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Comparative Study of Carburettor and Electronic Fuel Injection Systems: Performance, Fuel Efficiency, Emissions, and Reliability

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Abstract: ***Carburettor plays a significant role in automobile and aviation industry. It is a fundamental part of internal combustion engines, but with the advancements in technology and need for efficiency and emission control, the electronic fuel injection (EFI) system has emerged as a superior alternative. The aim of the paper is to explores the detailed working principles of carburettors and EFI systems, how each technology delivers the crucial air-fuel mixture necessary for engine operation. The paper draws a comparison between carburettor and its replacement electronic fuel injection system. Moreover, the paper sees advantages and disadvantages of carburettor and EFIs. the paper also discusses about reliability and operational effectiveness, considering the mechanical robustness of carburettors against the EFI systems. The paper aims to provide a thorough understanding of their respective merits, limitations, and their working. The paper uses various case studies to draw a valid conclusion. This paper highlights why EFIs have largely replaced the carburettors in modern applications, signalling a broader shift towards precision and sustainability in engine design.***

Keywords: Carburettor, Electronic Fuel Injection, Internal Combustion Engine, Fuel Efficiency, Vehicle Emissions

1. Introduction

The internal combustion engine works on three basic things- fuel, air, and source of ignition. The carburettor is an essential part of the internal combustion engine which governs fuel and air that goes into the engine. Combustion in an engine requires proper amount of fuel and air coming in. This is done by carburettor. Carburettor is a simple mechanical device that works on basis of simple laws based on mechanical properties of fluids such as venturi effect. It combines fuel and air in proper ratio to make a mixture that supports combustion.
The ratio depends on fuel type. For example, gasoline requires 14.7 part of air for every part of fuel for complete combustion, while diesel requires 14.5 part of air for every part of fuel.
The ratio can change according to the output needed from the vehicle- the ratio will vary for maximum fuel efficiency and for maximum power. Thus, carburettor has to be able to provide a leaner (more air) and richer (more fuel) air to fuel mixture.

However, due to invention of newer and efficient technologies, such as electric fuel injection systems, most of the manufacturers stopped using carburettors.

Electronic fuel injection system is complex device that uses advance technology and real time sensors to operate. By doing this it significantly reduces the emissions and increases the efficiency of the vehicle. Electronic fuel injection uses sophisticated computer controls to provide engine with proper fuel to air ratio. Because the electronic fuel injection system provides an ideal mixture, the engine works more efficiently and able to generate more mechanical power.

The fuel supply in electronic fuel injection system is controlled by electric control unit with performs complex calculations continuously. Considering distinct factors -such as engine speed, engine temperature, and throttle position- the ECU signals the fuel injection to supply the engine with appropriate fuel mixture that support complete combustion.

2. Working Principles and Components of a Carburettor

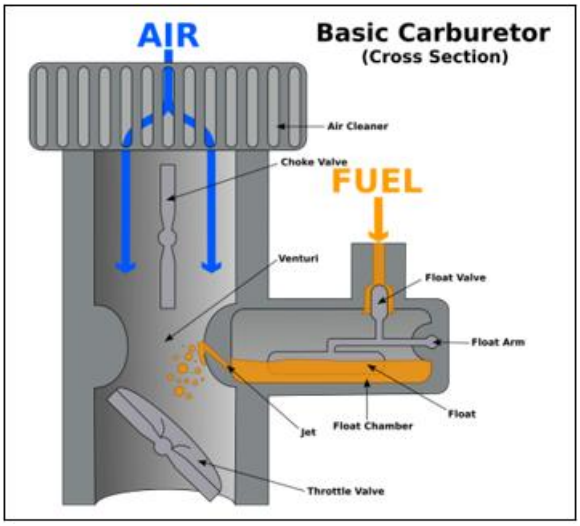

Figure 1: Cross sectional schematics

Basic carburettors work on Bernoulli's principle- states that as the speed of any guild increases its pressure decreases. The carburettor runs on the Venturi effect. As air flows through the Venturi, its speed increases, causing a pressure drop that draws fuel from the float chamber through the jets. The throttle valve controls the volume of the air-fuel mixture entering the engine, while the choke adjusts the mixture for optimal combustion during startup.

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2.1. Float Chamber

Carburettors have a float chamber that is open to the atmosphere to maintain the atmospheric pressure. The fuel comes to the float chamber from the fuel tank through a strainer. The strainer ensures that no solid particles enter the float chamber. The float chamber has a nozzle (jet) that opens into the Venturi tube.

2.2 Choke

The air enters the carburettor through choke valve. The choke valve controls flow of fluid by increasing or decreasing the size of the flow passage. In carburettor the choke influences the air to fuel ratio by regulating the air flow.

2.3 Venturi

From the choke valve the air passes through the Venturi which reduces the cross-sectional area. In the Venturi, the speed of the fluid increases. This phenomenon is known as Venturi's effect when a fluid passes through a narrow section of the pipe, its speed increases while the pressure decreases. The increased speed causes reduction on volume, which can be explained by Bernoulli's principle. The reduction on volume creates partial vacuum at the nozzle (jet) and hence the fuel is pulled out of the float chamber and mixed with the incoming air.

2.4 Throttle

The rate at which fuel and air mixture is sent to the engine is controlled by throttle. A wider opening allows more air and fuel to enter, increasing engine power. A narrower opening restricts airflow and fuel, reducing engine power and fuel consumption.

3. Working principle and components of an electrical fuel injection system

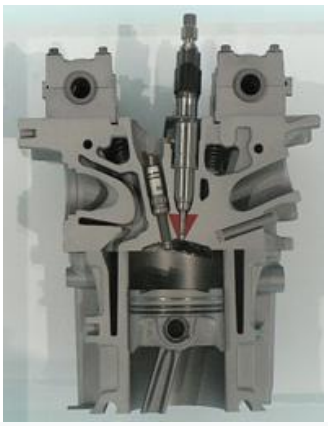


Figure 2: A cutaway model of a petrol direct-injected engine

3.1 ECU (Electronic control unit)

An electric fuel injection system works under the ECU (electronic control unit) of the car. ECU is equipped with multiple sensors and processors which helps it to measure engine rotation speed, create proper fuel to air mixture, moreover it also helps to identify the car keys, adjust the engine cooling fan etc.

3.2 Working

The fuel is pulled out the vehicles fuel tank and transported to the fuel injection system. The fuel is then pressurised to ensure proper injection. A fuel pressure regulator is also used to keep the reassure in optimal range.

The ECU then watches distinct factors through inbuilt sensors. On based on these sensors it performs complex calculations and regulates the amount of fuel injected.

3.3 The sensors used by the ECU to control EFI

1) **Oxygen sensor:** It monitors the oxygen levels in the exhaust gases, thereby finding that the fuel mixture is leaner or richer and then altering the fuel air mixture to maximise the combustibility.
2) **Airflow sensor:** It monitors the incoming air volume and allows ECU to make decisions.
3) **Coolant temperature:** It watches the engines temperature and thus allowing the ECU to determine the engine performance.
4) **Engine speed sensor:** It measures the vehicle's RPM and thus enables the ECU to perform calculations.

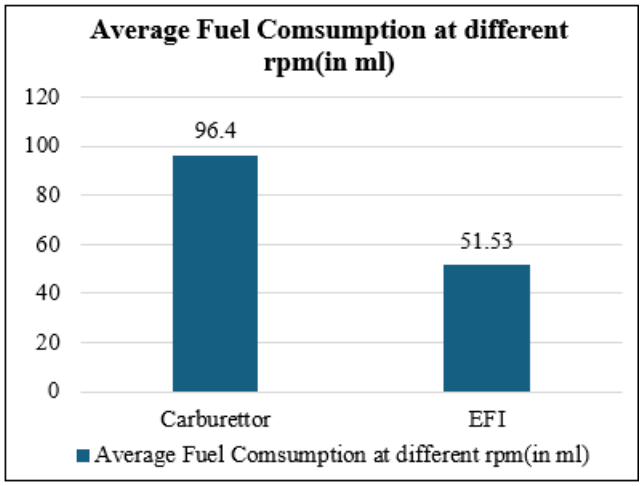
Other sensors used by ECU are voltage sensors which measures the voltage within the vehicle, throttle position sensors which tracks the throttle position.

4. Fuel efficiency

Carburettors are often less fuel efficient when compared to its counterpart EFI. Carburettors use mechanical ways to prepare to fuel air mixture which is less precise. Thus, carburettors are not able to actively change to fuel to air ratio according to the external factors, thereby limiting its adaptability. Carburettors may struggle to keep the best air-fuel ratio under variable conditions like change in altitude, temperature, or engine load, which can potentially lead to more fuel consumption.

Meanwhile its counterpart EFI, prepares a mixture that is precise. Electronic sensors present in the ECU continuously monitor the vehicles condition and dusts the fuel injection process to increase combustion. Moreover, EFI has real time adaptability which allows to it alter to rate of injection according to the changing external circumstances. Fuel injection system can alter the ratio depending on variable such as temperature, engine load, or airflow. According to research published by Daud Simon Anakottapary on the Fuel Consumption Analysis of Injection System and Carburettor System on Honda Beat Fi 2013, which finds out the average fuel consumption at different rpm of engine with 200ml of fuel where engine being run for 10 minutes, the average fuel consumption in injection system was 51.53 ml, whereas the

average fuel consumption in carburettor engine was 96.40 ml. That shows a difference of 47%.



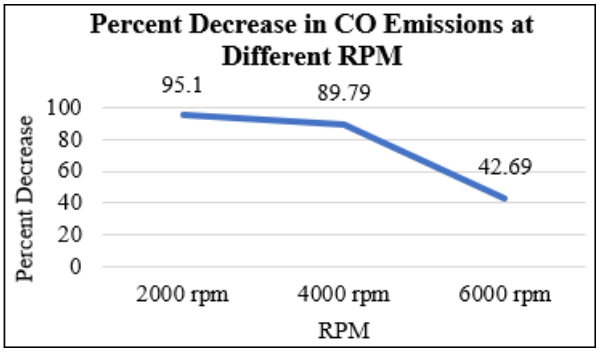
According to the research published by Shahzaib Ilyas, Usama Naveed and Junaid Khalid on improving fuel consumption using Electronic Fuel Injection Technology for low-powered Motorbike Engine, on use of 1 litre fuel in small motorbike, the carburettor equipped bike gave a mileage of 55 km while the bike equipped with the EFI system gave mileage of 64 km. This shows a difference of 16.36%.

By the two studies discussed above we can conclude that for both a small motorbike and a car the EFI system has shown a more favourable result.

5. Impact on Environment and Emissions

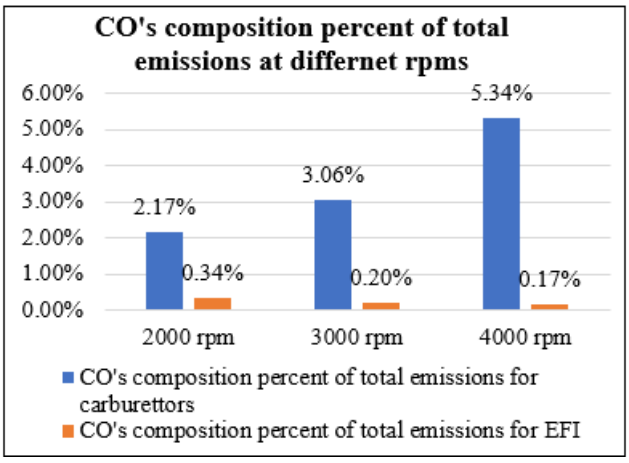
When it comes to environmental impacts, carburettor often provide more damage by emitting harmful pollutants. This is mainly due to their inability to actively change the fuel air ratio to increase combustion. Thus, partial combustion leads to more emissions. Meanwhile EFI can actively change the ratio that supports complete combustion. This leads to cleaner combustion that leads to emissions that have lower amounts of pollutants like carbon monoxide and nitrogen oxide.

According to research published by Adnan Katijan, Mohd Faruq Abdul Latif, and Qamar Fairuz Zahmani- an experimental study for emissions of four stroke carburettor and fuel injection motorcycle engine - when comparing fuel injection and carburettor systems at 2000, 4000, and 6000 rpms, CO emissions decreased by 95.1%, 89.79% and 42.69%, respectively. Consequently, at all three set speeds, this corresponds to an average improvement of 75.86%. The improvement in CO and HC (hydrocarbons)emissions was 30.1% and 56.42%, respectively.



We can say that EFI technology results in reduced fuel emissions. It is estimated that there is a 22% difference in the emissions of EFI based engine when compared to a carburettor-based engine.

By a study given by I. M. Suarta, I. P. G. Sopan Rahtika, P. W. Sunu, N. D. Susila, K. Bangse, in The Comparison of Exhaust Gas Emission Between Conventional and Electronic Fuel Injection System; the CO's composition percent of total emissions by carburettor were 2.17%, 3.06%, 5.34% for 2000, 3000, 4000 rpm respectively, while the CO's composition percent f total emissions by EFI system was 0.34%, 0.2%, 0.17% for 2000, 3000, 4000 rpm respectively.



The composition of other hydrocarbons showed similar data. This signifies that the EFI system significantly reduced the emissions of harmful substances such as carbon monoxide (CO), CO2 etc.

6. Maintenance and Reliability

There has been a rise in the problems related to carburettor after introduction of ethanol fuel. These fuels have pure alcohol, which when left untouched can cause corrosion to the carburettors. To prevent this, it is recommended not to keep fuel in your vehicle left untouched for more than 30 days.

A routine clean for carburettor includes keeping the air filter clean to prevent any dirty to enter the carburettor, the fuel should be clean and water free. The carburettor requires a heavy cleanup every 12,000 to 15,000 miles or every year. This heavy cleanup includes cleaning the throttle shaft, Venturi tube or the float chamber.

While the EFI require minimal maintenance, regular cleanups are often important to keep the system work efficiently. Cleaning the fuel injectors, which can get clogged with fuel residue overtime is a part of the cleanup. If not cleaned properly, they can cause a lean fuel air mixture which results in loss of power and fuel efficiency. Changing the fuel filter is also essential. It prevents dirty and debris from entering the injection system. Most EFI manufacturers recommend changing the same every 12,500 to 25,000 miles.

Carburettors are more affordable and simpler to maintain, but they are less efficient and reliable than EFI systems in the long run. EFI systems offer better performance, fuel efficiency, and reliability, but they are more expensive and complex to repair. The best choice depends on individual needs and preferences, but EFI systems are generally considered superior in terms of performance and reliability.

7. Advantages and Disadvantages

There are both advantages and disadvantages of anything. Accordingly, the advantages and disadvantages of carburettors are listed below.

7.1 Advantages of carburettors

- They are simple, cost effective, easy to replace
- They can be adjusted to provide the correct air/fuel mixture for different engine conditions.
- They can provide good fuel economy under light load conditions.
- A carburettor avoids the complex, turbulent fuel-air mix in the intake system.
- Carburettors are not integrated into the engine which helps to replace the without touching the engine.

7.2 Disadvantages of carburettors

- They are not effective and outdated.
- The fuel air ratio fluctuates and damages the engine.
- They have comparatively low fuel efficiency and can cause high emissions.
- They are difficult to start in freezing weather.
- Certain components of the carburettor are delicate and prone to damage.

7.3 Advantages of electric fuel injection system

- Atomisation allows better mixture and supports clean combustion.
- EFI provide better fuel efficiency.
- They have comparatively lower emissions.
- They need minimal maintenance.

7.4 Disadvantages of electric fuel injection system

- They are not cost effective- more expensive than carburettor.
- They are not simple and are not easy to repair and require professional service.
- They are sensitive to fuel quality and are susceptible to damages in presence of dirt in fuel.

8. Comparative Analysis

From the above listed points, we can observe the following:

Criteria	Carburettors	EFI
Fuel efficiency	Low	High
Emissions	High	Low
Maintenance	Frequent	Minimal
Performance	Vary according to conditions	Consistent
Cost	Low initial cost but high operational cost	High initial cost but lower operational cost

9. Conclusion

From this research, it is evident that electronic fuel injection (EFI) systems present a superior alternative to carburetors in most modern applications. While carburetors were historically important due to their mechanical simplicity, low cost, and ease of maintenance, they fall short in delivering consistent performance under varying environmental and load conditions. Studies have shown that carburetors consume significantly more fuel and produce higher emissions, as their mechanical design cannot continuously adjust the air–fuel ratio with precision.

In contrast, EFI systems use advanced sensors and electronic control units to provide accurate, real-time regulation of the fuel–air mixture. This results in better fuel efficiency, reduced emissions, and improved overall performance. Research cited in this paper demonstrates that EFI engines not only consume up to 47% less fuel but also produce far lower levels of harmful pollutants such as CO and hydrocarbons. Although EFI systems are more complex and costly to install and repair, their long-term efficiency, reliability, and environmental benefits outweigh these drawbacks.

Therefore, the transition from carburetors to EFI systems reflects a broader shift toward sustainable, efficient, and performance-driven engine technology. While carburetors may still find limited use in motorcycles, mopeds, and small machines due to their simplicity, EFI has become the preferred choice in modern vehicles, aligning with global demands for cleaner and more efficient transportation.

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