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PERFORMANCE ANALYSIS OF THE HONDA BEAT ESP INJECTOR ASSY ON COMBUSTION EFFICIENCY IN A 110 CC ENGINE

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Abstract

This study aims to evaluate the performance of the injector assembly on the Honda Beat eSP and its effect on combustion efficiency in a 110 cc engine. A common problem that occurs in fuel injection motorcycles is inaccurate fuel supply due to changes in the atomization pattern, which impacts gasoline consumption and emission characteristics. The methods used consist of testing the spray flow rate, fog pattern, fuel pressure, and measuring exhaust emissions as a direct indicator of the combustion process. Tests were conducted on standard injector conditions and on injectors that have experienced a certain service life to see the differences. The results showed that unstable atomization and decreased injector flow rate caused an increase in fuel consumption of more than 5% and an increase in HC levels in emissions. Conversely, injectors with optimal atomization patterns produced a more even air-fuel mixture and increased combustion efficiency. These findings confirm that injector performance plays a crucial role in maintaining engine performance and fuel consumption efficiency in small-capacity motorcycles.

Keyword: injector assy, combustion efficiency, Honda Beat eSP, 110 cc engine

INTRODUCTION

The development of technology in motorcycle fuel systems, especially in small-capacity engines, has significantly improved with the implementation of Programmed Fuel Injection (PGM-FI) technology (Widodo, 2020). The Honda Beat eSP, one of the best-selling models in Indonesia, relies on an injector assy to ensure precise fuel supply according to engine needs. Injector performance is crucial as it directly determines combustion quality, efficiency, and exhaust emissions. In practice, issues such as decreased engine response, increased fuel consumption, and incomplete combustion symptoms are often encountered due to changes in atomization characteristics. This indicates that injector performance greatly affects overall engine output.

Theoretically, an injector functions to spray fuel into a fine mist, allowing it to mix evenly with air in the combustion chamber. Parameters such as spray volume, spray angle, fuel pressure, and mist homogeneity determine the quality of combustion. Previous studies have examined the relationship between atomization quality and engine thermal efficiency, generally concluding that decreased injector performance can lead to fuel waste and increased hydrocarbon emissions. However, most studies focus on larger engines or different vehicle

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types, which may not accurately represent the specific characteristics of injectors in the Honda Beat eSP with its unique 110 cc engine management system.

A research gap exists due to the limited number of studies directly evaluating the performance of Honda Beat eSP injectors based on real-world usage, particularly regarding changes in spray patterns and their impact on combustion quality. Additionally, the contribution of injectors as components sensitive to clogging and fuel pressure changes has not been comprehensively studied in small eSP engines. Therefore, this research aims to experimentally measure injector performance, including fuel flow rate, atomization pattern, supply pressure, and exhaust emissions, to identify how injector performance changes affect combustion efficiency.

The objective of this study is to analyze the relationship between Honda Beat eSP injector assy performance and combustion efficiency in 110 cc engines based on experimental parameters. This research is expected to provide a deeper understanding of the role of injectors in fuel consumption and emission quality, serving as a basis for developing maintenance strategies and evaluating injection system performance in modern fuel-injected motorcycles.

METHODOLOGY

This study employs a quantitative approach with a laboratory experimental design aimed at directly measuring changes in the performance of Honda Beat eSP injector assy on combustion efficiency parameters in 110 cc engines. The experimental design was chosen for its ability to test variables in a controlled manner and obtain numerical data for objective analysis.

The population in this study consists of all injector assy units used in Honda Beat eSP motorcycles with PGM-FI generation. Two sample groups were selected: injectors in standard factory condition and injectors with a certain usage period. This selection allows for observation of performance differences and the impact of wear level on combustion quality. Each sample was tested using a testing machine matching the 110 cc Honda engine characteristics. Data collection techniques involved a series of tests, including injector spray volume measurement, atomization pattern examination, fuel pressure testing, and exhaust gas analysis. Instruments used include a fuel injector tester, fuel manometer, gas analyzer, and digital tachometer to ensure engine stability. All measurements were conducted under standard operating conditions and validated through repeated testing to minimize reading errors.

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The obtained data were analyzed using quantitative comparative techniques, comparing measurement results between sample groups. Analysis included calculating average changes in spray volume, mist homogeneity, and emission level differences as indicators of combustion efficiency. These analysis results were then used to draw conclusions about the relationship between injector performance and combustion efficiency in 110 cc engines.

RESULTS AND DISCUSSION

Physical Condition and Characteristics of Honda Beat eSP Injector Assy

The injector assy in Honda Beat eSP is a key component in the PGM-FI system that regulates the amount and pattern of fuel injection into the combustion chamber. This component consists of a nozzle tip, needle valve, solenoid coil, and filter screen that work together to produce high-pressure fuel mist with uniform droplets (Honda Motor Co, 2023). The nozzle tip, as the injector's outlet, shapes the spray pattern and angle. Due to its micro-sized holes, this part is prone to clogging, and even slight contamination can alter the spray pattern, leading to uneven fuel distribution. The needle valve inside the injector body opens and closes the fuel flow according to ECU signals; wear or contamination on this component can slow its response and reduce spray volume. The solenoid coil drives the needle valve through electromagnetic force, so the coil's condition significantly affects injection timing and duration. Meanwhile, the filter screen at the injector's inlet filters small particles that can disrupt fuel pressure and flow.

A comparison between new injectors and those used for approximately 20,000 km shows that used units have darker filters and nozzles with altered textures. These conditions contribute to decreased flow rate, irregular atomization patterns, and reduced combustion efficiency (Pratama & Sulistyo, 2021).

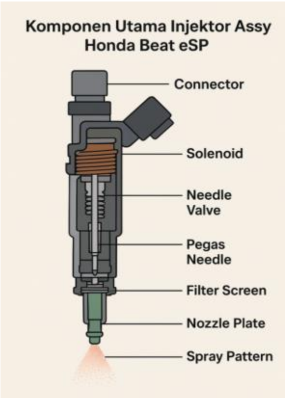

Figure 1. Main Component Schematic of Honda Beat eSP Injector Assy

The structure of the Honda Beat eSP injector assy shows seven main elements involved

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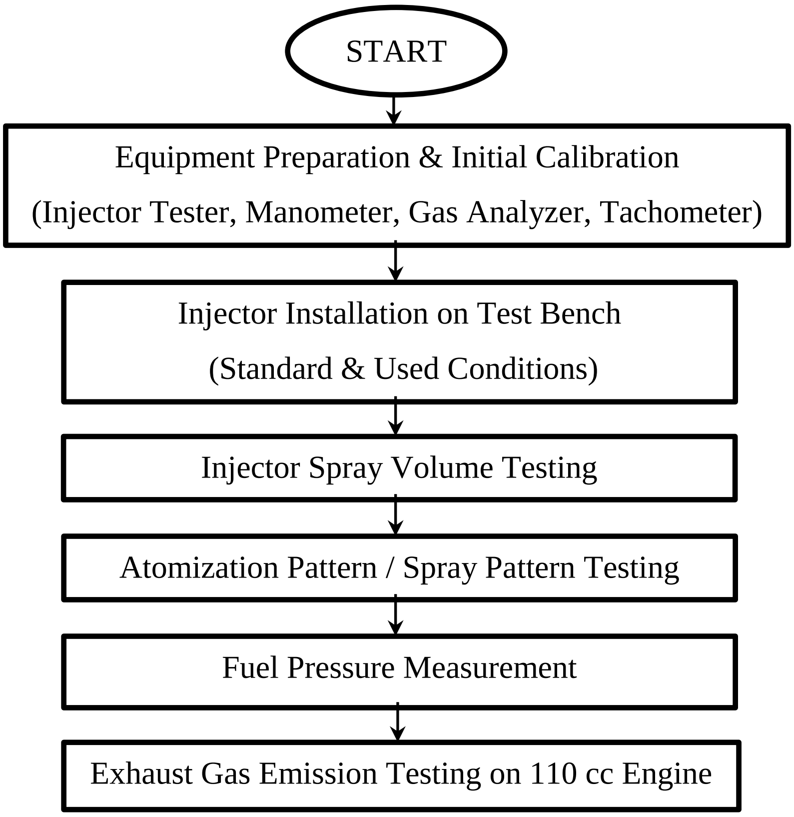
in the fuel injection process: ECU connector, solenoid coil, needle valve, needle spring, filter screen, nozzle plate, and the resulting spray pattern at the injector tip. The ECU connector receives electrical signals from the engine control unit, regulating the injector's operation time. The signal is responded to by the solenoid coil, generating electromagnetic force to pull the needle valve. The valve movement is controlled by a small spring that ensures the valve closes when the solenoid is deactivated, maintaining controlled fuel flow.

Before entering the injection chamber, fuel passes through the filter screen, which captures fine particles to prevent clogging in the injector passage. At the tip, the nozzle plate with micro-sized holes breaks the fuel flow into a fine mist. This mist pattern is depicted as a spray pattern in the figure, illustrating the spray distribution and atomization quality. The integration of these components determines the precision of the flow rate, spray uniformity, and effectiveness of air-fuel mixing in the combustion chamber.

Injector Assy Performance Testing Procedure

The testing procedure for the Honda Beat eSP injector assy is systematically designed to obtain accurate data on spray volume, atomization pattern, supply pressure, and emissions.

All equipment is calibrated beforehand to minimize measurement errors. The injector is then tested using a fuel injector tester to directly observe its performance, and subsequently installed on a 110 cc engine to assess its impact on combustion and emissions.



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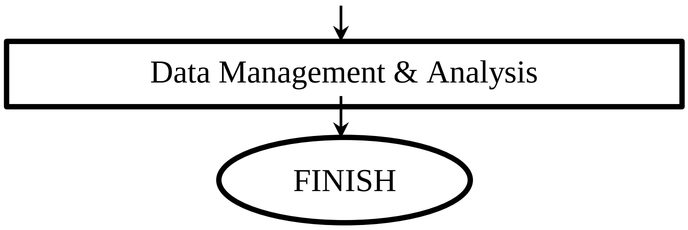

Figure 2. Flowchart of Injector Assy Performance Testing Procedure

Spray Volume Measurement Results

The spray volume test was conducted to determine the injector's ability to deliver fuel per minute. Both samples - standard injector and used injector (±20,000 km) - were examined using a fuel injector tester at the same pressure, and each measurement was repeated three times to obtain an average value. The results showed that the standard injector produced a flow rate of 46.8 ml/min, while the used injector only produced 43.9 ml/min.

This 6.20% decrease indicates flow obstruction, such as dirt on the filter or changes in solenoid response. This condition can disrupt fuel supply stability and affect combustion

process in 110 cc engines. In electronic injection systems, this flow rate decrease can also trigger the ECU to compensate injection duration, potentially increasing fuel consumption.

Table 1. Injector Spray Volume Comparison

Injector Condition	Flow Rate (ml/min)	Change (ml)	Change (%)
Standard (new)	46,8	-	-
Used	43,9	-2,9	-6,20%

Overall, these results show that the physical condition of the injector significantly affects the quantity of fuel injected. Decreased flow rate can lead to inhomogeneous combustion and impact emission levels (Siregar & Lubis, 2021). These findings provide a basis for further analysis on atomization patterns and emission quality measurements in the next section.

Analysis of Spray Volume Based on Fuel Pressure

The spray volume of an injector is strongly influenced by the fuel pressure entering the nozzle. In general, the relationship between flow rate and pressure follows the principle of fluid flow through an orifice, where the discharged fuel volume depends on the pressure differential, nozzle orifice area, and fuel density (Hartono, 2023). The mathematical relationship for injector spray volume can be expressed as:

$$Q = C_d \cdot A \cdot \sqrt{\frac{2\Delta P}{\rho}}$$

Where:

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- QQ = injector spray volume (m³/s)
- CdCd = nozzle discharge coefficient
- AA = total nozzle orifice area (m²)
- ΔPΔP = pressure difference between fuel and ambient (Pa)
- ρρ = fuel density (kg/m³)

From this equation, it is clear that the flow rate is directly proportional to the square root of the fuel pressure difference. This implies that even a small decrease in pressure can cause a relatively significant reduction in flow rate.

Spray Pattern Analysis

The spray pattern was observed to assess the quality of fuel atomization exiting the injector nozzle. Examination was conducted using a spray pattern tester at the same pressure to ensure differences resulted from injector condition. Results showed that the standard injector produced a conical spray pattern with even distribution and fine droplets (Nugroho & Prasetyo, 2022). This pattern indicates optimal atomization, allowing fuel to mix homogeneously with air.

In contrast, the used injector showed an asymmetrical mist pattern with fragmentation in some areas. Droplets appeared larger and less distributed (Oktaviano, 2022). These changes indicate nozzle hole disturbances, such as deposit buildup or slight clogging. This condition requires longer fuel evaporation time, increasing likelihood of uneven combustion in the combustion chamber.

This spray pattern difference directly impacts combustion efficiency. Unstable patterns cause some fuel to remain unvaporized before combustion, making air-fuel mixture less homogeneous. This potentially increases HC and CO emissions, as seen in subsequent emission test results.

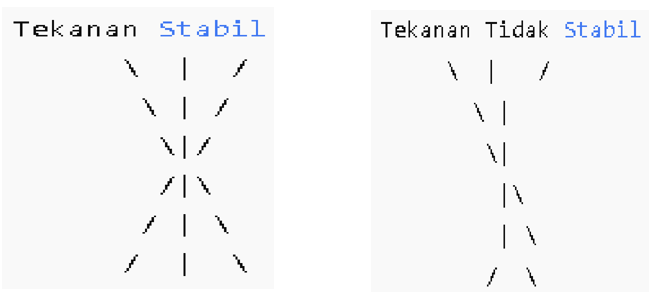

Figure 3. Comparison of Standard and Used Injector Spray Patterns

Fuel Pressure Stability Analysis on Injector Performance

Fuel pressure stability directly determines injector performance quality. At stable pressure, injectors can spray fuel with consistent volume and pattern, enabling optimal

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atomization. Conversely, pressure fluctuations cause uneven fuel flow to the nozzle, decreasing spray volume and forming larger droplets.

Test results show that standard injectors with stable pressure produce finer and more symmetrical sprays. Used injectors experience pressure drops during injection, triggering atomization disturbances and increasing risk of incomplete combustion (Rahman & Andika, 2024). This is evident from increased HC and CO levels, indicating unburned fuel residue.

Thus, maintaining stable fuel pressure is crucial for injectors to effectively produce homogeneous air-fuel mixtures and efficient combustion.

Table 2. Impact of Pressure Stability on Injector Performance

Parameter	Stable Preassure (Standard Injector)	Unstable Pressure (Used Injector)	Impact on Engine
Spray Volume	Flows steadily and optimally	Decreased and inconsistent	Air-fuel mixture not precise
Atomization Pattern	Even, small droplets	Uneven, Larger droplets	Poor atomization, slow evaporation
ECU Response	Injection duration control works normally	ECU increases injection duration for compensation	Pottential fuel consumption increase
Combustion Efficiency	Mixture forms more homogeneously	Incomplete combustion	More fuel residue
HC & CO Emissions	Lower	Increased	Indicates suboptimal combustion
Idle Stability	Engine runs smoothly	Engine vibrations more noticeable	Decreases comfort and engine responsiveness

Fuel pressure stability significantly affects injector performance. Stable pressure results in better spray volume, optimal atomization pattern, and more efficient combustion. Conversely, unstable pressure decreases injector performance, affecting engine response, worsening emissions, and increasing fuel consumption (Setiawan, 2024).

Exhaust Gas Emission Test Results

Exhaust gas emission testing was conducted to determine combustion quality based on HC, CO, and CO_2 levels. These values directly indicate combustion process efficiency in the combustion chamber.

1. HC (Hydrocarbon) indicates unburned fuel amount.
2. CO (Carbon Monoxide) occurs during incomplete combustion.
3. CO_2 (Carbon Dioxide) is a product of complete combustion; higher values indicate better combustion quality.

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Table 3. Exhaust Gas Emission Measurement Results for 110 cc Engine

Parameter	Standard Injector	Used Injector	Difference
HC (ppm)	128	173	+45
CO (%)	0,42	0,57	+0,15
CO_2 (%)	11,4	10,7	-0,7

Increased HC and CO levels indicate less complete combustion in used injectors (Yusuf, 2020). Decreased CO_2 indicates reduced fuel conversion efficiency. These results reinforce that decreased injector performance directly affects combustion efficiency.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The findings of this study indicate that the performance of the injector assembly plays a crucial role in determining the combustion efficiency of the Honda Beat eSP 110 cc engine. Injectors that have undergone extended use exhibit a 6.20% reduction in fuel delivery and a noticeable degradation in spray quality due to nozzle wear and filter blockage. This deterioration affects fuel pressure stability and prompts the ECU to adjust injection duration, which may consequently increase fuel consumption. Emission test results—marked by higher HC and CO values and a decrease in CO_2—further confirm the occurrence of incomplete combustion. Overall, the injector's condition has a direct impact on fuel efficiency, emission characteristics, and engine performance.

Recommendations

To maintain optimal engine performance, routine inspection of the injector is recommended, particularly after extended usage that may lead to clogging or altered spray characteristics. Regular maintenance of the fuel system, including pressure checks and component cleaning, is essential to ensure consistent fuel supply. Future studies should consider evaluating injector performance under varied operating conditions—such as different load levels, fuel pressure variations, or the role of auxiliary components like the fuel pump and ECU sensors—to provide a more comprehensive understanding of injector degradation in small displacement engines.

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