Articles

Productivity analysis focusing on internal combustion engine vibration when using local fuels and additives

Análisis de productividad enfocada en las vibraciones de un motor de combustión interna al usar combustibles y aditivos locales

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ABSTRACT

The purpose of this article is to analyze the vibrations and behavior of an internal combustion engine of three vehicles: A1, J1, K1 which are exposed to both the geography, relief and road conditions of the Metropolitan District of Quito. To implement the quantitative methodology in the research it is important to perform a complete analysis of the vehicle based on its technical data sheet: A1, J1, K1, in order to identify both fuel consumption and the use of additives to reduce the friction that cause vibrations in the engine, especially the condition of the road. In addition, it is important to check how the level of vibrations can be reduced, the percentage of fuel when using additives and to verify the data provided by the vibration study of each vehicle. The results show that the tests carried out at 3500 RPM in vehicle A1 show a value of 27%, in vehicle J1 a value of 17% and vehicle K1 a value of 15%, these values are related to the use of additives. The results of the research are linked to field tests, individual tests, comparison of results and discussion of the feasibility

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of each of the tests performed on each vehicle to find similarities or marked differences.

Keywords: Accelerometer, additive, combustion, friction, engine, vibrations.

RESUMEN
Este artículo tiene como fin analizar las vibraciones y el comportamiento de un motor a combustión interna de tres vehículos que son: A1, J1, K1 que están expuestos tanto a la geografía, relieve y condiciones de la calzada del Distrito Metropolitano de Quito. Para implementar la metodología cuantitativa en la investigación es importante realizar un análisis completo del vehículo en base a su ficha técnica: A1, J1, K1, para de esa forma poder identificar tanto el consumo de combustible como el uso de aditivos para poder reducir la fricción que provocan las vibraciones en el motor, sobre todo del estado de la calzada. Además, es importante comprobar cómo se puede reducir el nivel de vibraciones, el porcentaje de combustible al usar aditivos y constatar los datos que arroje el estudio de vibraciones de cada vehículo. Los resultados demuestran, que las pruebas realizadas a 3500 RPM en el vehículo A1 presenta un valor de 27%, en el vehículo J1 presenta un valor de 17% y el vehículo K1 que presenta un valor de 15%, dichos valores van en relación al uso de aditivos. Los resultados de la investigación están ligados a las pruebas de campo, pruebas individuales, comparación de resultados y la discusión de la viabilidad de cada una de las pruebas realizadas a cada vehículo para encontrar similitudes o diferencias marcadas.

Palabras clave: Acelerómetro, aditivo, combustión, fricción, motor, vibraciones.

INTRODUCTION
This research article describes the study on the behavior of an internal combustion engine A1, J1 and K1, when exposed to vibrations according to the fuels and additives that are offered at the national level. Most of the vehicles found in the Ecuadorian market are imported from other

countries, therefore, it has been observed that they are not adapted to the geographical conditions, an example is the highland area where there are cities that are over 2000 meters above sea level, which is a determining factor not only for the performance of the vehicle but also for the incomplete combustion of gasoline.
For this reason it is important that, when performing vibration tests on internal combustion vehicles, it is important to identify how the quantity in ml of additive together with the type of gasoline can reduce or increase the vibration level.
Within the steps to follow for the investigation of the article, the fuels and cars with new technologies that are offered at national level are analyzed, the types of additives offered and by means of a measuring equipment to analyze the vibrations that these engines demonstrate with these technologies including the fuels and additives to determine the level of vibration that these engines can generate at these atmospheric conditions. In the research "Study by means of the vibration technique of the effects of the pressure variation in the fuel rail on the combustion of a CRDi engine Model Hyundai Santa Fe 2.0" (Albarracín & Huiñisaca, Estudio mediante la Técnica de vibraciones de los Efectos de la Variación de Presión en el Riel de Combustible sobre la Combustión de un Motor CRDi Modelo Hyundai Santa Fe]é 2.0, 2015)The heat power associated with the fuel that will have a variation when using an additive as a component within the mixture as a second level, in conjunction with the process that occurs inside the cylinder in order to quantify the pressure levels in the rail area is analyzed. Thus, it is necessary to analyze the vibration behavior of a gasoline engine with different technologies, taking into account the altitude of the city where the study will be carried out.
The vibrations of an Otto cycle vehicle, in the research entitled "Analysis of the vibrations of an OTTO cycle engine with a gasoline and ethanol-based fuel mixture" (Gutiérrez, Iñiguez, Cadena, & Santiana, 2017) in which they specify that the behavior of vibrations depends on the quality of combustion and fuel properties since such vibrations are the consequence of alternating, rotating and linear movements originating in the combustion process. The research shows that the defects observed in internal combustion engines are linked to the quality and effects found in the combustion process, since the latter gives rise to a different vibration pattern.
In the research "Analysis of the degradation and additives of the lubricant of a spark ignition engine in M1 vehicles within the period of maintainability" (Panchi, 2020) (Panchi, 2020)It is identified that the additives are important for the operation of the internal combustion engine, that is why the evaluation of the degradation condition of the additive must have periods of maintainability in order to guarantee its correct use, since the gasoline of the country is of a lower quality than that of the countries of origin of the automobiles. Within the proposed research, it was found that there is a 25% to 32% reduction in the formation of acids related to oxidation, which notably reduces the capacity of the additive to reduce the vibrations that occur in the engine area.
In the research "Analysis of vibrations in internal combustion engines by means of ultrasound" (Cardenas, Cevallos, & Moyano, 2017), the method is established to identify internal shredding of internal engine components, in order to determine pressurized leaks that minimize the potential of complete fuel burning, on the other hand the ultrasonic warning allows to recognize the increase of low frequency vibrations and the progressive increase of temperature.
Thus, when comparing vibrations in internal combustion engines, both rotational balancing parameters and the construction of the engine used in the vehicle are interpreted. Therefore, the application of vibration instruments within the analysis of engine performance can improve the level of vibrations produced by preventive maintenance of the components.

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In the research "Analysis and diagnostics of vibrations in light internal combustion vehicles" (Vega, 2015)The recurring problems that occur in an internal combustion engine when there are excessive vibrations at the time of starting the vehicle are identified, so it is important to know the reason for the vibrations since in many cases it is due to not having an adequate additive that allows that at the time of combustion there is no damage to the internal components of the vehicle.

The research describes the sources of vibration generation within internal combustion vehicles, where the misalignment and imbalance of moving components can produce a progressive wear of the engine, at the same time it also presents that external factors such as the state of the road can generate a failure in the calibration so it is necessary to take early corrective actions.

In the research "Analysis of the performance of the ignition provoked engine, due to the presence of additives" (Rocha & Zambrano, 2015)identifies the operation of the engine based on the technology of the vehicle and the national fuels used, in addition to understanding the performance that the engine will have based on the additives used to mitigate excessive vibrations. When the additive is of liquid and solid type, it is mixed with the extra or super gasoline, in order to perform the different tests from the INEN Standard: 935:2012, which helps to determine the proportion of the vehicle considering the distance traveled.

The research analyzes the behavior of the engine, based on the proportion of fuel and the additive to be used based on the mileage traveled, in addition to considering external parameters such as the irregularity of the road, so the dynamic tests help to obtain real values about the level of vibrations.

All the research previously analyzed affirms that the vibrations of an engine can be reduced notably with the mixture of different types of components such as recycled oils, ethanol and additives which in low percentages are able to improve the internal combustion of the engine which has repercussions in having a reduced amount of vibration (Energies, 2018).

Within the information of the article, the following objectives have been established: To analyze the vibration behavior of a gasoline engine in the Metropolitan District of Quito. Through an analysis, define the percentages of vibrations produced in a vehicle with an Otto cycle engine. (Criollo & Matute, 2015). Compare results between ideal and real conditions. Intervene an additive to counteract vibrations. Check the reduction of vibrations. Establish the percentage of fuel needed for the use of the additive. the results in three different vehicles for a viable conclusion.

The vibration analysis was carried out under static conditions with a variation of rpm as well as with an atmospheric pressure of 2800 msm with the use of extra, super and extra fuel with the additive.

MATERIALS AND METHODS

Within the method to be used in the practical case of vibration analysis in vehicles A1 / J1/ K1, is the motor method, or also known as (ASTM, CFR-M or F2), which is necessary to obtain data that help to compare the three different vibration spectra that have been obtained from normal operation and when the vehicles are in working conditions, in conjunction with a quantitative approach that allows to recognize values that part of the use of the additive. In this way, an unbalance environment of the vehicle is created, to identify how vibration levels increase or decrease, as well as to determine how changing the normal operating conditions of the vehicle are perceived by the driver. Thus, the data obtained is performed in the engine area, for which the accelerometer should be located in a central position in the engine, so that the machine can provide better data.

Measuring equipment
The vibration analyzer is given by means of a magnet, which is mounted on reference points intended for the case study is located in the engine, for which is identified as much natural vibration at 5 Hz and produced between 20 Hz and 25 Hz.

Table 1. *Vibration analyzer*

Brand	**ADQ**
Communication desk dimensions	43*34*18 mm
Dynamic inputs	16
Trigger entries	2
Sampling frequency	100 to 24000 samples/second
Accuracy	+/- 0,1 %
Feeding	110 to 220 VAC

Source: (Central American, 2016)

The accelerometer within the tests is a sensitive sensor that reports the vibrations of the vehicle's engine, addressed to a device, where the vibrations are identified in real time (Cueva, 2019). The vibration data is taken from the SD card, in conjunction with an alarm configured to indicate the time of the test in the mentioned vehicles.

Table 2 . Accelerometer

Brand	**WILCOXON / RESEARCH**
Voltage source	18 - 30 VDC
Sensitivity	100 m V/g
Dimensions	43 * 34 * 18 mm
Weight	90 grams
Frequency response	0.7 - 12000 Hz
Acceleration range	80 g peak

Source: (Central American, 2016)

Regulations
ISO 10816-1
Evaluates the vibrations of machines with non-rotating parts. ISO 10816-6, Reciprocating machines with rated potential greater than 100 kw.
Describes the general guidance on the evaluation and measurement of mechanical vibration of industrial machinery, there will be a classification that is standardized from 4 classes. (Standardization, 2015).
Class I: The machine is separated from the driver or the units to be coupled, machines belonging to this class operate up to approximately 15 kw which is approximately 20 hp.
Class II: Electric machines/motors from 20 hp to 100 hp, without special foundations or rigidly mounted motors on machines up to 400 hp mounted on special foundations.

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RESULTS

A1 Vehicle Tests

Table 1. *Technical specification vehicle A1*

PARAMETERS	DESCRIPTION
Displacement	999cc
Engine	1.0L - Turbo
Gasoline	Extra / Super
Cylinders	3 cylinders in line

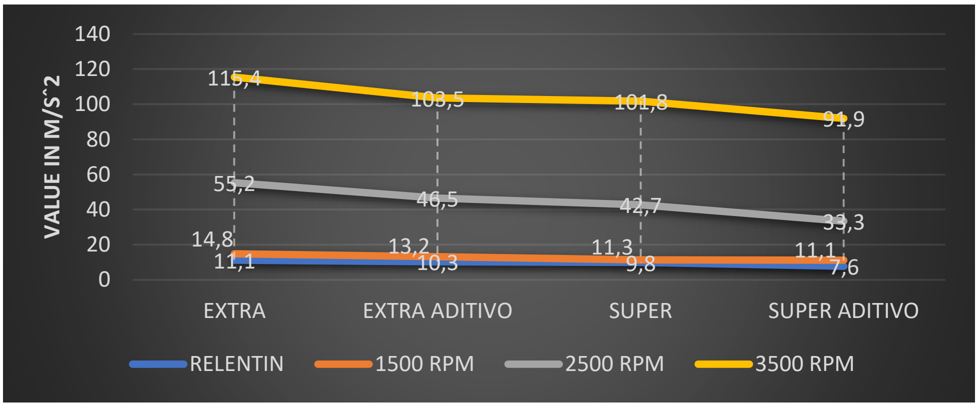
Table 42. *A1 vehicle tests*

	EXTRA	EXTRA-ADDITIVE	SUPER	SUPER-ADDITIVE
RALENTÍ	11,1	10,3	9,8	7,6
1500 RPM	14,8	13,2	11,3	11,1
2500 RPM	55,2	46,5	42,7	33,3
3500 RPM	115,4	103,5	101,8	91,9

Individual test A1

In this study the tests oscillate 27% taking into account that it is a 3-cylinder supercharged engine resulting in a reduction of vibrations, in addition this engine at low rpm has a low compression and at high rpm when loading the turbo reaches a point of stability.

Figure 1. A1 vehicle tests



Within the vibration a RALEN the minimum idling value of A1, a value of 11.1 (m. sˆ2) is observed in extra gasoline and a value of 9.8 (m. sˆ2) in super gasoline, which presents a data of 1.3% in favor of super gasoline.

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In the vibration analysis of maximum value of 3500RPM of the A1, a value of 115.4 (m. sˆ2) is identified in extra gasoline and in super gasoline a value of 101.8 (m. sˆ2), which presents a data of 13.6% in favor of super gasoline.
For the vibration analysis of the minimum idling value of A1, of extra gasoline with additive presents a value of 10.3(m. sˆ2) and with super gasoline with additive a value of 7.6 (m. sˆ2), which presents that there is a minimum idling vibration value of 2.7% in favor of super gasoline with additive.
In the vibration analysis of maximum value of 3500RPM of A1, it was recognized in extra gasoline with additive with a value of 103.5 (m. sˆ2) and in super gasoline with additive with a value of 91.9 (m. sˆ2), which presents a data of 11.6% in favor of super gasoline with additive.

J1 Vehicle Testing

Table 3 *Technical specification vehicle J1*

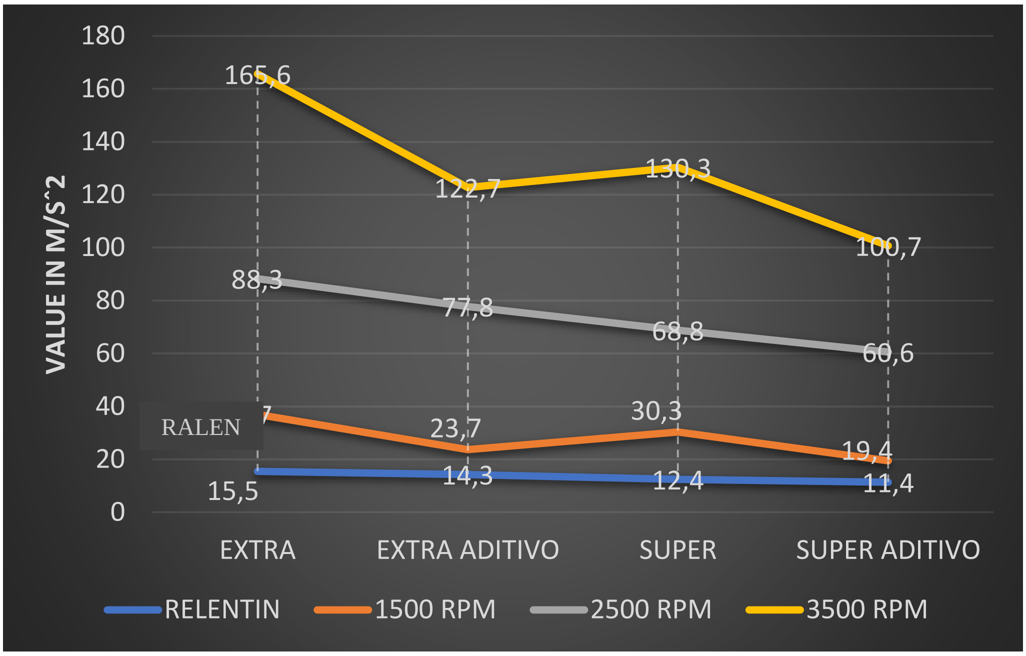
PARAMETERS	DESCRIPTION
Cylinder capacity	1,998 cc
Engine	SKYACTIV-G 2.0L/16-valve/Dual S-VT/Direct injection
Gasoline	Extra / Super
Cylinders	4 cylinders

Table 6. *Test data vehicle J1*

	EXTRA	EXTRA ADDITIVE	SUPER	SUPER ADDITIVE
RALENTÍ	15,5	14,3	12,4	11,4
1500 RPM	37	23,7	30,3	19,4
2500 RPM	88,3	77,8	68,8	60,6
3500 RPM	165,6	122,7	130,3	100,7

The J1 vehicle tests oscillate in a 17% having a positive response to the change of both additive and non-additive fuel since it has a direct injection technology which compresses the air-fuel mixture to a higher level thus extracting much more energy per fuel particle favoring the proper functioning of this engine by reducing vibrations.

Figure 2. Vehicle 1 tests



Within the vibration analysis of the minimum idling value of J1, extra gasoline is analyzed a value of 15.5 (m. sˆ2) and in super gasoline a value of 12.4 (m. sˆ2), which presents a data of 3.1% in favor of super gasoline.
In the 3500RPM maximum value vibration analysis of J1, a value of 165.6 (m. sˆ2) is indicated in extra gasoline and 130.3 (m. sˆ2) in super gasoline, which presents a data of 35.3% in favor of super gasoline.
For the vibration analysis of the minimum idling value J1, of extra gasoline with additive presents a value of 14.3(m. sˆ2) and with super gasoline with additive a value of 11.4 (m. sˆ2), which presents that there is a minimum idling vibration value of 2.9% in favor of super gasoline with additive.
In the 3500RPM maximum value vibration analysis of J1, it is seen in extra gasoline with additive with a value of 122.7 (m. sˆ2) and in super gasoline with additive with a value of 100.7 (m. sˆ2), which presents a data of 22% in favor of super gasoline with additive.

K1 Vehicle Testing

Table 7. Technical specification of vehicle K1

PARAMETERS	DESCRIPTION
Cylinder capacity	995 cc
Engine	1.2 SMART-TEC
Gasoline	Extra / Super
Cylinders	4 cylinders

Source: (Gutiérrez, Iñiguez, Cadena, & Santiana, 2017)

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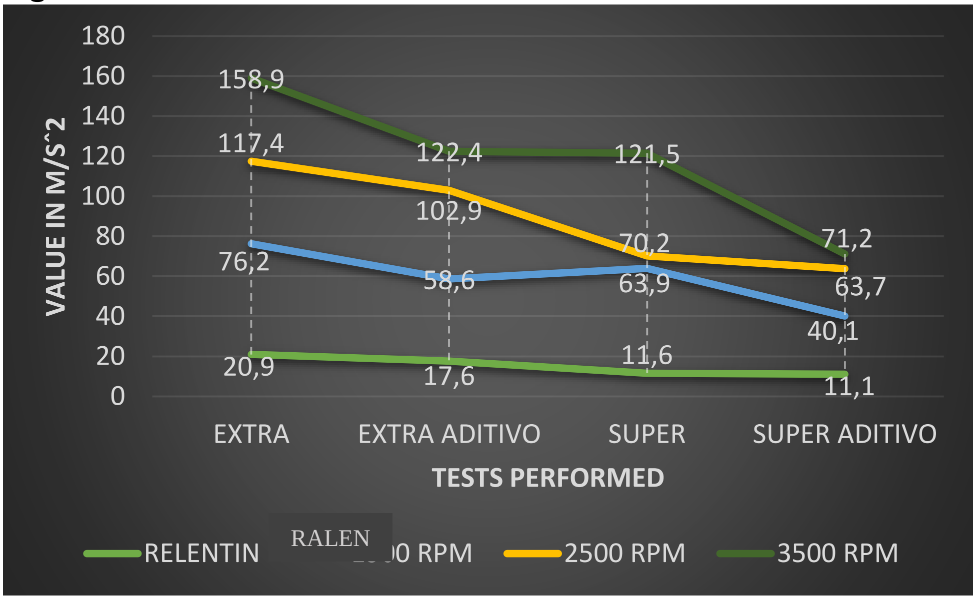
Table 8. *Test data vehicle K1*

	EXTRA	EXTRA ADDITIVE	SUPER	SUPER ADDITIVE
RALENTÍ	20,9	17,6	11,6	11,1
1500 RPM	76,2	58,6	63,9	40,1
2500 RPM	117,4	102,9	70,2	63,7
3500 RPM	158,9	122,4	121,5	71,2

Source: Prepared by the authors

The K1 vehicle, when tested, showed a 15% oscillation with traditional technology, as a result of using additive and higher octane fuels, a lower vibration reduction than expected was observed, being at the forefront and giving us moderately acceptable results.

Figure 3. *K1 vehicle tests*



Within the vibration analysis of the minimum idling value of K1, a value of 20.9 (m. s^2) is observed in extra gasoline and a value of 11.6 (m. s^2) in super gasoline, which presents a data of 9.3% in favor of super gasoline.

In the 3500RPM maximum value vibration analysis of K1, a value of 158.9 (m. s^2) was identified in extra gasoline and a value of 121.5 (m. s^2) in super gasoline, which presents a data of 37.4% in favor of super gasoline.

For the vibration analysis of the minimum idling value of K1**,** of extra gasoline with additive presents a value of 17.6(m. s^2) and with super gasoline with additive a value of 11.1 (m. s^2), which presents that there is a minimum idling vibration value of 6.5% in favor of super gasoline with additive.

In the vibration analysis of 3500RPM maximum value of K1, it is analyzed in extra gasoline with additive with a value of 122.4 (m. s^2) and in super gasoline with additive with a value of 71.2 (m. s^2), which presents a data of 51.2% in favor of super gasoline with additive, value of 11.4 (m.

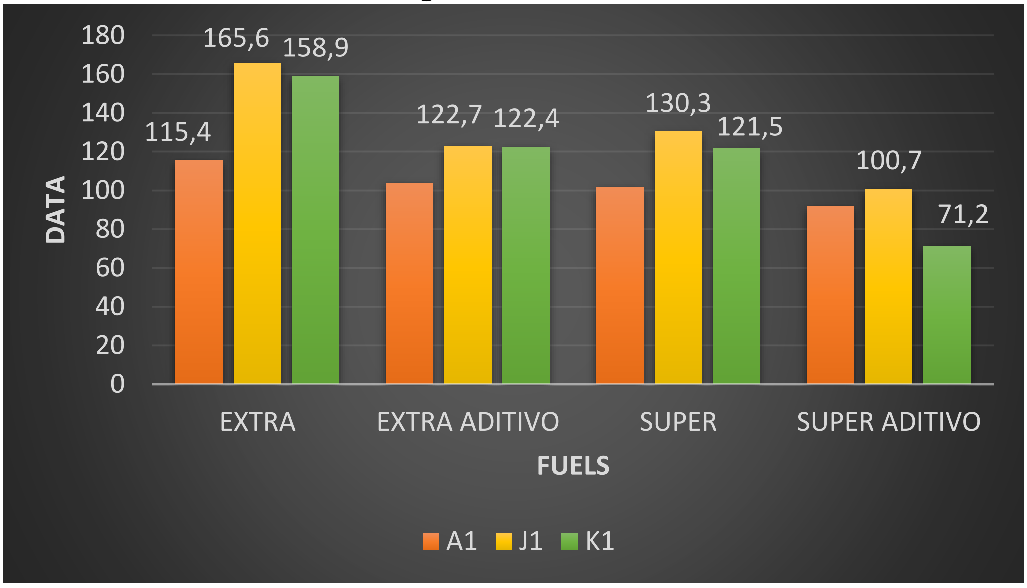
s^2), which presents that there is a minimum value of vibrations in idling of 2.9% in favor of super gasoline with additive.
In the 3500RPM maximum value vibration analysis of K1, it was recognized in extra gasoline with additive with a value of 122.7 (m. s^2) and in super gasoline with additive with a value of 100.7 (m. s^2), which presents a data of 22% in favor of super gasoline with additive.

Comparison of results

Table 9. *Tests at 3500 RPM*

VEHICLE	EXTRA	EXTRA-ADDITIVE	SUPER	SUPER-ADDITIVE
A1	115,4	103,5	101,8	91,9
J1	165,6	122,7	130,3	100,7
K1	158,9	122,4	121,5	71,2

Figure 4. Tests at 3500 RPM



Analysis tests at 3500 RPM

In the vibration analysis of 3500RPM value, vibrations were identified in extra gasoline with a value of A1= 111.5 (m. s^2) and in super gasoline with a value of A1= 101.8 (m. s^2), which presents a data of 9.7% in favor of super gasoline, with a lower level of vibrations.
In the vibration analysis of 3500RPM value, vibrations were determined in extra gasoline with a value of J1= 165.6 (m. s^2) and in super gasoline with a value of J1= 130.3 (m. s^2), which presents a data of 35.3% in favor of super gasoline, with a lower level of vibrations.
In the vibration analysis of 3500RPM value, vibrations were recorded in extra gasoline with a value of K1= 158.9 (m. s^2) and in super gasoline with a value of K1= 121.5 (m. s^2), which presents a data of 37, 4% in favor of super gasoline, with a lower level of vibrations.
Based on the data obtained at 3500 RPM, the vehicle with the lowest vibration index is A1 with 9.7%.

Based on the data obtained at 3500 RPM, the vehicle with the highest vibration index is K1 with 37.4%.

In the vibration analysis of 3500RPM value, vibrations are identified in extra gasoline with additive with a value of A1= 103.5 (m. s^2) and in super gasoline with additive with a value of A1= 91.9 (m. s^2), which presents a data of 12.4% in favor of super gasoline with additive, with a lower level of vibrations.

In the vibration analysis of 3500RPM value, vibrations are determined in extra gasoline with additive, with a value of J1= 122.7 (m. s^2) and in super gasoline with additive, with a value of J1= 100.7 (m. s^2), which presents a data of 22% in favor of super gasoline with additive, with a lower level of vibrations.

In the vibration analysis of 3500RPM value, vibrations are recognized in extra gasoline with additive, with a value of K1= 122.4 (m. s^2) and in super gasoline with additive, with a value of K1= 71.2 (m. s^2), which presents a data of 50.3% in favor of super gasoline with additive, with a lower level of vibrations.

Based on the data obtained at 3500 RPM with additive it is distinguished that the vehicle with the lowest vibration index is A1 with 12.4%.

Based on the data obtained at 3500 RPM with additive, the vehicle with the highest vibration index is K1 with 50.3%.

CONCLUSIONS

Within the analysis of the problem it has been possible to recognize which are the main parameters that create considerable vibrations in the study vehicles, for which it was necessary to have appropriate materials that allow to have an adequate reading to be able to identify how the additive is a component that allows to reduce vibrations and improve the process of the vehicle start-up.

In conclusion, it is identified that the vehicle with the lowest vibration index is the A1, since it presents a considerable reduction of 27%, being a transcendental factor the type of engine, cylinders and above all the total burning of fuels at the time of the combustion process, resulting in less wear in the internal and external parts of the engine.

In summary, vehicle K1 is the one that presents high vibrations in consideration of vehicle A1 and J1, which shows that, despite the use of additives in the mixture of extra and super gasoline, it will pass almost imperceptibly in the engine start-up in the context of vibrations.

In the vibration analysis of maximum value of 3500RPM of A1, it is identified in extra gasoline with additive with a value of 103.5 (m. s^2) and in super gasoline with additive with a value of 91.9 (m. s^2), which presents a data of 11.6% in favor of super gasoline with additive.

In the 3500RPM maximum value vibration analysis of J1, it is identified in extra gasoline with additive with a value of 122.7 (m. s^2) and in super gasoline with additive with a value of 100.7 (m. s^2), which presents a data of 22% in favor of super gasoline with additive.

In the 3500RPM maximum value vibration analysis of K1, it is identified in extra gasoline with additive with a value of 122.4 (m. s^2) and in super gasoline with additive with a value of 71.2 (m. s^2), which presents a data of 51.2% in favor of super gasoline with additive.

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