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Determination of torque and power of internal combustion engine using gasoline magna, ethanol blend with gasoline magna and E85 biogasol

Determinación de torque y potencia de motor de combustión interna usando gasolina magna, mezcla de etanol con gasolina magna y biogasol E85

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Abstract

The present research focuses on the study of the power generated in a 105 hp four-stroke in-line reciprocating internal combustion engine (MCIA) using three different renewable and non-renewable fuels: E85 biogasol and gasoline-oxyfuel. The power and torque generated with the blends were compared for the three fuels. The device used to measure torque and power was a dynamometer based on the prony brake principle. According to the results obtained, the power and torque generated using E85 biogasol are 16% lower than those generated using 100% gasoline. This is due to the fact that in the case of renewable fuels, the lower powers obtained were generated by the use of a poor mixture in the combustion chamber of the engine due to lack of calibration of the fuel map. In the case of the magna gasoline-oxyfuel blend, a torque value similar to that of the magna gasoline was obtained but at lower rpm, this effect indicates an advantage for the implementation of renewable fuels in a MCIA.

Test bench, Fuel, Ethanol

Resumen

La presente investigación se enfoca en el estudio de la potencia generada en un motor de combustión interna alternativo (MCIA) de cuatro tiempos en línea de 105 hp utilizando tres diferentes combustibles renovables y no renovables: biogasol E85 y gasolina magna-oxyfuel. Las potencias y torques generados con las mezclas se compararon para los tres combustibles. El dispositivo utilizado para realizar la medición del torque y potencia fue un dinamómetro basado en el principio del freno de prony. De acuerdo a los resultados obtenidos se observa que la potencia y torque generados utilizando biogasol E85 son menores en 16% que las generadas utilizando la gasolina magna al 100%. Esto es debido a que, en el caso de los combustibles renovables, las potencias más bajas obtenidas se generaron por el uso de una mezcla pobre en la cámara de combustión del motor por falta de calibración del mapa de combustible. En el caso de la mezcla gasolina magna- oxifuel se obtuvo un valor de torque similar al de la gasolina magna pero a menores rpm, este efecto indica una ventaja para la implementación de combustibles renovables en un MCIA.

Banco de pruebas, Combustible, Etanol

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Introduction

Today, the world relies mainly on fossil fuels to meet its energy demand, and more than 80% of total global energy is obtained from burning fossil fuels, of which 58% is consumed by the transport sector alone [1].

In the transport sector the majority of vehicles are operated by petrol or diesel [2] and in recent decades the growth of the automotive sector has accelerated [3]. As a consequence, pollutant emissions into the environment have increased and generate negative health effects [4].

These issues have prompted researchers to look for renewable fuel alternatives for use in engines. As a result, biofuels (renewable fuels) are found to be feasible energy solutions that generate less pollution and have no additional impact on climate change compared to emissions generated by fossil fuels [3].

According to Bansal *et al.*, [5], biofuels can be considered as any liquid or gaseous fuel made from biomass and used as a partial substitute for fossil fuels. Zabed *et al.*, [1] mentions that bioethanol would be an attractive alternative biofuel option due to its ease of production.

Currently, research has been conducted on the use of biofuels in spark ignition engines, for example, the use of methanol as a source of biofuel. A clear example is the research by Obelesu *et al*., [6], in which an increase in engine torque, braking power and volumetric efficiency has been observed when using low methanol and ethanol content rates compared to pure gasoline operation.

There is also work focused on studying the performance of internal combustion engine internal parameters using ethanol, such as effective pressure and volumetric efficiency. As is the case of Kemal *et al.*, [7], where he observed that, compared to the use of gasoline, the effective pressure in the engine cylinder increases during the use of ethanol fuels, regardless of the fuel mixture. And also, Kannan *et al.*, [8], observed in their experimentation that when the proportion of ethanol in the fuel mixture increases, the volumetric efficiency of the engine increases.

On the other hand, research has been carried out on the power and torque behaviour of an internal combustion engine. Such is the case of Govindaraj *et al.*, [2], which demonstrates the performance behaviour using a dynamometer. In his experimentation he used renewable fuel (hydrogen) and fossil fuel (gasoline), the experimentation was performed on a two-cylinder engine. He concluded that the hydrogen engine experiment is successful and the result is slightly in favour of the gasoline tests compared to the hydrogen tests at low rpm, but there is a smaller difference when the engine was operated at higher rpm.

Finally, research has also been carried out to determine the performance of a MCIA using liquefied petroleum gas (LPG). Bejarano [9] conducted a study analysing the before and after performance of the conversion of a Toyota engine to use LPG since he mentions that this fuel represents an alternative to gasoline and therefore should be taken into consideration in the future for transportation purposes. In this research it was concluded that the conversion, which has a direct effect on the performance of the Toyota engine by decreasing the torque in the engine.

Both the research and applications reviewed above have the main objective of understanding the behaviour of biofuels, therefore, the focus of this research is directed towards experimenting with biofuels within a MCIA and thereby creating a point of comparison for future work.

Methodology

In this research, experimental torque and power tests were carried out. The fuels and the percentages of biofuel used in each test are described. The type of engine and dynamometer and the standard used are also described in order to obtain quantitative results depending on the local altitude and geographical conditions.

Fuels

The fuels used in this project are: 1) a mixture of 50% of gasoline and 50% of Oxifuel, 2) Biogasol E85 and 3) 100% gasoline.

Table 1 describes the percentage by volume of the components of magna gasoline.

Gasoline with minimum content 87 octane (PEMEX Magna)	
Chemical name	
Aromatics	ZMVM: 25 % maximum volume ZMM, ZMG: 32% maximum volume
Olefins	ZMVM: 10% maximum volume ZMM, ZMG: 11.9 % maximum volume
Benzene	ZMVM, ZMM, ZMG: 1,00 Rest of the country: 2.00% max volume
Hexane	3.36% volume
Toluene	1.27 - 1.45% volume
Ethanol	5.80% volume

Table 1 Description of Gasolina Magna
Source: (Pemex, 2015) [10]

Table 2 shows the components of OxiFuel Plus Ethanol fuel.

Anhydrous Ethanol (OxiFuel Plus)	
Chemical name	Ethyl Alcohol, 1-Ethanol, Ethyl Hydrate, Methyl Carbinol
Chemical properties	Formula: C_2H_6O, CH_3CH_2OH.
	Molecular weight: 46.07 G/Mol.
	Composition: C: 52.24% H: 13.13% O: 34.73%
Characteristics	Colourless, volatile liquid with a characteristic odour and burning taste.
Aromatics	25% maximum volume Rest of the country: 32% maximum volume
Olefins	10% Maximum volume 11.9%.
Additive	Rest of the country: 12.5%. maximum volumen.
Benzene	1,00 % maximum volume Rest of the country: 2.00% maximum volume
Hexane	1.02% volume.
Toluene	0.69% volume.

Table 2 Oxifuel Plus fuel description
Source: (Grupo Balmex, 2017) [11].

In the case of Biogasol E85 fuel, a favourable response to the request for the chemical composition of this fuel was not obtained, however, it is known to have 113 octane [12].

Description of the test engine

The combustion engine is located on a test bench, it is a four-cylinder Tsuru III engine from Nissan Motor Company Ltd. and complies with the Mexican pollution standard NORMA OFICIAL MEXICANA NOM-042-SEMARNAT-2003 [13]. The engine description is presented in table 3.

Parameter	Description
Brand	Nissan Motor Company Ltd.
Origin	Japan
Model	ga16dne
Number of Cylinders	4
Type of injection	Multipoint electronics
Displacement	1597cc
Power	105hp at 6000rpm
Power per Litre Displacement	65.625
Torque	102lb/ft at 4000rpm
Number of valves	16
Timing	Twin-shaft (fixed) overhead (no angle variator)
Lubrication	Wet crankcase
Piston Stroke	88mm
Piston Diameter	76mm
Compression Ratio	9.5:1
Material	Aluminium cylinder head and iron block
Induction	Natural aspiration
Oil Capacity	3.5 L

Table 3 Characteristics of the test engine
Source: (Roiz González, 2020) [13].

An overview of the test engine is shown in figure 1.

Figure 1 Test Engine
Source: (Vidal, 2022) [14]

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Description of the Dynamometer

For the measurement of torque and power a dynamometer was used which operates according to the principles of a Prony Brake. The dynamometer is capable of measuring up to 105 hp and 102 lb-ft of torque.

This fabricated design consists mainly of three parts: a shaft, a lever part and a load cell. With these three elements it is possible to obtain the torque. By means of an Arduino module and programming, it is possible to obtain data provided by the load cell, which is also displayed on a screen.

The reading of power and torque is possible because the dynamometer consists of a piece that serves as a lever arm, this has two plates with holes, which, through a torque force on a screw that joins them, generates a brake load by friction on the shaft, and as part of the geometry of this piece is an arm on which an equal and opposite force to the torque coming from the shaft is applied. Figure 2 shows the components of the dynamometer.

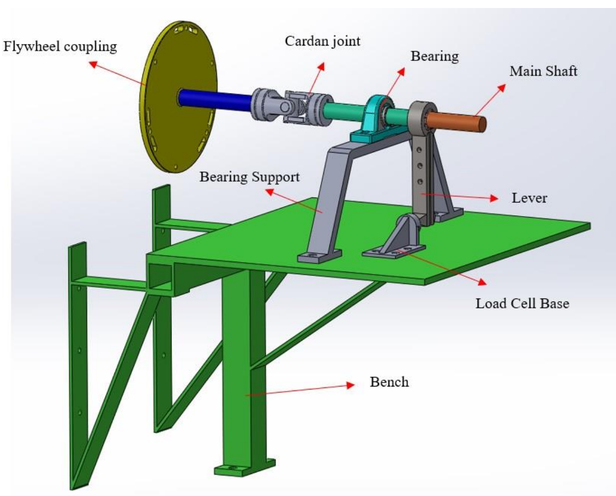

Figure 2 Design of the dynamometer
Source: (Vidal, 2022) [14]

Figure 3 shows the dynamometer manufactured and implemented in the test engine.

Figure 3 Dynamometer implemented in the test engine
Source: (Vidal, 2022) [14]

The implementation of the load cell consists of the creation of a space where the data obtained by the force sensor can be controlled. Figure 4 shows the load cell installed. This sensor is indispensable for the operation of the dynamometer.

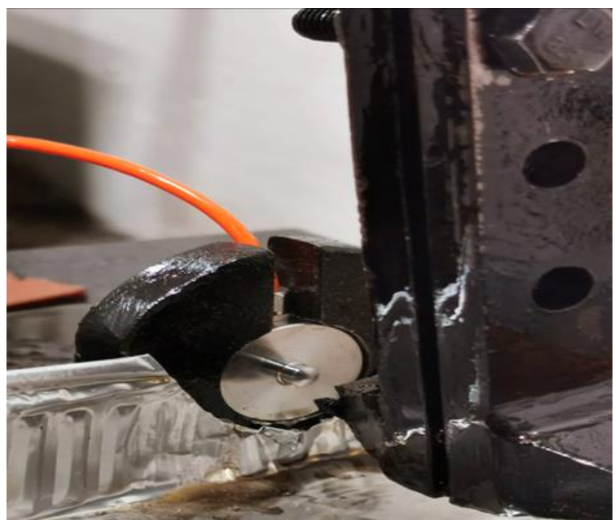

Figure 4 Installed load cell
Source: (Vidal, 2022) [14]

Once all the components of the brake have been implemented, it is ready for experimental tests.

Standards

Two standards were used during the experimentation process: the first is local, NORMA OFICIAL MEXICANA NOM-041-SEMARNAT-2015, whose purpose is to control the emission of pollutants from mobile sources, imported or domestically produced according to their respective categories and display limits [15].

The second standard for performing the tests has been selected from a comparison of standards with this approach [16], this second standard is the American standard SAE J139, which determines the performance in an engine at full load with torque and power values on a dynamometer, as seen in table 4 taking the reference atmospheric values during the tests [17].

	Standard condition	Limit range
Air inlet (absolute) pressure	100 Kpa	--
Dry air (absolute) pressure	99 Kpa	90/105 Kpa
Air inlet temperature	25°C	15 -35 °C

Table 4 Atmospheric conditions
Source: (SAE, 2011) [17]

Test Protocol

The experimental tests were carried out in the Thermal Test Laboratory of the Faculty of Engineering, which has the necessary test engine and equipment to perform the tests. The Faculty of Engineering is located on the coast of the city of Bocal del Río, Veracruz.

The SAE J1349 standard establishes the basis for the engine power range, the air inlet conditions, the method for correction of the power observed at full load and the basis for determining the power at full load using a dynamometer.

The tests are performed with the same throttle body opening (approximately 20 % opening) in order to have a measurement reference point between fuels.

Results

The experimental tests were carried out using the methodology of the SAE J1349 standard, which indicates the procedure for determining the engine's net power and torque. Table 6, 7 and 8 compile the data for the 100 % magna gasoline, the blend of magna gasoline with oxyfuel and the E85 biogasol respectively for each torque and power test performed. The values shown for maximum and minimum rpm, torque in lb-ft and power in HP before and after the correction established by the standard.

In the content of the Article all graphs, tables and figures must be editable in formats that allow to modify size, type and number of letters, for editing purposes, these must be in high quality, not pixelated and must be noticeable even reducing the image to scale.

Magna Gasoline Results					
	Maximum Minimum RPM	Torsional Torque [lb-ft]	Power [hp]	Corrected Torsional Torque [lb-ft]	Corrected Power [hp]
Assay 1	2617	0.31	0.014	0.41	0.02
	512.5	41.82	4.08	53.76	5.24
Assay 2	2260	0.059	0.025	0.076	0.032
	763	31.60	4.59	40.64	5.90
Assay 3	2429	0.022	0.010	0.029	0.013
	851	28.70	4.65	36.89	5.98

Table 5 Magna Gasoline Results
Source: (Vidal, 2022) [14]

	Maximum Minimum RPM	Torsional Torque [lb-ft]	Power [hp]	Corrected Torsional Torque [lb-ft]	Corrected Power [hp]
Assay 1	1847	5.82	2.04	7.48	2.63
	478	42.72	3.89	54.91	5.01
Assay 2	1933	0.60	0.22	0.77	0.28
	513	25.48	2.49	32.75	3.20
Assay 3	1924	0.41	0.15	0.52	0.19
	656	31.56	3.94	40.55	5.06

Table 6 Magna Gasoline and Oxifuel Fuel Blending Results [1:1]
Source: (Vidal, 2022) [14]

Results Biogasol E85					
	Maximum Minimum RPM	Torsional Torque [lb-ft]	Power [hp]	Corrected Torsional Torque [lb-ft]	Corrected Power [hp]
Assay 1	1705	1.64	0.53	2.11	0.68
	769	36.15	5.29	46.46	6.8
Assay 2	1885	1.16	0.41	1.50	0.53
	943	21.95	3.94	28.22	5.06
Assay 3	1858	0.93	0.33	1.20	0.42
	487	25.27	2.34	32.48	30.1.

Table 7 Biogasol E85 results
Source: (Vidal, 2022) [14]

Analysis of results

From the data obtained, the characteristic experimental curves of the engine were generated. In graph 1 and 2 the torque and power are observed respectively.

Graphic 1 shows all the torque data obtained in the test bench for the three fuels used in this research. It is observed that the magna gasoline presents the highest torque, followed by the mixture of magna gasoline and fuel with oxyfuel, while the biofuel biogasol E85 presents the lowest torque.

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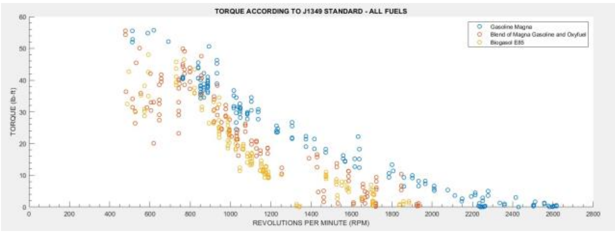
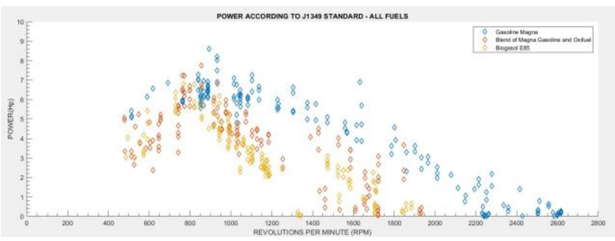
Graphic 2 shows the power output. The highest power is obtained with magna gasoline, followed by the mixture of magna gasoline and oxyfuel, while biogasol E85 obtained the lowest power among the fuels used in the tests.



Graphic 1 Torque according to SAE J1349 Standard
Source: (Vidal, 2022) [14]



Graphic 2 Power output according to SAE J1349 Standard
Source: (Vidal, 2022) [14]

The power factor for value correction is set by SAE J1349 standard according to the environment in which the experimental tests are performed. The environmental values and geographical conditions, such as temperature, air density, barometric pressure and relative humidity determine the value of the power correction factor.

In graphs 1 and 2 there is a marked correlation between the torque and the power obtained during the experimentation, since as the engine speed increases, the torque and power values decrease.

From the curves obtained in the tests, it can be observed that magna gasoline presents higher torque and power. This result is expected since the engine under test is designed to operate with this fuel.

In the case of gasoline magna, the behavior of the curves continued to increase as the engine speed decreased. When applying the regulations, the maximum power of 8.60 hp was obtained at 892 rpm, on the other hand, the maximum torque is 55.72 lb-ft at 619 rpm.

In the case of the mixture of magna gasoline and oxyfuel, the maximum power obtained was 7.74 hp at 855 rpm; on the other hand, the maximum torque obtained was 55.54 lb-ft at 478 rpm.

In the case of the E85 biogasol, the behavior of the curves remained ascending during the rpm range from 850 to 1300 rpm. The maximum power obtained was 6.80 hp at 769 rpm; on the other hand, the maximum torque obtained was 48.03 lb-ft at 592 rpm.

Financing

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Conclusions

In the present work, experimental tests were carried out on a 105 HP Nissan engine using biofuels and fossil fuels: 1) mixture 50% magna gasoline and 50% Oxifuel, 2) Biogasol E85 and 3) 100% magna gasoline.

Based on the behavior of the data under test, a curve was obtained to ensure that the engine tested complied with the output conditions specified by the manufacturer.

In the case of E85 biogasol, the power and torque generated are 16% lower than those generated using 100% gasoline.

In the results obtained for the power, it can be observed that the results favor the gasoline, this is due to the fact that the engine has ignition and injection maps for the use of gasoline and not another fuel that is not specified by the manufacturer. Because of this, the engine's ECU (electronic control unit) is not able to adapt the data already programmed to obtain a stoichiometric mixture for the other two fuels with which it has been experimented.

Analyzing the renewable fuels used in this study, it is observed that the blend of gasoline magna and oxyfuel has more stable power and torque values than Biogasol E85, since there were no different peak values between the tests performed.

It is concluded that the torque value obtained using the magna-oxifuel gasoline blend was similar to the value obtained using 100% magna gasoline, but favorably in the case of the blend the maximum torque was obtained at lower rpm, this is a positive effect for the implementation of biofuels.

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