UNIVERSIDAD POLITÉCNICA SALESIANA
SEDE CUENCA

CARRERA DE INGENIERÍA MECÁNICA AUTOMOTRIZ

Trabajo de titulación previo
a la obtención del título de
Ingeniero Mecánico Automotriz

ARTÍCULO ACADÉMICO:

“FUEL CONSUMPTION ANALYSIS PRODUCE BY ELECTRIC-POWER ASSISTEDSTEERING SYSTEM AND DEFINITION OF A SOLAR TYPE GENERATION SYSTEM”

AUTOR:

CRISTHIAN XAVIER ARIAS TIGSI

TUTOR:

ING. ADRIÁN XAVIER SIGÜENZA REINOSO, MSc.

CUENCA - ECUADOR

2022

CESIÓN DE DERECHOS DE AUTOR

Yo, Cristhian Xavier Arias Tigsi con documento de identificación N° 0105519524, manifiesto mi voluntad y cedo a la Universidad Politécnica Salesiana la titularidad sobre los derechos patrimoniales en virtud de que soy autor del trabajo de titulación: **"FUEL CONSUMPTION ANALYSIS PRODUCE BY ELECTRIC-POWER ASSISTED STEERING SYSTEM AND DEFINITION OF A SOLAR TYPE GENERATION SYSTEM"**, mismo que ha sido desarrollado para optar por el título de: *Ingeniero Mecánico Automotriz,* en la Universidad Politécnica Salesiana, quedando la Universidad facultada para ejercer plenamente los derechos cedidos anteriormente.

En aplicación a lo determinado en la Ley de Propiedad Intelectual, en mi condición de autor me reservo los derechos morales de la obra antes citada. En concordancia, suscribo este documento en el momento que hago la entrega del trabajo final en formato digital a la Biblioteca de la Universidad Politécnica Salesiana.

Cuenca, febrero de 2022.

Cristhian Xavier Arias Tigsi

C.I. 0105519524

CERTIFICACIÓN

Yo, declaro que bajo mi tutoría fue desarrollado el trabajo de titulación: **"FUEL CONSUMPTION ANALYSIS PRODUCE BY ELECTRIC-POWER ASSISTED STEERING SYSTEM AND DEFINITION OF A SOLAR TYPE GENERATION SYSTEM"**, realizado por Cristhian Xavier Arias Tigsi, obteniendo el *Artículo Académico,* que cumple con todos los requisitos estipulados por la Universidad Politécnica Salesiana.

Cuenca, febrero de 2022.

Ing. Adrián Xavier Sigüenza Reinoso, MSc.

C.I. 0103827366

DECLARATORIA DE RESPONSABILIDAD

Yo, Cristhian Xavier Arias Tigsi con documento de identificación Nº 0105519524, autor del trabajo de titulación: **"FUEL CONSUMPTION ANALYSIS PRODUCE BY ELECTRIC-POWER ASSISTED STEERING SYSTEM AND DEFINITION OF A SOLAR TYPE GENERATION SYSTEM",** certifico que el total contenido del *Artículo Académico*, es de mi exclusiva responsabilidad y autoría.

Cuenca, febrero de 2022.

Cristhian Xavier Arias Tigsi

C.I. 0105519524

AGRADECIMIENTO

Agradezco a Dios por bendecirme la vida, por guiarme a lo largo de mi existencia, ser el apoyo y fortaleza en aquellos momentos de dificultad y de debilidad. Gracias a mis padres: Luis y Eva; y de manera especial a mis abuelos Abel y Hermelinda, por ser los principales promotores de mis sueños, por confiar y creer en mis expectativas, por los consejos, valores y principios que me han inculcado. Agradezco de igual manera a los docentes de la Universidad Politécnica Salesiana, por haber compartido sus conocimientos a lo largo de la preparación de mi profesión, de manera especial, al Ingeniero Adrián Xavier Sigüenza Reinoso tutor de mi Artículo Científico quien ha guiado con su paciencia, y su rectitud como docente.

DEDICATORIA

Dedico este trabajo principalmente a Dios, por haberme dado la vida y permitirme el haber llegado hasta este momento tan importante de mi formación profesional. A mis abuelos, por ser el pilar más importante y por demostrarme siempre su cariño y apoyo incondicional sin importar las situaciones difíciles de nuestras vidas. A mis padres, a pesar de nuestra distancia física, siento que estuvieron conmigo siempre y aunque nos faltaron muchas cosas por vivir juntos, sé que en este momento ellos se alegran junto a mí el poder alcanzar una meta de las muchas que deseo lograr. A mis tíos y familia, porque estuvieron siempre apoyándome, y también a mi novia, porque desde los inicios de mi carrera me supo apoyar y dar las fuerzas necesarias para continuar.

FUEL CONSUMPTION ANALYSIS PRODUCE BY ELECTRIC-POWER ASSISTED STEERING SYSTEM AND DEFINITION OF A SOLAR TYPE GENERATION SYSTEM

Cristhian Xavier Arias Tigsi [1]

Resumen

El consumo de combustible es un factor que actualmente se encuentra en estudio, esto por la necesi-dad de la reducción de emisiones contaminantes yla búsqueda de motores de combustión interna con mayor eficiencia. El presente artículo tiene como ob- jetivo analizar el gasto energético producido por la utilización del sistema de dirección asistida por un mo- tor eléctrico, por medio del almacenamiento de datos y estudio del ancho de pulso de inyección, para la definición de un sistema de compensación de energía en un vehículo de transporte de personas a gasolina. La metodología de estudio, se basó en la creación de un módulo de medición de corriente sobre el motor dela dirección, dentro de 15 rutas definidas. De acuerdo a los resultados se obtuvo que los puntos críticos de consumo se producen a velocidades bajas (15- 30 km/h) con un amperaje de 4,1 A. Dichos resultados permiten una propuesta de un sistema de compensación de energía por medio de paneles solares que tendrán la finalidad de suministrar energía hacia la batería de 12V.

Palabras clave: Consumo de combustible,consumo de amperaje, dirección asistida, sistema de compensación.

Abstract

Fuel consumption is a factor that is currently under study, due to the need to reduce polluting emissions and the search for more efficient internal combustion engines. The objective of this article is to analyzethe energy consumption produced by the use of the power steering system by an electric motor, by stor- ing data and studying the injection pulse width, for the proposal of an energy compensation system in a gasoline powered vehicle for transporting people. The study methodology was based on the creation of a current measurement module in the steering motor, within 15 defined routes. According to the results, it was obtained that the critical points of consumption occur at low speeds (15-30 km/h) with an amperage of 4.1 A. These results allow a proposal of an energy compensation system by means of solar panels, These results allow a proposal for an energy compensation system through solar panels that will have the purpose of supplying energy to the 12V battery consumption.

Keywords: Fuel consumption, amperage consumption, compensation system.

1. Introduction

Ecuador has increased the vehicle fleet by 8.8% between 2016 and 2017, with a value of 2,237,264 vehicles, of which Azuay registered 6.34% of the total number of vehicles registered nationwide [1]. According to [2], it presents the comparative analysis between the hydraulic steering systems versus the electrical assistance systems, demonstrating great fuel saving advantages by the electro-assisted steering, which is why this project has the purpose of analyzing the fuel consumption generated by the steering system described above and defining a system that improves the performance of the vehicle by compensating the energy expenditure that occurs.

The technical sheet detailed in [3], defines the use of an electric motor assisted steering, in which fuel consumption is directly proportional to the time of use of the steering [4], concluding that, at a lower speed, greater power is produced in the electric motor and therefore an energy expenditure defined as fuel consumption is generated, which is measured in kilometers per gallon (Km/gal).

With respect to [4], it could be defined that the power required within an electric steering system is approximately 195 watts (W). Absorbed from the electrical system of the battery and the engine alternator. Based on the previous concept, the different test and measurement protocols will be directed to the injectiontime or pulse width, to the intensity or steering cur-rent consumption and finally to the voltage present in the battery. In this case, the tests that will be carried out will be directed within the bus routes. Within the sampling protocol, the incident factors that are taken into account are: vehicular traffic, routes, time of use of steering system, weight of the vehicle and load generated in the engine. Finally, with the tests carried out and the data stored, the real fuel consumption will be determined against the different relief and driving conditions, to finally define a compensation system for the EPS electric assistance steering system.

Authors in [5] state that the main advantage of electrically assisted steering is that it uses few components, slightly and positively influencing fuel consumption. According to [6], a power steering system brings the advantage of coupling this mechanism with a smaller reduction, thus causing faster turn on the wheels, being very convenient even on buses. Taking into account the previously mentioned considerations, the present study is aimed at establishing the incident factors of fuel consumption from the electric steering, in order to define a compensation system for energy expenditure, maintaining the efficiency of the steering system.

For the definition of a solar generation system [8], in his research, proposes 3 types of regenerators of electricity, wind system, regeneration on the wheels and through solar panels. The Wind System, this is a of the oldest forms used by the humanity, the main advantages that have electric wind turbines, is that they do not produce gas emissions pollutants and are a source of energy renewable, avoiding extraction processes underground or open air; so not presents environmental risks. However, regenerators they present fluctuation, dispersion and variability, usually caused by rotational speed of the pallets, in the same way the contamination auditory would be another of the factors that disadvantage in the application of these systems. Another proposal is regenerative braking systems can store lost energy in the form of heat during braking in vehicles at internal or standard combustion [7].

Finally the Solar Panel System system, which is regenerates by means of solar panels, is one of the methods of greater application within the automotive branch, thanks to its characteristics such as efficiency, aerodynamics and ease assembly [8]. With this in mind, the present study defines the compensation system developed by, Nilo Reyes and entitled "Design and implementation of an electrical charge generator system, using solar panel, for a increase the autonomy of an electrical vehicle KIA SOUL". [9], as the most optimal, for use inside an internal combustion vehicle.

2. Materials and Methods

The method used in the present study was the experimental and quantitative method. Therefore, tests were carried out in a commercial vehicle for transporting people (taxi), on specific routes within the city. On the other hand, with respect to the quantitative method, in this methodology load data will be obtained on the direction, variation of the injection pulse and fuel consumption, which will be quantified and adapted to an experimental model that will help us to observe which are the main effects that have been generated with respect to the consumption indexes of the steering system. The 3 study stages are defined below.

2.1. Data Collection

In the present study, data collection was carried out by means of the current measurement module and the OBDLINK mx+ module, based on the driving cycles on 15 specific routes, with a duration of each of approximately 45 minutes with response results. per second, after that, the data was filtered according to the use of the steering with a computer base of 3138 results, within which they present indicators of engine revolutions, fuel consumption, speed, and current consumption, which derives directly from the sampling and protocols followed during its execution, which is why, for the development of this investigation, different factors were taken into account that guarantee its quality. Such as the vehicle that was used, the same one that is detailed in Table 1.

Table 1. Vehicle specifications.

Details	Specifications
Brand	Hyundai
Model	Accent
Displacement	1.4L
Address	Electrical Assistance EPS

On the other hand, obtaining the current consumption was carried out from the design of a module through the programming of an Arduino board and based on a block of resistances, the scheme is presented below.

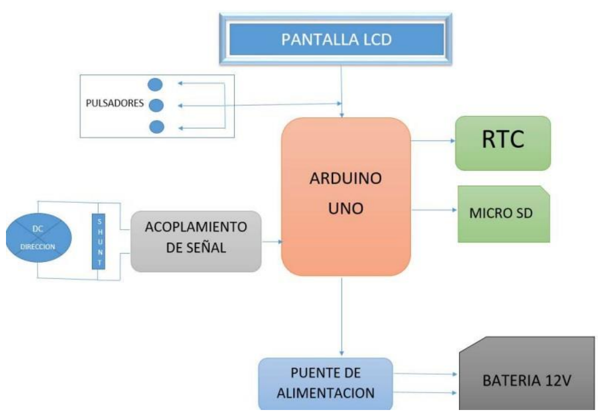


Figure 1. Schematic of the measurement module.

The connection of said module was made in parallel to the electric steering motor.
Another important factor was the time of data collection, from 6:00 p.m. to 11:00 p.m., presenting the measurement during peak hours initially and contrasting with little influx of vehicles or vehicular traffic in the last hours. Next, in Table 2, the specifications carried out for the sampling protocol are presented.

Table 2. Sampling Protocol.

Details	Values
Passenger on board	2 people
Occupant weight	230 pounds

In the same way, the state of the auxiliary devices of the vehicle was taken into consideration, these are detailed in Table 3.

Table 3. Status of Auxiliary Devices.

Device	Status
Radio Frequency	OFF
Stereo AM/FM	ON
Vehicle lights	ON
EPS steering system	ON
USB charging system	ON
OBDII interface module	ON

Prior to the sampling protocol, different processes were generated for the connection and stipulation of the correct methods during data collection, which are detailed in Figure 2.

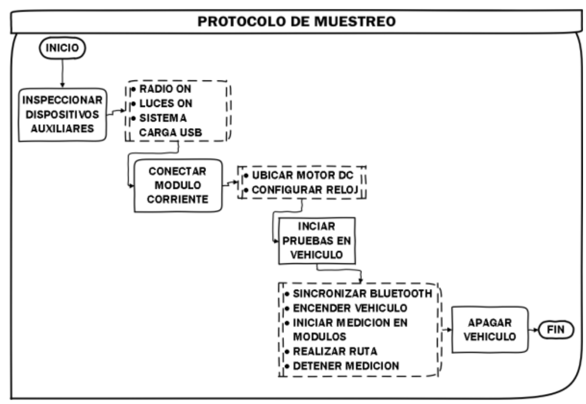


Figure 2. Flow chart.

2.2. Factors Considered for the Study

The factors considered in the study are defined according to the operation presented by the engine and the electronic system of the vehicle, within which, mention can be made of the electric steering system, the pulse width commanded by the ECU towards the injectors , the type of surface on which the vehicle is located and the time the steering has been used.

2.2.1. Electric-Power Assisted Steering EPS (motor DC)

The Electric Power Steering (EPS) or electro-assisted steering consists of an electric motor that drives a gearbox to generate movement on the rack according to the signals received from the motor control unit ECU [10], which allows the minimization of energy consumption.
In [10], it states that the following variables can be defined as the most influential in this study: current consumption, which is expressed in amps and is in charge of defining the amount of current necessary for

the movement of the direction, the greater the degree of rotation of the steering wheel, the greater the cur- rent consumption, and the type of surface on which it circulates, can be better visualized in Figure 3.

Figure 3. Degree of Slip. [11]

Another extremely important variable is the injection pulse, described as the amount of fuel that is injected in a certain time and depends on the time in which the voltage is applied by the control unit to the injector, it can be seen in figure 4, It is between 2 ms to about 15 ms.

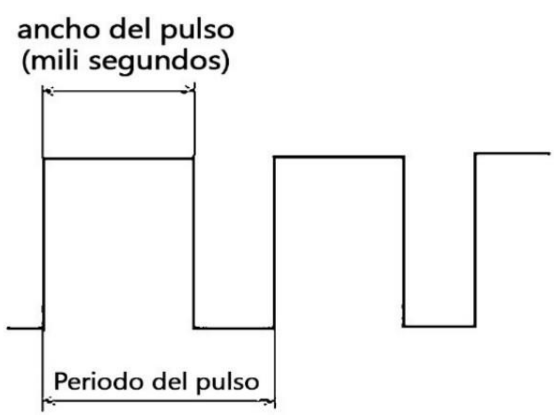


Figure 4. Injection Pulse. [6]

The engine revolution variable is directly related to the injection pulse, since according to the acceleration and the revolutions per minute RPM with which the engine rotates, the ECU engine control unit determines if the pulse width must increase or decrease. Vehicle speed is an important study variable, because it is directly related to the force exerted on the steering, this being inversely proportional to the current consumed. This is the reason why at low speeds the vehicle requires more steering assistance over the wheel.

Within the study, instantaneous fuel economy is an indicator that expresses the real-time amount of liters consumed for every 100 km traveled. As well as the total fuel saving, which indicates the total fuel consumed according to the route made. And of course the time of use, this being a variable that allows knowing the amount of time that the steering was used in an established route, by means of which the percentage of use of the EPS system in a certain time can be known, this is can be seen in the following equations.

$$t_{use} = t_{route}(seconds) - t_{utilization}(seconds) \quad (1)$$

$$\%_{utilization} = \left(\frac{100 * t_{utilization}}{t_{route}}\right) \quad (2)$$

Through the data obtained, it was possible to generate the correlation of variables, in order to know the behavior between them. Next, the relationship results are presented, which are in a range of +1 and -1; when you have a value close to -1 the two variables are associated in the opposite direction, when you have values close to +1 the variables are directly associated and a result equal to zero 0, there is no linear relationship between the variables, see (Figure 5).

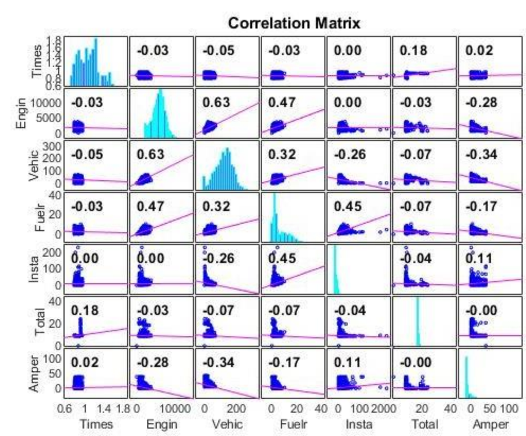


Figure 5. Correlation of Variables.

2.3. Linear Model

Through the use of Minitab software, the treatmentof a linear model was carried out, based on a multi-ple regression of several variables, which were already defined in the previous sections.

3. Results and Discussion

As a starting point, through multiple regression analysis and having as a study factor the instantaneous fuel consumption (l/100km), in which the variables detailed below are immersed.

Table 4. Variables of the balanced equation.

Abbreviation	Variable
X1	Engine RPM
X2	Vehicle speed
X3	Injection pulse
X4	Total fuel consumption
X5	Steering Amperage

It was possible to verify by means of the computer software that the 5 study variables present a relationship of 0.001, it can be verified in Figure 6; so it is defined as a statistically significant model.
Similarly in Figure 6, the model obtained can explain the behavior of instantaneous fuel consumption by approximately 49.14%, where it is noted that there are other variables, such as driving style, geographic variation and traffic vehicles that are immersed and therefore an optimal result cannot be obtained. Knowing the different factors that affect the decrease in the reliability percentage of the analysis, the analysis was carried out based on the speed ranges, presented in Table 5.

Table 5. Speed Ranges.

Speed	Values
Low	15 to 30 km/h
Mean	31 at 45 km/h
High	46 to 70 km/h

In this way, the reliability increases considerably, obtaining greater confidence at medium speed (Figure 8) and high speed (Figure 9) close to 100%; while at low speed (Figure 9), a result of 93.89% was obtained.

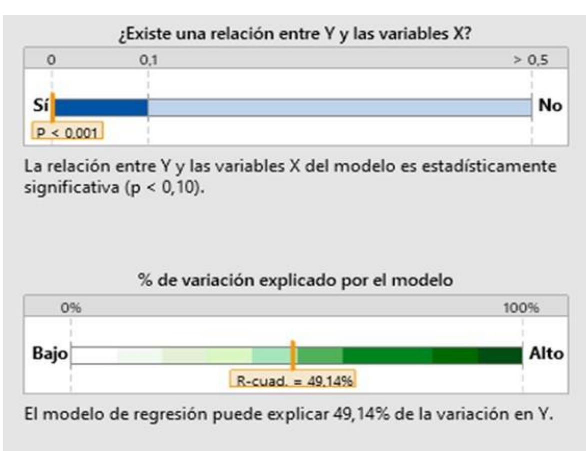


Figure 6. Reliability of the overall study.

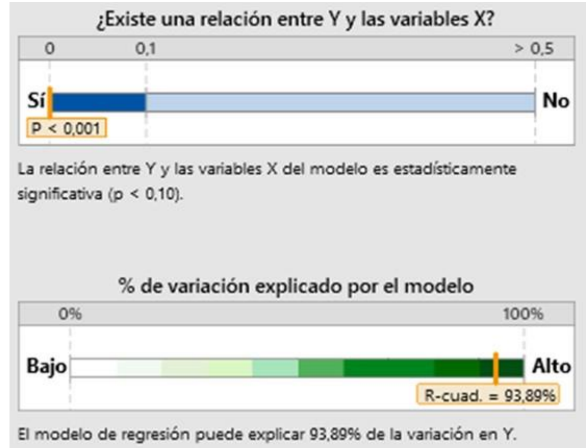


Figure 7. Low speed study reliability.

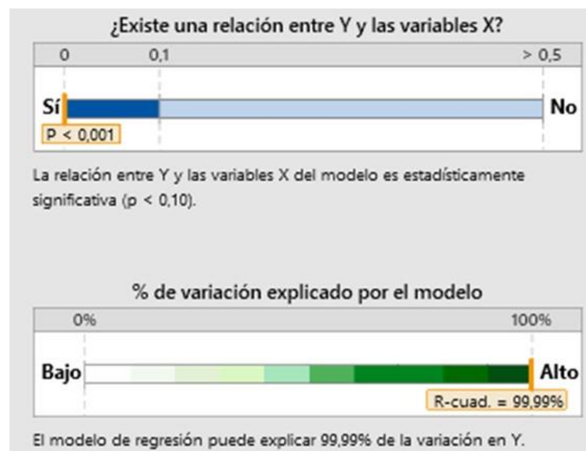


Figure 8. Moderate speed study reliability.

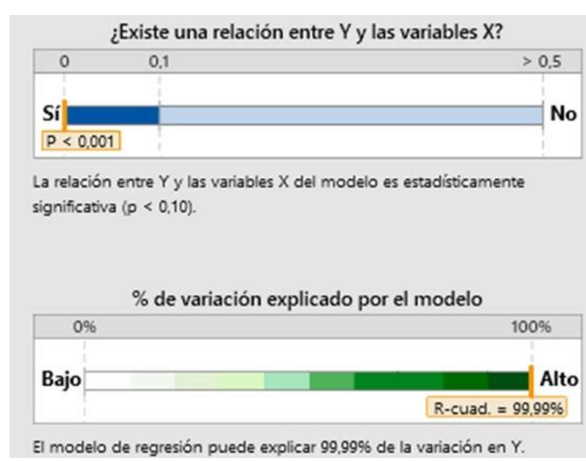


Figure 9. High speed study reliability.

From the previously stated variables and knowing that the critical behavior occurs at low speed , the mathematical model (3) shown below is generated:

- Instantaneous Fuel Consumption at Low Speed

$$
\begin{aligned}
= \; & 13,23 + 0,000273X_1 - 1,926X_2 + 11,89X_3 \\
& + 0,546X_4 + 0,5428X_5 + 0,05225X_2^2 \\
& - 0,00575X_5^2 - 0,00004X_1X_5 - 0,2885X_2X_3 \\
& - 0,0897X_3^2 - 0,02078X_2X_4 \\
& - 0,00923X_2X_5 - 0,01923X_4X_5
\end{aligned}
\quad (3)
$$

However, the models that will be presented below represent the instantaneous fuel consumption by part of the range of speeds previously exposed. Which synthesizes the consumption of three speeds: low, medium and high speed, defining:
At low speed it is displayed that the amperage consumption is higher and therefore the fuel consumption increases in relation to the degree of rotation of the steering, denoted based on the intensity that circulates through the EPS module. The consumption values obtained due to the speed effect are around 50 l/h (Figure 10).
In the Average Velocity, the trend of the curve of consumption versus speed and the amperage keeps decreasing, however, with reference to the speed the change occurs more proportionality while consumption compared to amperage, the trend occurs with less visualization, therefore, the reduction against low speeds we have a difference of approximately 30 l/h (Figure 11). And finally at high speed fuel consumption is 16 l/h (Figure 12).

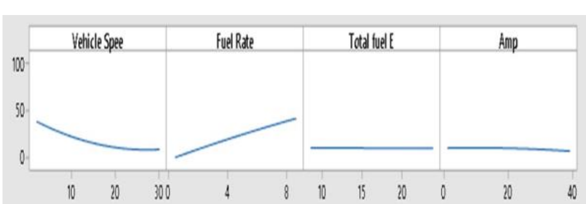


Figure 10. Behavior of variables at low speeds.

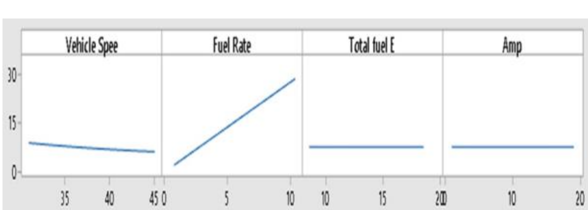


Figure 11. Behavior of variables at medium speeds.

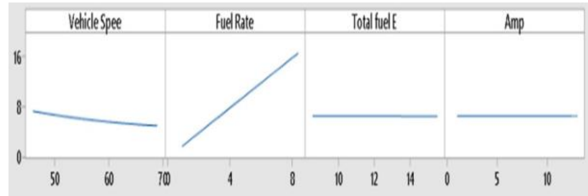


Figure 12. Behavior of variables at high speeds.

Based on these results, it is concluded that when you have medium and high speeds, There is a reductionin consumption of fuel, for management use, with 40%and 68% respectively compared to the low speeds.

In the following images, you can see the different events that are carried out during driving and fuel consumption versus turning radius and steering actuation.

Low Speeds

- Injection Pulse:
  Within this range, you can identify that the consumption of fuel is usually given for the steering use, with values from 27 l/100km to the 57 l/100 km of consumption instant fuel.

- Amperage:
  Here it is possible to identify that the consumption previously explained is given by the repetitive steering use with a consumption of 5 A, from 15A to 20A; Y by turns of the direction exceed 35A.

- Speed:
  In this first range the speed has little influence on the fuel consumption, as they return to low speeds, and the injection pulse is altered largely by steering, Figure 13.

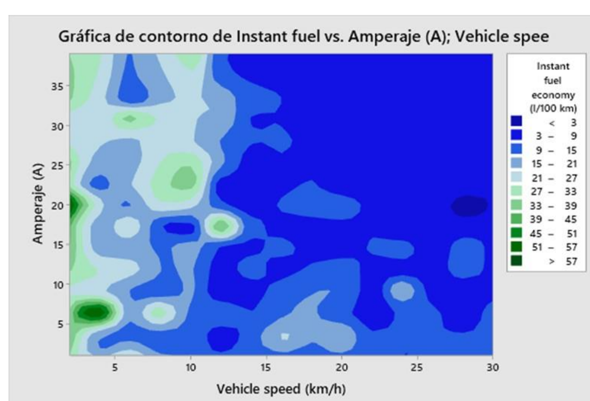


Figure 13. Instantaneous fuel consumption vs. amps vs. vehicle speed at low speeds.

Average Speeds

- Injection Pulse:
  Instant consumption of fuel in this range maximum is 24 l/100 km, while the consumption was reduced by about 58 % as for the pulse of injection refers.

- Amperage:
  Consumption per steering use is maintained present, but in a way lower than the previous one, radii of turns identified within the amperage are found over 10 A in speeds close to 32 km/h.

- Speed:
  Speed starts to be an incident factor in fuel consumption, because having speeds of about 45km/h you have the maximum consumption of 24 l/100km. Everything previously described can be identified in Figure 14.

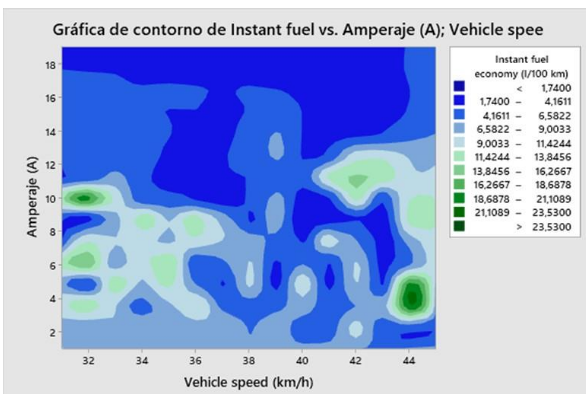


Figure 14. Instantaneous fuel consumption vs. amps vs. vehicle speed at average speeds.

High Speeds

- Injection Pulse:
  Fuel consumption at low speeds was significantly reduced, with values of up to 71%, concluding that the maximum consumption in this case is 16.5 l/100km.

- Amperage:
  The steering presents a brief glimpse of consumption of 9 l/100km, having a amperage draw up to 6 A, this regularly caused by imperfections inside of the road, and curves lesser degree of turning on expressways (Freeways).

- Speed:
  The speed more criticism at this point gave at 60 km/h, I feel the value considerable inside Of consumption produced by the width increment of pulse. This can be seen in Figure 15.

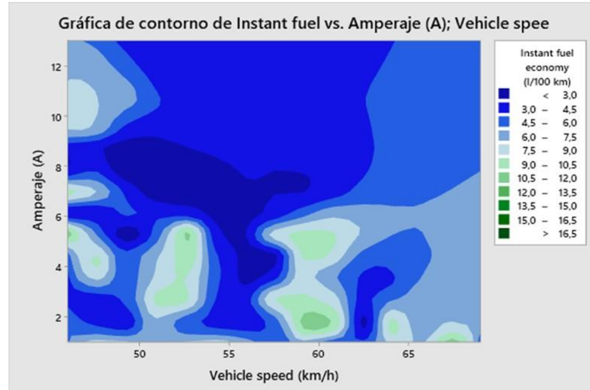


Figure 15. Instantaneous fuel consumption vs. amps vs. vehicle speed at high speeds.

Another relevant finding was the representation of the behavior of fuel consumption versus RPM, ve- hicle speed, fuel consumption total fuel and current consumed when actuating the steering. evidencing it following:

- There is higher fuel consumption in peak hours, since the speed of the vehicle is low, the speeds are between 25 km/h and 35 km/h.

- fuel consumption instantaneous presents a correlation with the injection pulse of 0.45, which indicates a great relationship between the two.

- fuel consumption instant is directly proportional to the degree of rotation of the steering, represented by the current consumption on the module of the EPS.

Once the evaluation of the statistical data through linear regression within the computer software, we proceeded to define the proposal of a compensation for the EPS steering system. From the results obtained in the current consumption measurement tests caused by the use of the steering in the vehicle, it can be established that, for avoiding such consumption is necessary use of a regeneration source energy, in order to meet the cost energetic. This proposal defines the use of a solar panel and a charge controller, which will supply electricity to the vehicle's 12V battery, thus allowing the energy accumulation.

This system will provide energy in the moment of critical consumption, which is carried out at low speeds,the average will then be presented. of consumption according to the three speeds.

Table 6. Average Critical Consumption.

Speed	Critical Consumption
Low	4.1 A
Means	2.2 A
High	1.8A

Considering the proposed system, will be based on the technical data of the solar module SLP100-12, to The following will detail the electrical characteristics [8].

Table 7. Electrical Characteristics.

Characteristics	Values
Max Power	100 W
Voltage at full power point	18.3 V
Open Circuit Voltage	22.1 V
Current at maximum power point	5.46 A
Short Circuit Current	5.89 A
Dimension	1062mm x 675mm

The charge regulator made up of a DC/DC converter 15V -10 A and regulator 10 amp 12/24 volt solar charging, It is presented as a device that controls the amount of electrical energy circulating from the solar module to the 12V battery, the characteristics are presented below.

Table 8. Converter technical data.

Characteristics	Values
Input voltage range	18V-36V
Output voltage	15 V
Output Current	10 A
Working Temperature	-20ºC to 80ºC

Table 9. Technical data of the Solar Charge Controller.

Characteristics	Values
Input voltage range	12V-24V
Output voltage	14.4 V
Input Current Range	10 A

Figure 16. Compensation system for 12V battery for Hyundai Accent 1.4l. [9]

4. Conclusions

The study carried out allowed the analysis of thefuel consumption produced by the use of the electro-assisted steering in a Hyundai Accent 1.4l internal combustion vehicle, within which different phases for the realization could be verified.

At the beginning of the study, sampling protocols werecarried out with which the quality of the sampling is guaranteed, taking into account the weight of the occupants, the auxiliary elements that were used at the time of data collection and the correct synchronization of the collection devices. of information.

After them, a linear model was generated that is cor- rectly coupled according to the variables by using the MINITAB software, in this way having as a result scat-ter graphs, within which it was possible to know the behavior of the incident factors of the study. Among the most relevant are the injection pulse, the speed of the vehicle, where different consumption curves are generated, resulting in critical fuel consumption of up

to 4.1 A at low speeds, generating 68% of consumption more compared to medium and high speeds. Finally, according to the result obtained, it was possible todefine the use of the solar panel system, whose pur- pose is the regeneration of energy to supply the energy expenditure consumed in the 12V battery, in this way, efficiency can be increased within the system. vehicle and therefore the fuel savings produced by the steering system.
It is recommended in further studies take into account the changes can be caused by the action of factors of noise, which may be present in the vehicle's electrical system, as well as also in the modules that were designed, which may vary the collection of information, Likewise, take into account that the vehicle driving is under action resulting in variations.

Acknowledgments

In this study, I want to extend my gratitude to the teachers who allowed to take out, to Ing. Juan Paul Ortiz, for facilitating the access to information on studies carried out previously, which served as a guide for the execution of this work; of the same Ing. Adrian Xavier Siguenza, who was the tutor and was directing with his knowledge and patience in the course of this publication.

References

[1] Agencia Nacional de Tránsito, "Anuario de Estadísticas de Transporte 2017", INEC, 2018.

[2] R.B.Cabezas Aguirre, "Análisis comparativo entre los sistemas de dirección Hidráulica y Eléctricapara determinar el consumo de combustible en un vehículo de 1300 cc" 2018.

[3] Hyundai, "Ficha Técnica Accent", Hyundai , 2018.

[4] O. F. Condori Cute, "Evaluación y comparación del sistema de dirección asistida hidráulica y electrónicamente, mediante un simulador didáctico EPS", 2015.

[5] D. Pebe ,"Tipos de Dirección Asistida", 2018.

[6] R. Sandoval, "Estudio del sistema de dirección asistida electrónicamente",2016, [Online]. Available: https://silo.tips/download/capitulo-1-estudio- del-sistema-de-direccionasistida-electronicamente- eps.

[7] A. Méndez, M. Cely, and W. Monar, "Diseño del Sistema de Freno Regenerativo de Automóviles Híbridos", Revista Politécnica, Vol.37, No. 2, 2016.

[8] J.F. Parapi, G.I Pesantez,"Implementación de un sistema generador de carga eléctrica, utilizando paneles solares, para el incremento de la autonomía de un vehículo eléctrico KIA SOUL", Cuenca, 2020.

[9] N.J. Reyes, "Diseño de un sistema regenerativo de cargas de baterías con paneles solares para un vehículo eléctrico KIA SOUL", Cuenca, 2018.

[10] J. Calvo, "Mecánica del automóvil actual", Reverte,1997.

[11] Km77.com, "Ángulo de deriva y agarre lateral", 2014, [Online]. Available: https://www.km77.com/tecnica/bastidor/angderiva/t04.asp.

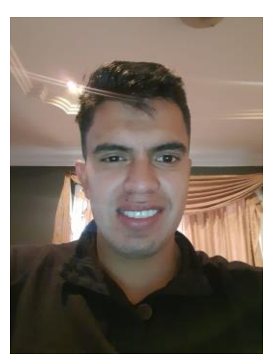
[12] L.A García, F.L. López, C. G. Moreno, and C. C. Ortigosa, "El método experimental profesional en el proceso de enseñanza–aprendizaje de la Química General para los estudiantes de la carrera de ingeniería mecánica,» Scielo, vol.30 no.2, 2018.

[13] D.A. Neill, and L. Cortez, "Procesos y fundamentos de la investigación cientifica", Machala, Ecuador, Editorial UTMACH,2018.

[14] F. Supervielle,"Revista digitalsobre armamento, defensa y fuerzas ar- madas", 2021, [Online]. Available: https://www.revistaejercitos.com/2021/05/03/introduccion-a-la-guerraelectronica-naval/.

[15] I. K. Quezada, "Modelo de Negocios para la creacion de una cooperativa de taxis electricos en la ciudad de Cuenca", 2018.

[16] B. A. Lima and E. J. Galvez, "Análisis de consumode combustible de los vehiculos de categoria M1 que circulan en el centro histórico de la ciudad de Cuenca en horas de máxima demanda en función de ciclos de conducción", 2016, [Online].



Author C. Arias. Born in Cuenca-Ecuador on November 16, 1996. He finished his primary studies at Pio XII School, the secondary studies were at Abdon Calderon High School, his undergraduate studies were at Salesian Polytechnic University from 2015 to date.