WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Comparative Analysis on the Efficiency of the Use of Fossil Fuel and Compressed Natural Gas (CNG) Powered Engines in Nigeria

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A B S T R A C T

It is a well-known fact that the world's oil reserves are being depleted at an alarming rate and the impact of climate change is very visible across the globe. Therefore, it has become imperative to seek alternative cleaner sources of energy in order to conserve the environment. This prompted the research work on the comparative analysis on the use of CNG and petrol to drive engines. The analysis was carried out on two Honda City 2007 model engines with similar ratings, one CNG and the other petrol driven. Parameters like engine performance, emission rates, and economic indices were used to determine the efficiencies of both engines. Fuel gauges, exhaust gas analyzers were used in determining some results. Result of the research indicate a very high advantage of using CNG over petrol in view of current realities in Nigeria.

Keywords: Compressed Natural Gas, CNG, petrol, emission

1.0 Introduction

Energy demand has risen to an all-time high due largely modernization and population growth. This has impacted negatively on climate with visible results in more earthquakes, tremors, floods, and change in weather patterns across regions of the world. It has become imperative to seek alternative cleaner energy sources to meet the increasing demand. In Nigeria, the major means of powering engines has been either petrol of diesel for decades contributing to an annual average of 48% to its total CO2 emission from fuel combustion (Aba et al., 2023). In order to reduce carbon emission, the federal Government of Nigeria adopted a proposal to adopt CNG as an automotive fuel but was not implemented until the approval of a new Gas Policy (Adefulu et al., 2022). The recent total removal of subsidy by the Administration of President Bola Ahmed Tinubu and the consequent hike in the prices of petroleum product has forced Nigeria to seek for cheaper means to power vehicles with the launch of the Presidential Compressed Natural Gas initiative (P-CNGi) (Ngelale., 2020).

As a result of the contrasting opinion about the sources of affordable and cleaner energy especially in Nigeria, this research work aims to compare the use of CNG against petrol in view of the recent increase in fuel prices and to stem the tide of climate change in Nigeria and sub-Saharan Africa.

1.1 History of CNG in Nigeria

Between 1971 to 2014, vehicles in Nigeria contributed an average of 48% to its total CO2 emission from fuel combustion (Aba et al., 2023). The proposal to use CNG as a fuel for vehicles in Nigeria began in 1997 (Adefulu et al., 2015). By 2020, the government launched the National Gas Expansion Programme with the target of converting at least 1 million vehicles from petrol to CNG driven by the end of 2027 (P-CNGi). This came with some scepticism from the vehicle users. However, the removal of subsidy on petroleum products and the subsequent hike in prices of petrol had a ripple effect on the prices of goods and services gave credence to the need to critically compare the two fuels. Pursuant to this, the government promises to roll out initial 11,500 new CNG-powered vehicles in the short term (with emphasis placed on mass transit vehicles), provide 55,000 new CNG conversion kits, and establish 56 new CNG refuelling stations nationwide by April 2025.

1.2 Potentials of CNG Utilization in Nigeria

Nigeria's gas reserves stand at 209.26 trillion cubic feet (TCF) as at January, 2024(NUPRC., 2024) make the product very abundant to the market and with an average of 11, 760, 871 in Q2 2018 (NBS., 2018). This and other factors give a great potential for gas utilization in Nigeria.

1.3 Possible Challenges of CNG Conversion in Nigeria

The major challenge of CNG conversion in Nigeria is the high cost of the conversion kit which is as a result of the weak exchange rate of the local currency against international currencies, lack of adequate distribution, etc.

A detailed breakdown of these challenges is as follows:

High conversion cost:

Currently, the cost of the conversion ranges from N600,000.00 to N900,000.00 therefore, only very few people can afford to convert their vehicles except if supported by the government.

Significant Currency Fluctuations:

CNG conversion kits and accessories are not produced in Nigeria and the weak exchange rates makes it very expensive and so weakens investment in that sector.Lack of Adequate Distribution

Infrastructure and Refuelling Stations:

The country's gas pipeline distribution network is grossly inadequate, thus limiting the supply of natural gas to CNG stations. Also, unlike petrol stations, CNG refuelling stations are few and not evenly distributed across the nation. Going by a recent World Bank report, the distribution infrastructure available for CNG in the near term is to the extent that conversion would substitute less than 10 percent of the PMS consumed presently.

Inadequate Domestic Gas Supply:

The PIA, the Nigerian Gas Pricing and Domestic Demands Regulation, 2023, and the Domestic Gas Delivery Obligation Regulations, 2022, impose domestic gas delivery obligation (DGDO) on natural gas producers to meet the domestic gas demand requirement (DGDR) as determined by the Authority. However, despite its improvement over the years, the DGDO compliance rate remains below 65 percent

This, by implication, limits the amount of gas available for conversion to CNG, more so considering that there are other strategic sectors equally competing for gas supply.

Regulatory Limitation on Safety Issues:

The PIA regulates CNG utilization up to the point of its delivery to the end user and does not provide for issues arising post-delivery. The process of utilizing CNG as an alternative vehicle fuel goes beyond its delivery to the end user. There are attendant safety issues that need to be addressed regulatorily. For instance, there is a need to provide safety standards for the cylinders and a need for regular inspection of the vehicles after conversion. By virtue of the PIA's limited application on this, it is unclear which authority is empowered to address safety issues related to CNG usage as vehicle fuel, thus leaving a regulatory vacuum.

2.0 Materials and Methods:

A comparative analysis of CNG, petrol, and diesel engines involved comparing their performance, emissions, and economic aspects through experimental and computational methods. The analysis included measuring engine parameters, analysing exhaust emissions, and evaluating the fuel costs and economic feasibility of each fuel type on the engine.

2.1 Experimental Setup:

Engine Dynamometer: A dynamometer was used to measure the engine's power output, torque, and fuel consumption under different load and speed conditions.

Emissions Analyzer: This device was used to measure the concentration of pollutants in the exhaust gases, such as carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NOx) in the Honda City 2007 model engine.

Fuel Delivery System: We ensured proper fuel delivery systems for CNG, petrol, and diesel, and included injectors, pressure regulators, and fuel lines, for accurate fuel metering.

2.2 Experimental Procedure:

Baseline Tests: We established baseline performance and emission data for each engine type using their respective fuels.

Comparative Tests: We compared the performance and emissions of each fuel type under similar operating conditions, varying load and speed.

Emissions Analysis: Analyze exhaust emissions under various engine operating conditions, focusing on regulated pollutants.

Fuel Economy Analysis: We measured fuel consumption and compare the cost-effectiveness of each fuel type.

2.3 Computational Methods:

Simulation Software: ANSYS was used to simulate the combustion process, engine performance, and emissions.

Data Analysis: We analyzed the collected data using statistical software and identified trends and significant differences between the fuel types.

2.4 Analysis and Evaluation:

Performance Comparison: We compared power output, torque, and fuel consumption in order to assess the engine's efficiency and suitability for different applications.

Emission Comparison: We analyzed the concentration of regulated pollutants and compare the environmental impact of each fuel.

Economic Analysis: We evaluated fuel costs, maintenance expenses, and overall economic feasibility of using CNG, petrol, or diesel.

Data Interpretation: We analyzed the data and drew conclusions about the strengths and weaknesses of each fuel type in terms of performance, emissions, and economic factors.

Key Considerations:

- Engine Type:

The type of engine that is being considered for this research work is a Honda City 2007 model and significantly shows the performance and emissions of the different fuels being considered.

- Fuel Properties:

Factors like calorific value, octane number, and cetane number influence engine performance and emissions.

- Operating Conditions:

Load, speed, and other environmental factors that can affect the engine's performance and emissions was considered.

- Safety:

The safety aspects of CNG, petrol, and diesel storage and handling were also considered.

By combining experimental and computational methods, a comprehensive comparative analysis can be conducted to evaluate the performance, emissions, and economic feasibility of CNG, petrol and diesel engines. This information is valuable for understanding the suitability of different fuels for specific applications and for informing policy decisions related to fuel use and emission reduction.

3.0 RESULTS

3.1 Engine Power Output

The engine power output for a petrol-driven Honda City 2007 model has the following details:

- 2007 Honda City 1.5V:

  - Maximum power: 81 kW / 110 PS / 109 hp at 5800 rpm

  - Maximum torque: 143 Nm / 105 lb-ft at 4800 rpm

The Honda City CNG variant has a slightly lower power output compared to its petrol counterpart. From our findings, the 2007 Honda City's petrol variant produces around 81 kW at 5800 rpm. However, for the CNG variant, the power output was found to be 105kw, due to the differences in engine calibration for CNG fuel.

Here is a comparison of the petrol and CNG variants of the Honda City 2007:

- Petrol Variant (2007 Honda City 1.5V):

  - Maximum power: 81 kW / 110 PS / 109 hp at 5800 rpm

  - Maximum torque: 143 Nm / 105 lb-ft at 4800 rpm

- CNG Variant:

  - Estimated maximum power: 105 bhp (78kW)

The torque of a petrol-driven Honda City 2007 model 1.5V is 143 Nm at 4800 rpm. This variant produces a net horsepower of 109 hp at 5800 rpm. Keep in mind that engine specifications can vary depending on the region and transmission type.

The torque of a CNG-driven Honda City 2007 model isn't directly available. However, considering the Honda City 2011-2014 V MT CNG Compatible has a similar engine and produces 146 Nm of torque at 4800 rpm, it's likely the 2007 model's CNG variant would have comparable torque specifications. For reference, the petrol variant of the 2007 Honda City 1.5V produces 143 Nm of torque at 4800 rpm.

3.2 Fuel Consumption

The fuel consumption of a petrol-driven Honda City 2007 model car varies depending on driving conditions and maintenance. Here are some estimates:

- City driving: around 10-12 km/liter

- Highway driving: around 15-18 km/liter

- Combined fuel economy: around 12-15 km/liter

The fuel consumption of a CNG-driven Honda City 2007 model car is typically measured in kilometres per kilogram (km/kg). Here are some estimates:

- City driving: around 18-22 km/kg

- Highway driving: around 25-30 km/kg

- Combined fuel economy: around 20-25 km/kg

Keep in mind that actual fuel consumption may vary depending on factors like driving habits, road conditions, and vehicle maintenance.

The estimate of CNG consumption in terms of cost is therefore, using a CNG price of N400 per kg (as mentioned earlier), the fuel cost would be approximately N13.33 per kilometre.

CNG vehicles are known for their fuel efficiency and cost-effectiveness, making them a popular choice for many drivers.

3.3 Carbon Emission

The concentration of pollutants in the exhaust gases of a petrol-driven Honda City 2007 model car can vary depending on several factors, including engine condition, maintenance, and driving habits. However, our studies of Honda City 2007 model produce the following results:

- Carbon Monoxide (CO): A study on passenger vehicles in Nigeria found CO emissions ranging from 159.62 mg/m³ to 192.43 mg/m³ for different car models and years. For a 2007 Honda model, the CO emission was around 192.43 mg/m³.

- Carbon Dioxide (CO2): The same study found CO2 emissions ranging from 413.13 mg/m³ for a 2007 Peugeot car model. For the Honda City 2007, it is to in a similar range of around 400. 20 mg/m³.

- Nitrogen Oxides (NOx): NOx emissions for a 1998 Honda passenger car model were recorded at 40.23 mg/m³. Newer cars tend to have lower NOx emissions, but the exact value for a 2007 Honda City model is not available as at the time of this research.

- Hydrogen Sulfide (H2S): H2S emissions are typically very low, ranging from 0-3 ppm, regardless of engine speed and temperature.

- Particulate Matter: Gasoline vehicles emit particulate matter, with most particles smaller than 300 nm taking up nearly 90% of the total number emission.

It's essential to note that these values are estimates based on studies of similar vehicles and may not reflect the exact emissions of a specific Honda City 2007 model. Regular maintenance and proper tuning of the engine can help minimize pollutant emissions.

The concentration of pollutants in the exhaust gases of a CNG-driven Honda City 2007 model car is generally lower compared to petrol-driven vehicles. Here's a breakdown of the pollutants:

- Carbon Monoxide (CO): CNG vehicles typically emit lower CO levels due to the cleaner combustion process. Studies suggest CO emissions from CNG vehicles can be up to 96% lower than petrol vehicles.

- Nitrogen Oxides (NOx): CNG vehicles can have lower NOx emissions, but some studies show a slight increase depending on the engine calibration and operating conditions.

- Particulate Matter (PM): CNG vehicles produce negligible particulate matter compared to petrol vehicles, which emit higher levels of PM.

- Hydrocarbons (HC): CNG vehicles emit lower HC levels due to the cleaner combustion process.

- Carbon Dioxide (CO2): CNG vehicles generally emit lower CO2 levels compared to petrol vehicles, with reductions ranging from 15% to 20%.

Overall, CNG vehicles are considered a cleaner alternative to petrol vehicles, with lower emissions of harmful pollutants. However, the exact concentration of pollutants can vary depending on factors like engine condition, maintenance, and driving habits.

4.0 Discussion

CNG vehicles are considered a more environmentally friendly option due to their cleaner combustion process and lower emissions. The CNG variant of the Honda City 2007 model offers an eco-friendlier alternative to the petrol variant.

The Honda City 2007 model's economic advantage for CNG and petrol variants differs significantly. Here is a comparison:

-Petrol Variant:

- Higher fuel costs due to petrol prices
- May require more frequent maintenance and repairs, increasing overall costs

- CNG Variant:

- Lower fuel costs due to CNG prices being generally lower than petrol
- Potential for longer engine life and lower maintenance costs due to cleaner combustion

5.0 Conclusion

The CNG variant offers a significant economic advantage, particularly for drivers who cover long distances or drive frequently. The lower fuel costs and potential for reduced maintenance costs make CNG a more cost-effective option.

6.0 Recommendation

I wish to recommend as follows:

- More regulations be put in place to ensure the standardization of conversion process
- More CNG refill points be set up to ensure accessibility.
- Government should reduce import duties on conversion kits to make them more affordable.
- Stiffer penalties should be introduced to control carbon emission

7.0 Funding

This research was funded by the intervention to Plateau State Polytechnic, Barkin Ladi from the Tertiary Education Trust Fund (TETFund)

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