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Impact of start-stop systems on motorcycle fuel savings in urban traffic

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ABSTRACT

The start/stop (S/S) system implemented in motorcycles aims primarily at fuel savings. This study was conducted to assess the effectiveness of this system in conditions of heavy traffic and traffic lights in Lima, using a virtual channel identifier (VCI) and a technical schedule. The detailed analysis covered critical aspects of the S/S system, the description of the route taken, and its segmentation to understand the number of stops and mileage. Speed limits, schedules, and measurement equipment were established, including the MICODUS-ORBD2 device and the VCI-Hero. The study included tests conducted with and without the MICODUS-ORBD2 device, recording times, distances, and fuel consumption. Data were collected with the S/S activated and deactivated, concluding the system achieves a 10.1% fuel saving. This finding provides valuable insights into understanding the system's effectiveness in actual traffic conditions and emphasizes the importance of maintaining key vehicle components to optimize S/S performance.

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1. INTRODUCTION

In the early 1980s, companies such as Volkswagen (VW Polo) and Fiat (Fiat Regata) stood out by offering the first start-stop (S/S) systems in their vehicles. Nowadays, most car manufacturers have adopted this technology in their models [1]–[5], including brands like Bayerische Motoren Werke (BMW), Mazda, Honda, and VW. However, in the European market, four significant suppliers primarily offer this technology: Bosch, Denso, INA (Schaeffler Technologies), and Valeo [6]–[8]. The S/S system stands out as an optimal technology that significantly contributes to fuel consumption reduction and emissions [1], [9]–[14]. Currently, it has become the epicenter of the automotive industry.

The research around the S/S system primarily focuses on two key aspects: the improvement of relevant system components such as the engine, battery, and sensor, among others [4], [15], [16], and the refinement of the S/S control strategy, which includes coordinating engine start and stop, among other aspects [17]. The S/S system faces two main challenges: ineffective engine stops in idle situations, and the frequent sequences of the vehicle start and stops, which can result in a decrease in fuel savings and premature wear of vehicle parts [11], [12], [18]–[20]. Therefore, optimizing the S/S system's control strategy can positively impact its overall performance. The fundamental control strategy of an S/S system is based solely on considering the drivers' intent and the state of the vehicles, without considering the influence of common issues such as inefficiency during times when the car is running but stationary, either due to traffic situations or extended pauses, resulting in unnecessary gasoline consumption. These periods are referred to as idle stops

[13], [21]–[23]. During these phases, the engine continues running without an immediate purpose, leading to fuel waste without significantly contributing to the vehicle's displacement.

In the context of growing global energy scarcity and environmental concerns, energy-saving and emission-reducing technology has become a matter of public interest. Electric vehicles, despite being emission-free, face limitations in range and costs. A more accessible and efficient solution is the S/S system, which is integrated into conventional cars. This system automatically turns the engine on and off, reducing fuel consumption and emissions in traffic situations such as traffic jams [6], [17], [21]–[23].

Three approaches were applied to assess the impact of the S/S system on a four-wheel-drive diesel vehicle. These included carbon dioxide (CO_2) emissions measurements, a modal statistical analysis, and a calculation of the energy emission factor. The results of these methods indicate a significant reduction in CO_2 emissions in real urban traffic situations, showing a decrease of 20% at an average speed of 15.5 km/h. This reduction is partially due to engine modifications and the absence of idle emissions. The modal statistical analysis helps explain the variability in CO_2 emissions in real traffic situations. The energy emission factor analysis supports the notion that the decrease in CO_2 emissions is due to an overall improvement in the vehicle's energy efficiency with the S/S system [24]–[26]. On the other hand [4], [27]–[37] analyzed the process dynamics, conducting a simulation to compare fuel efficiency between a reference vehicle and one equipped with an intelligent S/S system. The simulation was performed using MATLAB and ADVISOR software in the European New Driving Cycle (NEDC). Subsequently, motor start-up and emissions tests were carried out on a vehicle with an intelligent start/stop system using a standard chassis dynamometer. Fuel consumption per kilometer in the car equipped with the S/S system decreased by 3.63% compared to the reference model, and the fuel savings test results aligned with the simulation.

Unlike cars, motorcycles have specific engine power and responsiveness requirements, which are reflected in the fuel consumption of both vehicles, with cars having more references. The effectiveness of the S/S system in motorcycles, especially in traffic and urban driving situations, poses additional challenges. In this context, the following question arises: Can the S/S system in motorcycles provide significant fuel savings? It is essential to address this issue, given the uniqueness of motorcycles and the need to assess whether this technology can effectively adapt to their specific characteristics.

2. METHOD

The S/S system is composed of a key switch, start switch, capacitive discharge ignition (CDI), clutch switch, neutral switch, ignition coil, alternating current generator, revolutions per minute (RPM) sensor, rectifier or voltage regulator, relay, fuses, sensors, and battery. With all this in mind, to verify if the S/S system allows fuel savings, a data collection analysis was performed using a device known as the virtual channel identifier (VCI) and a technical schedule through which information about the established route is collected. Subsequently, this information is compared to determine if the S/S system provides significant fuel consumption savings.

2.1. Ignitor 125 5G-HERO

The Ignitor 125 5G motorcycle, as evidenced in Table 1, began production in 2022 and has emerged as one of the most popular low-displacement vehicles in India and Latin America. Not only has it achieved notable commercial success, but it has also been recognized as a pioneer in adopting the S/S system to optimize fuel savings. Its ability to effectively implement the S/S system distinguishes it as a benchmark in the industry, paving the way for other vehicles in its category.

Table 1. Technical specifications

Specifications	Feature
Engine (cc)	124.7
Number of cylinders	1
Power (hp)	11.1
Engine type	4-stroke OHC chain
Compression ratio	10:01
Bore×Stroke (mm)	52.4×57.8
Ignition system (V)	CDI 12
Front and rear suspension	Telescopic forks and lateral shock absorbers
Brakes	Ventilated disc
Front and rear pneumatic	80/100/18/90/90/18

2.2. Route delimitation

The highlighted route includes numerous stops at traffic lights and has been strategically planned for a more detailed analysis. The route is divided into five parts: from Jicamarca to Bayóvar, from Bayóvar to La Cultura station, from La Cultura station to Marina, from Marina to Comas, and from Comas to Jicamarca, as illustrated in Figure 1 for better understanding. This subdivision aims to calculate the number of stops per location and monitor the moments of activation of the S/S system to evaluate fuel consumption. This route is ideal for research as it tests the S/S system by containing numerous stops in each journey segment.

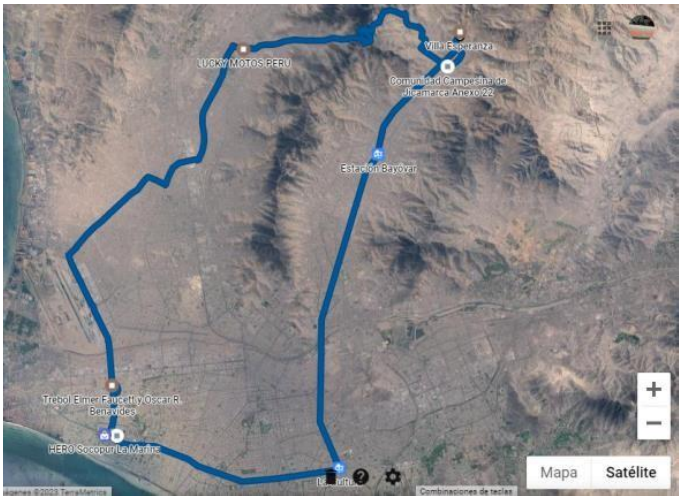

Figure 1. Route mapped in Lima to represent urban driving in Peru

2.3. Average speed

For road safety, variations in speed limits were identified during the route journey, as detailed in Table 2. A rider and a motorcycle were involved in conducting this study. The journey commenced at 8:00 am and was extended until 6:00 pm to gain insights into travel conditions and the motorcycle's behavior at different times. This time-focused approach aimed to capture traffic conditions and other factors that could influence the performance and efficiency of the evaluated S/S system in the study.

Table 2. Speed ranges in Lima-Peru

Location	Average speed (Km)	Limit speed (Km)
Jicamarca	30–40	60
Av. Los Próceres – San juan de Lurigancho	30–40	60
Cercado de Lima – San Borja	30–40	60
Marina - Callao	30–40	60
Av. Universitaria – Comas	40–80	90
Pasamayito – Jicamarca	30–40	60

2.4. Measurement equipment

2.4.1. Device MICODUS–ORBD2

The MICODUS–ORBD2 device is a global positioning system (GPS) fleet management software. It stands out for its remarkable user-friendly interface, as it only requires connection to the vehicle's ORBD-II connector. This device provides a wide range of real-time data from the mobile application without needing prior user experience. The most relevant data it offers are real-time fuel consumption, battery status, vehicle speed, and precise geolocation.

2.4.2. VCI-Hero

The VCI-Hero is a specialized electronic tool for diagnosing motorcycle issues. It provides functions such as reading and clearing error codes, real-time data display, adjustments, engine control unit programming, and connecting to the bike through a diagnostic port. These tools are essential for service technicians, motorcycle owners, and enthusiasts who aim to keep their bikes in optimal operating conditions and troubleshoot electronic problems.

2.5. Information before the comparative fuel consumption study

To analyze the consumption values, the route was evaluated considering the traffic and departure time, highlighting that, at approximately 8:00 am and 6:00 pm, the peak hour with the highest traffic on the initial route is presented. Route data type forms were created, focused on research, and guidelines were established to be followed before starting each test on the road, thus ensuring accurate information collection. Within this point, the quantities of traffic lights in the city are being considered since it tests the S/S, as shown in Table 3.

Table 3. Traffic lights in Metropolitan Lima and distance covered

Route	N° Traffic light	Distance (Km)	Coordinates
Av. Naciones unidas Jicamarca	1		11.9124, -76.9541
Av. Proceres de la independencia – S.J. L	30	10.5	-11.9591, -76.9871
Av. Rivaguero – El Agustino	18	8.5	-12.0528, -77.0102
Av. Aviación – La Victoria	17	5.8	-12.0869, -77.0036
Av. Javier Prado	10	2.9	-12.0918, -77.0289
Av. La Marina	11	8.1	-12.0752, -77.0975
Av. Elmer Faucett	15	8.6	-12.0388, -77.0995
Av. Universitaria	18	15.9	-11.9723, -77.0760
Av. Pasamayito – Collique con Jicamarca	5	14.3	-11.9127, -77.0005
Total	125	74.6	

2.6. Test without MICODUS–ORBD2 device

The Ignitor 125 5G motorcycle is equipped with an advanced instrument panel that provides detailed information on fuel consumption and performance, adapting to the driver's mode of operation. After obtaining detailed data according to Table 1, a process involving the full tanking of fuel and the completion of a specific route, as indicated in Figure 1. The results of this operation are reflected in Tables 4 and 5, detailing the tank filling before and after the journey, respectively.

Table 4. Data obtained with S/S without Micodus-ORBD2

Route data	Day 1	Day 2	Day 3	Day 4
Segment	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana
Tank capacity (l)	10.9	10.9	10.9	10.9
Premium gasoline price per liter (soles)	4.84	4.84	4.84	4.84
Date	05/09/2023	06/09/2023	07/09/2023	08/09/2023
Test	1	2	3	4
Departure time	08:00	08:00	08:00	08:00
Stop time	46.6	48.2	45.1	48.6
Arrival time	18:04	18:15	17:57	18:20
Rout time (min)	604	615	597	620
Number of S/S stops	134	139	125	160
Distance traveled (Km)	73.2	74	73.1	74.1
Fuel consumption per route (l)	1.33	1.35	1.32	1.34
Cost per route (soles)	6.44	6.53	6.38	6.48

Table 5. Data obtained without S/S with Micodus-ORBD2

Route data	Day 1	Day 2	Day 3	Day 4
Segment	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana
Tank capacity (L)	10.9	10.9	10.9	10.9
Premium gasoline price per liter (soles)	4.84	4.84	4.84	4.84
Date	19/09/2023	20/09/2023	21/09/2023	22/09/2023
Test	1	2	3	4
Departure time	08:00	08:00	08:00	08:00
Arrival time	18:03	18:07	18:00	18:32
Rout time (min)	602	606	657	631
Distance traveled (Km)	73.4	73.6	74.1	72.7
Fuel consumption per route (L)	1.48	1.49	1.5	1.47
Cost per route (sole)	7.16	7.21	7.26	7.11

2.7. Test with MICODUS–ORBD2 device

The MICODUS–ORBD2 device was connected to corroborate the unit's information. Despite the connection, obtaining the data automatically through this system was impossible. Faced with this limitation, manual data collection was conducted to compare and verify the information obtained manually and through the mentioned system. Tables 6 and 7 detail the collected data, comparing the information obtained manually and the information recorded by the MICODUS–ORBD2 device.

Table 6. Journey with S/S with MICODUS–ORBD2

Route Data	Day 1	Day 2	Day 3	Day 4
Segment	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana
Date	05/09/2023	06/09/2023	07/09/2023	08/09/2023
Departure time	08:01	08:00	08:03	08:01
Arrival time	18:04	18:15	17:57	18:20
Route time (min)	604	615	593	619
Stop time for start/stop system (min)	46.6	48.2	45.1	48.6
Initial mileage (Km)	0	73.2	147.2	220.4
Final mileage (Km)	73.2	147.2	220.4	294.5
Estimated consumption (L)	1.33	1.35	1.32	1.34

Table 7. Journey without S/S with MICODUS–ORBD2

Route Data	Day 1	Day 2	Day 3	Day 4
Segment	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana	Lima Metropolitana
Date	19/09/2023	20/09/2023	21/09/2023	22/09/2023
Departure time	08:01	08:01	08:03	08:01
Arrival time	18:03	18:07	18:00	18:32
Route time (min)	602	606	657	631
Initial mileage (Km)	0	73.4	147	221.1
Final mileage (Km)	73.4	147	221.1	293.8
Estimated consumption (L)	1.48	1.49	1.5	1.47

2.8. Fuel consumption result

The following results reflect weeks of real-time testing to evaluate the start/stop (S/S) system in both activated and deactivated modes. During these tests, the system's flexibility in response to variations in fuel consumption was observed, particularly during periods of exponential traffic, considering the context of Lima, a densely populated city facing challenges such as accidents, rain during the winter season, and breakdowns. These combined factors result in increased fuel consumption, and it is in these situations that the S/S system comes into play, as seen in Figure 2.

Based on the results presented in Figure 2, we can conclude that implementing the S/S system in motorized vehicles using (1) results in a fuel saving of 10.1%. This saving is achieved by applying the principle of S/S control, which involves turning off the engine when the vehicle is idle and restarting it through clutch action. In addition to the evident economic benefits in terms of fuel savings, this practice also contributes to improving the user's economic efficiency.

$$\%\ fuel\ savings = \left(\frac{value\ without\ S/S - value\ with\ S/S}{value\ without\ S/S}\right) \quad (1)$$

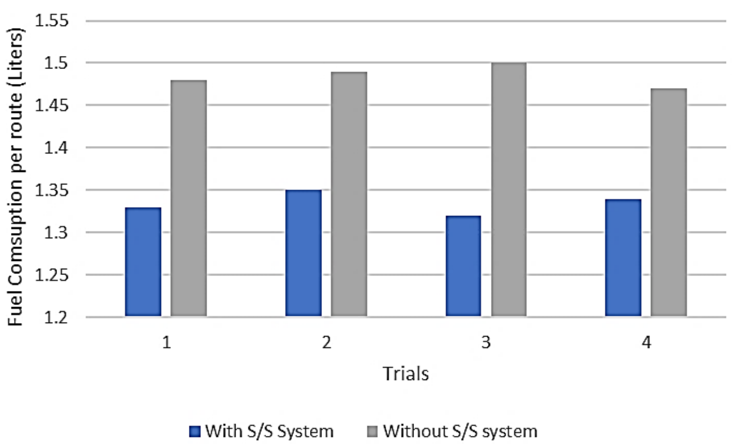

Figure 2. Fuel consumption data (liters) per route in Metropolitan Lima

3. CONCLUSION

An assessment of the fuel consumption of a Hero Ignitor 125 5G motorcycle equipped with the S/S system was conducted, both activated and deactivated. Selecting a route with numerous traffic lights and dense traffic provided a conducive environment for the tests. To evaluate fuel consumption, the vehicle was scanned to obtain the real-time fuel level multiplied by the tank capacity. This methodology allowed for calculating consumption in kilometers traveled. The S/S system demonstrated a fuel saving of 10.1%, as it shuts off the engine during brief stops, reducing fuel consumption compared to cars, which provided a 5.3% fuel saving. However, for future research, assessing the wear and tear of the engine and components associated with the S/S system is crucial. This is because, depending on the frequency of stops due to traffic lights and congestion, the vehicle may experience a higher number of ignition and shutdown cycles, potentially impacting the long-term performance of these components.

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