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ENHANCING FUEL EFFICIENCY AND COMBUSTION THROUGH MODIFICATION OF CARBURETOR-CONTROLLED SINGLE-CYLINDER SPARK IGNITION ENGINES— A REVIEW

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ABSTRACT

Fuel efficiency and emission control are geared toward energy-saving policy and environmental protection respectively. Modification of conventional fuel metering systems such as carburetors has been identified as a step forward in achieving this objective. The rationale behind this review is to have basic knowledge of the choice of engine suitable for retrofitting for enhanced engine efficiency and combustion improvement. In particular, a motorcycle engine using a traditional carburetor is retrofitted with a fuel-injection unit by swapping out the carburetor and manifold sections while retaining traditional parts such the engine and the electrical systems, this optimizes the air mass flow rate into the engine at a given time to mix with the correct amount of gasoline so that the amount of fuel produced is accurate for complete combustion and emission reduction. This review concludes that by retrofitting (FIS) into the existing engines to replace carburetors, the new technology is capable of saving cost, increasing fuel efficiency, and reducing exhaust emissions

KEYWORDS: Fuel efficiency, Carburetor, Emissions, Fuel injection system, and Combustion.

INTRODUCTION

In the past, carburetors (CARB) were used to regulate how much fuel and air entered the combustion chambers in small-capacity engines such as motorcycles (Muslim et al., 2014), however, there are currently two methods of fueling small gasoline engine, systems: namely electronic fuel injection (EFI) and carburetor systems (Archer & Bell, 2001). Small engines with high power-to-weight ratios and low emissions are in high demand (Mason & Lawes, 2024). This is because the EFI system has better fuel efficiency, higher power output, and lower emissions characteristics than the conventional fueling method (Mohammed et al., 2021).

According to (Komuro et al, 2005) EFI can reduce carbon monoxide (CO) and hydrocarbon (HC) emissions by up to 36% and 75%, respectively, while increasing fuel economy by up to 15%. (Latey et al., 2005). It has been recognized that motorcycles, tricycles particularly in urban areas, constitute a significant source of air pollution considering their daily increase on the road, especially in the urban center (Dinye, 2013). Therefore, it is on this note that researchers are reviewing carburetor-controlled fuel system and engine modifications to counteract these effects in the environment

There are different types of spark ignition engines that can be retrofitted in a motorcycle engine, including single-cylinder, multi-cylinder, two-stroke, four-stroke, and diesel engines (Mohd Noor, 2006). Single-cylinder engines are simple and lightweight, while multi-cylinder engines offer better performance. (Rourke et al., 2012). Diesel engines are more fuel-efficient but heavier and more.

Carburetor motorcycle engines emit several pollutants, including CO, HC, and NOx (Yao et al., 2009). Compared to four-stroke engines, two-stroke engines are lighter but less fuel-efficient and emit more pollutants causing significant implications on air pollution, public health, and environmental. CO is a toxic gas that can cause headaches, nausea, and dizziness, and high levels of exposure can be fatal. HC are a component of smog and can irritate the eyes, nose, and throat, and can also contribute to the formation of ground-level ozone, which can have harmful effects on the respiratory system. Nitrogen oxides are a key contributor to acid rain and can also contribute to the formation of smog.

In addition to the health impacts, emissions from carburetor motorcycle engines also contribute to climate change. One of the atmospheric gases that causes global warming is carbon dioxide CO2 and carburetor engines emit higher levels of CO2 than modern fuel-injected engines. Reducing emissions from carburetor motorcycle engines is important for public health and the environment. This can be achieved through various means, such as putting into place more stringent emissions regulations, supporting the use of cleaner fuels, and fostering the adoption of newer, more efficient engine technologies.

In developing countries like Nigeria, where the number of three-wheelers on the roads is high, many of them still use carburetors (Refaat, 2018), which require a rich mixture at low load, and their inability to balance the air-fuel ratio at medium load, has placed carburetor-controlledengines among the emission producing fuel metering devices (Howlett, 1998), coupled with poor maintenance culture in Nigeria, and more importantly, there are few or no traffic laws to restrict their use on the roads, resulting in high traffic congestion and air pollution.

This has been shown to be responsible for up to 90-95 percent of carbon monoxide (CO) 80-90 percent of nitrogen oxide (NO2), sulfur oxide (SO2), hydrocarbons (HC), and particulate matter (PM) in Nigeria and other developing countries in sub-Saharan Africa and other regions of the world (Oghenerukevwe et al., 2022).

The growing demand for tricycles in Nigeria has triggered a pollution warning signal as most of the tricycle engines have traditional fuel metering system known as carburetors which greatly increases energy consumption and a subsequent increase in gaseous emissions (Adekunle, 2021). Therefore, the need for an urgent attention in improving fuel metering system and advances in fuel technology.

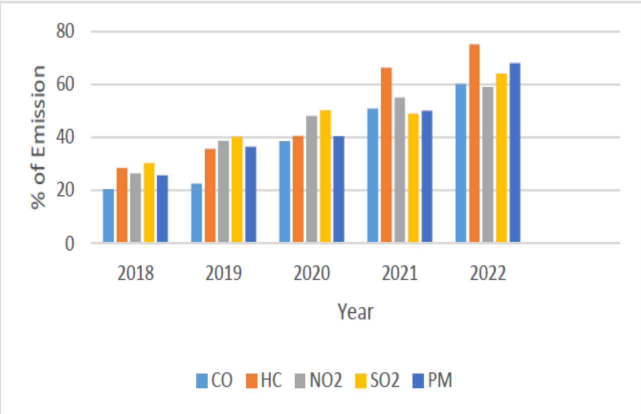

Figure 2: Emissions from the carburetor-controlled spark ignition engines in Nigeria.

Because of their portability, lightness, affordability, and door-to-door capability, carburetor tricycles remain the preferred mode of transport in Nigeria over EFI, port fuel injection (PFI), and direct injection (DI), for personal and commercial use (Komuro et al, 2005). This is a resultof the country's weak public transport system and poor road network, which continues to expand the use of tricycles for public transport and is gradually replacing the public transport system in some Nigerian states (Oladipo, 2012).

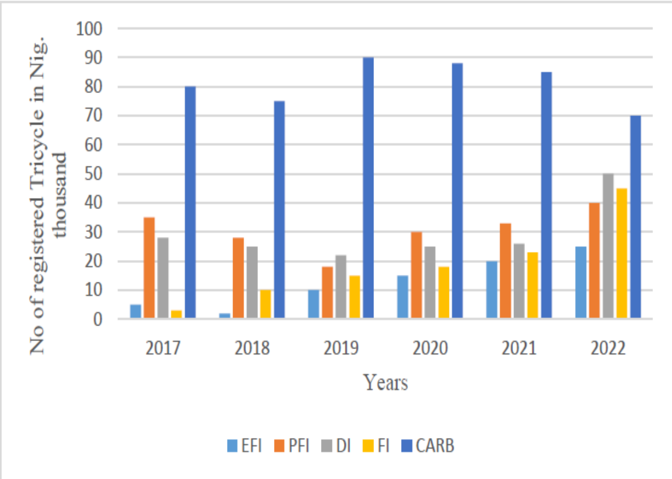

Figure 2: Tricycle registered in Nigeria (2017-2022) (reproduced from Nnaemeka, 2020, Oladipo, 2022).

Operating a spark ignition engine with a retrofitted fuel injection system (FIS)

Various researchers have presented various retrofit designs for small carburetor engines, such as motorcycle engines. They have given insight into the workings of the technology and the experimental details (Muslim et al., 2014). Lorenz et al., (2005) compared the emissions and efficiency of a carbureted engine and a fuel injection engine that had been retrofitted, they found that the retrofitted engine had greater fuel efficiency and lower emissions.. Similarly, Yontar & Doğu, (2018) presented an experimental and numerical investigation of a gasoline engine with a retrofitted electronic fuel injection system. The authors found that the retrofitted system improved engine effectiveness and reduced emissions. Javed, et al., (2016) investigate the performance and emission characteristics of a spark-ignition engine retrofitted with a gasoline direct injection system. The authors found that the retrofitted system improved engine performance and reduced emissions, particularly NOx and CO emissions. In general, upgrading the carburetor can improve the engine's performance by providing a more precise fuel-to-air ratio. Carburetors with larger venturis and more precisely calibrated jets can provide more fuel to the engine at higher revolution per minutes, which can increase horsepower and torque. However, larger carburetors may also reduce fuel efficiency and increase emissions. Similarly, upgrading the ignition system can as well improve performance by providing a stronger spark and more precise timing. This can increase horsepower and torque, and also improve fuel efficiency. However, more advanced ignition systems may require higher octane fuel, which can increase emissions. Overall, retrofitting a carbureted motorcycle engine can have both positive and negative effects on performance and emissions. Upgrades that improve airflow and fuel delivery can increase horsepower and torque, but may also increase emissions. Modification that improve ignition timing and fuel efficiency can increase performance while reducing emissions. It is important to carefully consider the effects of each upgrade on performance and emissions, and to choose upgrades that are appropriate for the intended use of the motorcycle. The noticeable features when retrofitting conventional carburetor system including the electrical systems which were redesigned with a PFI and TBI as part of the common change. Other modified units include a fuel pump, pressure sensor, and engine control unit (ECU) (Archer & Bell, 2001). The sensor units are modified in such a way that physical parameters of the engine have different sensor mounted at different locations on the system.

Specifically, the motorcycle using traditional carburetor is simply modified with injection unit by swapping out the carburetor and manifold sections while leaving traditional parts such as the engine and the electrical systems (Muslim et al., 2014). The majority of retrofit systems use the factory fitted spark ignition setting. This method has created functional systems that arestraightforward, affordable which has significantly prevented the need to modify the whole unit to satisfy the desired retrofit technology (Hushim et al., 2013).

In the contemporary fuel injection systems, the ECU monitor the state of engine,and control the volume of fuel, as well the angle of ignition advance at specific time (Archer & Bell, 2001, Muslim et al., 2014,). The engine state is defined by its speed (RPM) and charge, which is an indication of angle of throttle opening at the intake. The ECU relies on the oxygen signal which measure the amount of oxygen present in the combustion gases, the quantity of the fuel signal the ECU whether the fuel supply is rich, weak or lean. However, sensor is responsible to normalize the mixture composition and make it as close as possible to the stoichiometric. Physical data of the engine such as temperature, pressure and thermal condition and other data related to the amount of fuel and angle of ignition advance are kept as fuel and ignition map respectively. This aid the ECU to adjust the existing fuel data and supply the required amount of fuel to the engine at a given time.

The retrofit (FIS) also uses conventional control approach. The fundamental distinction lies whether the retrofit regulates the ignition advance or not, but the majority of inexpensive retrofit (FIS) do not completely control the spark advance. Typically, the ECU unit of the retrofit (FIS) obtains the stock ignition values directly from sensors, and then calculate, and control variable like the ignition timing. However, where major component of the electrical unit of the retrofit system are rebuilt, then, the choice for the cost-saving is no longer visible, as retrofit (FIS) may show a comparable cost to the modern (FIS).

In general, the fundamental challenge for both carburetor and fuel injection systems is to correctly calculate the mass air flow into the engine at a given time to mix with the correct amount of gasoline so that the amount of fuel produced is accurate for complete combustion.

Uniform air flow at uniform temperature and pressure would result in uncomplicated operation, but pressure and temperature fluctuations result in dynamic operation of the engine at wide open throttle and part load respectively. For this reason, a fuel metering system must be able to meet these operating conditions and requirements.

Spark-ignition engine pollution can be greatly improved and reduced in a number of ways by retrofitting a carburetor system to a fuel injection system: Several ways of doing this include:

i. **Precise fuel metering:** Fuel injection systems deliver precise amounts of fuel to each cylinder based on the engine's requirements, whereas carburetor systems rely on air velocity and pressure changes to meter fuel. The precise fuel metering of the fuel injection system results in more efficient combustion, reduced fuel consumption, and lower emissions.

ii. **Improved fuel atomization:** Fuel injection systems atomize the fuel into smaller particles, ensuring improved fuel and oxygen blending in the combustion chamber. This promotes more thorough burning and reduced unburnt HC emissions and CO.

iii. **Better control over combustion:** Fuel injection systems provide more control over the combustion process by allowing for better fuel injection timing and duration. This allows for more efficient combustion, reduced emissions of NOx, and better power output.

iv. **Easier cold starting:** Fuel injection systems provide better cold starting performance by automatically adjusting the air-fuel ratio and timing based on engine temperature and other operating conditions.

Overall, converting an existing engine with carburetor to a fuel injection system can improve combustion efficiency and reduce emissions, resulting in better fuel economy, improved engine performance, and reduced environmental impact.

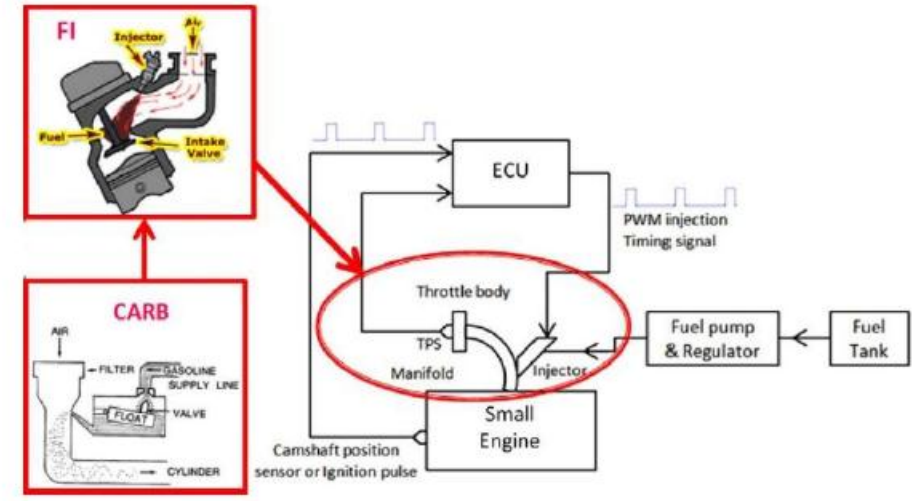

Figure 4: Retrofit (FIS) 125cc engine (Source: Muslim et al., 2014).

Electronic fuel injection (EFI) system

New fueling unit that control and supply an accurate fuel delivery to combustion chamber is called electronic fuel injection (EFI) system. Due to its capabilities, and rising in popularity, it is therefore viewed as a potential replacement for the traditional carburetor system as a fueling method for petrol engines. The EFI is made to directly transfer high-pressure fuel into the combustion chamber in a ratio that balances the amount of intake air, increasing cold starting performance, reducing exhaust pollution outputs, and lowering engine operating temperatures. It consists of three main components: an electronic control unit (ECU) that regulates the amount of fuel to be injected, a fuel pump that supplies pressurized fuel, and fuel injectors that inject fuel in reaction to the ECU's input. Locations of fuel injection system are used to categorize the spark ignition engines into direct into GDI and PFI, though they both showed similarities but there aresignificant differences between them.

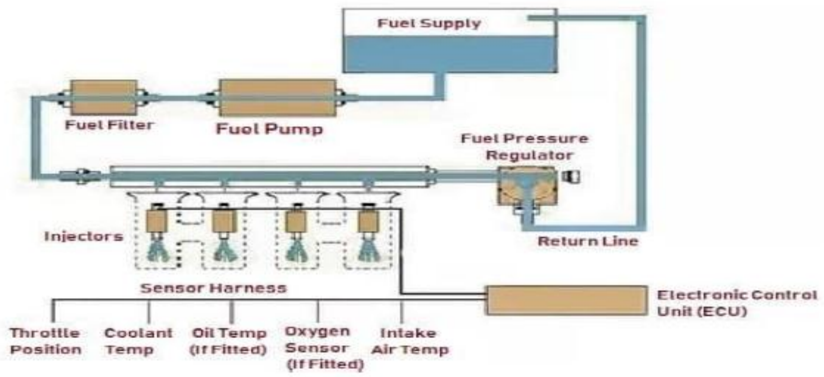

Figure 5: Electronic Fuel Injection system (EFI).

CONCLUSION

This paper reviews the retrofit fuel injection technology as an improvement over a single - cylinder motorcycle gasoline engines currently in use, to improve on fuel efficiency and combat harmful associated emissions. By retrofit (FIS) into the existing engines to replace carburetors, the new technology is capable of saving cost, increase fuel efficiency and reduce exhaust emissions. In addition, the review has identified the various fuel injection systems suitable for retrofit applications such as DI, PFI, TBI, GDI, and MPI, their benefits and drawbacks were alsoidentified. Specifically, the systems that use the TBI and PFI methods are easier to use and less expensive. The PFI technique is chosen to reduce errors brought on by fuel delivery delays or the "pooling effect," however the DI is more efficient at eliminating these effects and providing superior fuel injection control. Even though the retrofit PFI system has produced a respectable outcome, the retrofit DI system outperforms it in terms of fuel economy and emissions reductions. In comparison to the PFI system, the DI system has superior fuel efficiency, better performance, and cleaner exhaust emissions. The PFI system is considerably less expensive than the retrofit DI system. However, further studies would be needed to determine the suitability ofdifferent retrofitted motorcycle engines of a given capacity for an improve performance and emissions reduction.

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