamas, T., Kateris, D., Xyradakis, P., and Tsiropoulos, K.,” Detection of fuel type on a spark ignition engine from engine vibration behavior”, Applied Thermal Engineering 54 (2013) 171 – 175, doi: 10.1016/j.applthermaleng.2013.02.003.

Haycock, R. F., Hillier, J. E. and Caines, A. J., Automotive lubricant reference book, 1st edition, Professional Engineering Publishing, 2004.

Keskin A., “The Influence of Ethanol Gasoline Blends on Spark Ignition Engine Vibration Characteristics and Noise Emissions,” Energy Sources Part A: Recovery, Utilization and Environmental Effect (20): 1851-1860, August 2010, doi:10.1080/15567030902804749.

Khuong, L. S., Masjuki, H. H., Zulkifli, N. W. M., Mohamad, E. N., Kalam, M. A., Alabdulkarem, A., Arslan, A., Mosarof, M. H., Syahir, A. Z. and Jamshaid, M., Effect of gasoline–bioethanol blends on the properties and lubrication characteristics of commercial engine oil, RSC Advances, 2017, doi.org/10.1039/C7RA00357A.

Kurre, S. K., Garg, R. and Pandey, S., A review of biofuel generated contamination, engine oil degradation and engine wear, Biofuels, 8:2, 273 - 280, 2017, doi: 10.1080/17597269.2016.1224291.

SAE International Surface Vehicle Standard, Engine Oil Viscosity Classification J300_201304, 2013.

Santana, C. M., Barros, J. E. M., and Junior, H. A. A., “Analysis of Vibration and Noise of an Internal Combustion Engine by Application of Test and Experimental Analysis of the Frequency Spectrum”, SAE Technical Paper, 2013-36-0103, 2013, doi:10.4275/2013-36-0103.

Santana, C. M., Barros, J. E. M., Gutierrez, J. and Junior, H. A. A, “Effect of Fuel and Lubricant on Engine Vibration” SAE Technical Paper 2020-01-1015, 2020, doi:10.4271/2020-01-1015.

Santana, C. M., Barros, J. E. M., Junior, H. A. A. and Braga, J. O., “Vibration Analysis on the Crankshaft Axis of an Internal Combustion Engine”, XXVII International automotive engineering symposium, p.370 - 385, doi:10.5151/simea2019-PAP31.

Standard Test Method for Base Number of Petroleum Products by Potentiometric Perchloric Acid Titration, ASTM D 2896, 2001.

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