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The Effect of Fuel Cell Reactor Volume on a Pertalite-Fueled Drive Engine Per 75 ML

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Abstract

The increasing number of motor vehicles has led to a continuous rise in Pertalite fuel consumption, while petroleum reserves remain limited and non-renewable. One proposed solution is the application of a fuel cell (HHO generator), which utilizes water electrolysis to produce hydrogen and oxygen gases to support the combustion process inside the engine. However, studies examining the effect of fuel cell reactor volume on engine performance remain limited. This study aims to determine the effect of fuel cell reactor volume on the performance of a Pertalite-fueled engine using 75 mL of fuel. The research employed an experimental approach by comparing engine performance without a fuel cell and with a fuel cell equipped with a 180 mL reactor volume (containing an electrolyte solution of 5 g of caustic soda and 180 mL of distilled water, with a current of 3.5 Ah) at three engine speed levels (2000, 3000, and 4000 RPM), with each condition tested three times. The measured parameters included engine speed, operating duration, engine temperature, and battery voltage using a tachometer, stopwatch, temperature gauge, and avometer. The results showed that the use of a fuel cell with a 180 mL reactor volume increased the engine operating duration for the same fuel volume, with an average improvement of approximately 27.5% across the three tested speed levels. However, the final engine temperature tended to be higher, and the battery voltage slightly decreased after testing. These findings indicate that a 180 mL reactor volume provides improved fuel efficiency compared with the engine condition without a fuel cell.

INTRODUCTION

The increasing number of motor vehicles from year to year has caused the consumption of petroleum-based fuels, such as Pertalite, to continue rising, while petroleum reserves remain limited and non-renewable. This condition encourages various parties to seek methods for improving combustion efficiency in internal combustion engines without requiring changes to the type of fuel used (Dahham et al., 2022; Rossi & Logan, 2022).

One of the technologies widely developed for this purpose is the HHO generator, which is also commonly referred to as a fuel cell in automotive applications (Akl et al., 2025; Nabil & Dawood, 2019; Oluwadare et al., 2024). This device operates through the water electrolysis process to produce hydrogen and oxygen gases (HHO gas or Brown's gas), which are subsequently introduced into the engine intake system to support the fuel combustion process in the combustion chamber (Mursid & Hamzah, 2013; Nabil, 2019). The electrolysis process is generally supported by an electrolyte solution, such as caustic soda (NaOH), mixed with distilled water and supplied with electrical current from the vehicle's charging system (Artamevia et al., 2025; Yusupbekov et al., 2024).

Previous studies have shown that the application of HHO generators using NaOH catalysts at various concentrations can improve fuel efficiency with a relatively significant percentage increase at certain engine speeds (Nugroho & Yunianto, 2016). Other studies have reported that the addition of an HHO generator can extend engine operating duration while reducing specific fuel consumption. In addition to influencing fuel consumption, the application of a fuel cell has also been reported to improve engine power and torque while enhancing vehicle exhaust emission quality (Saepudin, Sutrisno, & Rifatulloh, 2025; Sudrajat, Nugroho, Lestari, & Repi, 2020).

One factor suspected to influence fuel cell performance is the reactor volume, as it determines the capacity of the electrolyte solution contained within the reactor, which subsequently affects the amount of HHO gas generated during the electrolysis process (Rusdianasari et al., 2019; Vethamony & Thangavel, 2023; Yusof et al., 2022). However, studies specifically investigating the effect of fuel cell reactor volume variations on the performance of Pertalite-fueled engines remain limited (Harman & Ahyar, 2019).

Based on the aforementioned description, this study was designed using three fuel cell reactor volume variations, namely 120 mL, 150 mL, and 180 mL, to investigate their effects on the performance of a Pertalite-fueled drive engine using 75 mL of fuel. Among these variations, the 180 mL reactor volume was selected for further testing and analysis because it demonstrated the most efficient fuel consumption performance compared with the other two reactor volumes (Hebala et al., 2025). The testing process was conducted by comparing engine performance without a fuel cell and with a fuel cell, with the observed parameters consisting of engine speed (RPM), operating duration, engine temperature, and battery voltage (Alpaslan et al., 2023; KoteswaraRao et al., 2024).

The purpose of this study is to determine the effect of using a fuel cell with a 180 mL reactor volume on engine speed (RPM), operating duration, engine temperature, and battery voltage in a Pertalite-fueled drive engine using 75 mL of fuel compared with an engine operating without a fuel cell. The findings provide valuable insights for the automotive sector and vehicle users regarding strategies for improving fuel efficiency without changing fuel types, potentially reducing operational costs and addressing challenges associated with declining petroleum reserves. Furthermore, the results may serve as a reference for developing more efficient and environmentally friendly fuel cell technologies. This study also contributes to the existing body of knowledge regarding the application of HHO generators in internal combustion engines by providing empirical data on the relationship between reactor volume and engine performance, which can support future research on optimizing fuel cell parameters, including reactor volume, electrolyte concentration, and electrical current.

METHOD

Research Design

This research was a quantitative experimental study that compared two test conditions: an engine without a fuel cell (control) and an engine equipped with a fuel cell with a 180 mL reactor volume (treatment) (Sugiyono, 2018).

Tools and Materials

The tools used for data collection in this study are as follows:

1. Avometer, used to measure battery voltage.
2. Tachometer, used to measure engine speed (RPM).
3. Temperature gauge, used to measure engine temperature.
4. Stopwatch, used to measure engine operating time.
5. Measuring cup, used to measure the volume of fuel and distilled water.

The materials used include 75 mL of pertalite fuel, 5 grams of caustic soda (NaOH), and 180 mL of distilled water as the electrolyte solution in the fuel cell reactor tube.

Research Variables

The independent variable in this study is the test condition, namely without a fuel cell and with a fuel cell of 180 mL reactor volume. The dependent variables include average RPM, engine operating duration, engine temperature before and after testing, and battery voltage before and after testing. The control variables include the volume of pertalite fuel (75 mL), the weight of caustic soda (5 grams), electric current (3.5 Ah), and three initial test speed levels (2000 RPM, 3000 RPM, and 4000 RPM).

Research Procedure

1. Preparing the test engine with a standard carburetor and filling the test tank with 75 mL of pertalite fuel.
2. In the test without a fuel cell, the engine is run directly at speeds of 2000, 3000, and 4000 RPM in sequence, each repeated three times.
3. In the test with a fuel cell, the reactor tube is filled with 180 mL of distilled water and 5 grams of caustic soda as the electrolyte solution, then connected to a 3.5 Ah current source to produce HHO gas which is channeled to the engine intake.
4. Before the engine is started, the initial engine temperature and initial battery voltage are measured using a temperature gauge and an avometer.
5. The engine is run at speeds of 2000, 3000, and 4000 RPM in sequence with the fuel cell active, each repeated three times.
6. Engine operating time is recorded using a stopwatch from the moment the engine is started until the fuel runs out, indicated by a drastic decrease in RPM from the target value.
7. After the test is complete, the final engine temperature and final battery voltage are measured.
8. All RPM, time, temperature, and voltage data are recorded and then averaged from the three repetitions at each speed level.

RESULTS AND DISCUSSION

Test Results Without Fuel Cell

The test without a fuel cell was carried out using a standard carburetor with a pertalite fuel volume of 75 mL at three initial speed levels, namely 2000 RPM, 3000 RPM, and 4000 RPM, each repeated three times. The test result data are presented in Tables 1 to 3.

Table 1. Test Results Without Fuel Cell at Initial Speed of 2000 RPM

Parameter	Test 1	Test 2	Test 3
Second 0	2000	2000	2000
Second 1	2075	2038	2020
Second 2	2131	2068	2027
Second 3	2119	2079	2028
Second 4	2082	2075	2011
Second 5	2063	2046	2016
Second 6	2111	2029	2005
Second 7	2063	2023	2011
Second 8	2095	2031	2017
Second 9	2042	2050	2016
Second 10	2071	2025	2004
Second 11	1635	1746	1217
Average RPM	**2040.6**	**2017.5**	**1947.7**
Operating Time	**00:10:25**	**00:10:34**	**00:10:55**
Cold Engine Temperature (°C)	**33.4**	**40.8**	**42.9**
Hot Engine Temperature (°C)	**117.5**	**122.9**	**98.7**

Source: Research primary data, 2025

Table 2. Test Results Without Fuel Cell at Initial Speed of 3000 RPM

Parameter	Test 1	Test 2	Test 3
Second 0	3000	3000	3000
Second 1	3018	3043	3083
Second 2	3006	3063	3067
Second 3	3017	3022	3024
Second 4	3025	3030	3073
Second 5	3028	3000	3089
Second 6	3066	3061	3011
Second 7	3064	3034	3016
Second 8	3015	3042	3012
Second 9	1276	2263	1587
Average RPM	**2851.5**	**2955.8**	**2896.2**
Operating Time	**00:08:26**	**00:08:21**	**00:08:19**
Cold Engine Temperature (°C)	**37.3**	**43.7**	**51.1**
Hot Engine Temperature (°C)	**99.5**	**119.1**	**127.9**

Source: Research primary data, 2025

Table 3. Test Results Without Fuel Cell at Initial Speed of 4000 RPM

Parameter	Test 1	Test 2	Test 3
Second 0	4000	4000	4000
Second 1	4035	4022	4041
Second 2	4018	4039	4040
Second 3	4013	4044	4032
Second 4	4014	4043	4021
Second 5	4000	4042	4028
Second 6	2635	2799	2428

Parameter	Test 1	Test 2	Test 3
Average RPM	**3816.4**	**3855.6**	**3798.6**
Operating Time	**00:05:05**	**00:05:05**	**00:05:18**
Cold Engine Temperature (°C)	**39.1**	**44.7**	**56.9**
Hot Engine Temperature (°C)	**111.5**	**97.9**	**116.8**

Source: Research primary data, 2025

Table 4. Average Test Results Without Fuel Cell (Tests 1–3)

Initial Speed	Time	Average RPM	
2000 RPM	**00:10:38**	**2001.9**	**-**
3000 RPM	**00:08:22**	**2901.2**	**-**
4000 RPM	**00:05:01**	**3823.5**	**-**

Source: Research primary data, 2025

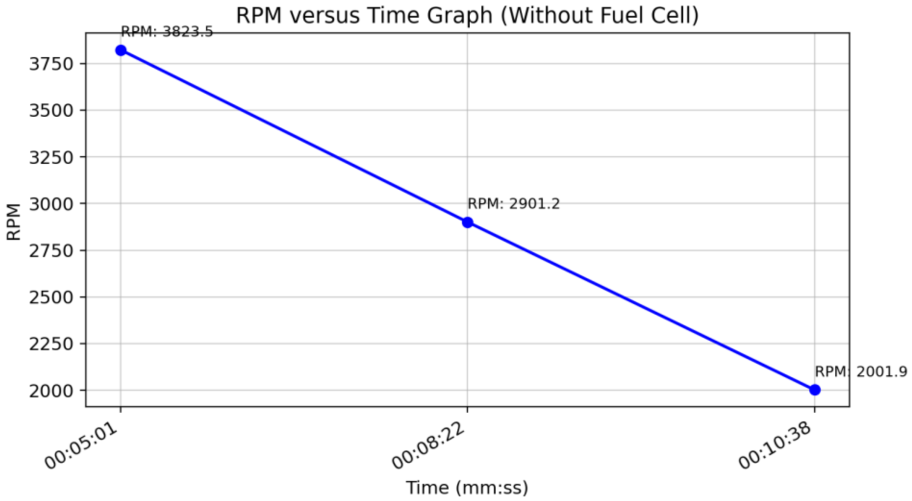

Figure 1. RPM versus Time Graph in the Test Without Fuel Cell
Source: Research primary data, 2025

Test Results With Fuel Cell (180 mL Reactor Volume)

The test with a fuel cell was carried out using a reactor volume of 180 mL of distilled water, 5 grams of caustic soda, and a current of 3.5 Ah, with the same pertalite fuel volume of 75 mL, at the same three initial speed levels as the test without a fuel cell. The test result data are presented in Tables 5 to 7.

Table 5. Test Results With Fuel Cell 180 mL at Initial Speed of 2000 RPM

Parameter	Test 1	Test 2	Test 3
Engine Temperature Before (°C)	**41.0**	**49.2**	**52.1**
Battery Voltage Before (V)	**12.9**	**12.8**	**12.7**
Second 0	2000	2000	2000
Second 1	2034	2030	2035
Second 2	2058	2049	2055
Second 3	2057	2058	2057
Second 4	2042	2050	2055

Parameter	Test 1	Test 2	Test 3
Second 5	2045	2048	2040
Second 6	2039	2040	2035
Second 7	2057	2055	2049
Second 8	2037	2040	2050
Second 9	2053	2049	2051
Second 10	2063	2057	2065
Second 11	2064	2067	2061
Second 12	2032	2029	2030
Second 13	2011	2015	2011
Second 14	2057	2048	2055
Second 15	2039	2040	2041
Second 16	1789	1659	1747
Average RPM	**2028.06**	**2019.65**	**2025.71**
Operating Time	**00:15:54**	**00:15:12**	**00:15:30**
Engine Temperature After (°C)	**104.1**	**156.7**	**105.0**
Battery Voltage After (V)	**12.0**	**12.4**	**12.5**

Source: Research primary data, 2025

Table 6. Test Results With Fuel Cell 180 mL at Initial Speed of 3000 RPM

Parameter	Test 1	Test 2	Test 3
Engine Temperature Before (°C)	**46.0**	**32.0**	**41.1**
Battery Voltage Before (V)	**12.7**	**12.9**	**12.8**
Second 0	3000	3000	3000
Second 1	3052	3029	3055
Second 2	3041	3039	3063
Second 3	3059	3048	3061
Second 4	3028	3032	3041
Second 5	3048	3038	3036
Second 6	3036	3021	3046
Second 7	3044	3050	3044
Second 8	3043	3046	3033
Second 9	3049	3041	3021
Second 10	1293	1331	1617
Average RPM	**2881.18**	**2879.55**	**2910.64**
Operating Time	**00:09:46**	**00:09:36**	**00:09:41**
Engine Temperature After (°C)	**111.4**	**99.6**	**129.0**
Battery Voltage After (V)	**12.4**	**12.6**	**12.6**

Source: Research primary data, 2025

Table 7. Test Results With Fuel Cell 180 mL at Initial Speed of 4000 RPM

Parameter	Test 1	Test 2	Test 3
Engine Temperature Before (°C)	**48.1**	**51.6**	**49.3**
Battery Voltage Before (V)	**12.7**	**12.6**	**13.1**
Second 0	4000	4000	4000
Second 1	4051	4015	4041
Second 2	4011	4033	4051
Second 3	4021	4051	4071
Second 4	4040	4039	4022

Parameter	Test 1	Test 2	Test 3
Second 5	4022	4021	4023
Second 6	4060	2013	4071
Second 7	2510	-	2019
Average RPM	**3839.38**	**3738.86**	**3787.25**
Operating Time	**00:06:32**	**00:05:57**	**00:06:21**
Engine Temperature After (°C)	**131.0**	**129.3**	**109.6**
Battery Voltage After (V)	**12.3**	**12.1**	**12.5**

Source: Research primary data, 2025

Table 8. Average Test Results With Fuel Cell 180 mL (Tests 1–3)

Initial Speed	Time	Average RPM	
2000 RPM	**00:15:32**	**2024.4**	**-**
3000 RPM	**00:09:41**	**2890.4**	**-**
4000 RPM	**00:06:03**	**3621.8**	**-**

Source: Research primary data processed, 2025

Comparison of Results Without and With Fuel Cell

The comparison of engine operating duration between the condition without a fuel cell and with a fuel cell of 180 mL reactor volume at the same fuel volume (75 mL) is presented in Table 9 and Figure 2.

Table 9. Comparison of Engine Operating Duration Without and With Fuel Cell 180 mL

Initial Speed	Without Fuel Cell	With Fuel Cell	Increase
2000 RPM	00:10:38	00:15:32	+ 46.1 %
3000 RPM	00:08:22	00:09:41	+ 15.7 %
4000 RPM	00:05:01	00:06:03	+ 20.6 %

Source: Research primary data processed, 2025

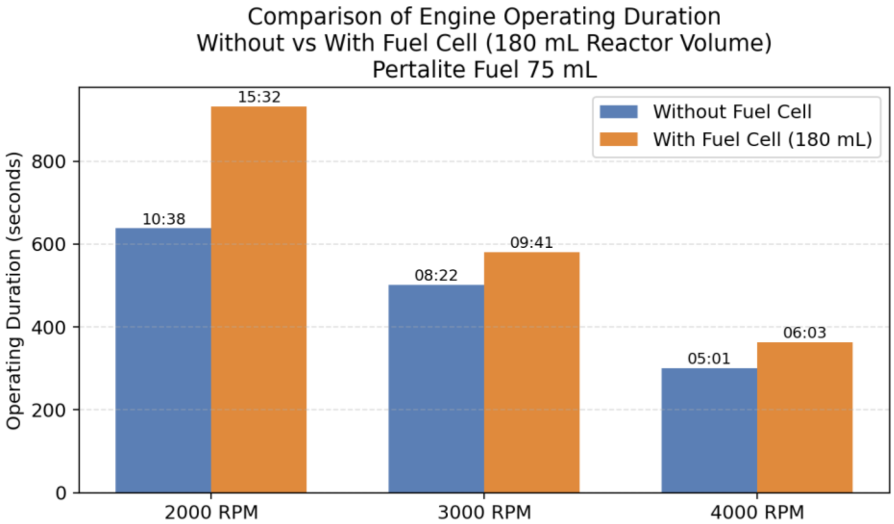

Figure 2. Comparison Graph of Engine Operating Duration Without and With Fuel Cell 180 mL

Source: Research primary data processed, 2025

Based on the data in Table 9, the use of a fuel cell with a 180 mL reactor volume was shown to extend the engine operating duration at all three tested speed levels for the same pertalite fuel volume of 75 mL. At an initial speed of 2000 RPM, the operating duration increased from 00:10:38 to 00:15:32, an increase of about 46.1 percent. At an initial speed of 3000 RPM, the duration increased from 00:08:22 to 00:09:41, or about 15.7 percent, while at an initial speed of 4000 RPM the duration increased from 00:05:01 to 00:06:03, or about 20.6 percent. On average, the use of a fuel cell with a 180 mL reactor volume extended the engine operating duration by about 27.5 percent compared to without a fuel cell.

The increase in operating duration at the same fuel volume indicates that pertalite consumption per unit of time becomes lower when a fuel cell is used, which means fuel use efficiency increases. This is in line with the working mechanism of the fuel cell, in which the HHO gas resulting from water electrolysis that is channeled to the engine intake helps perfect the combustion process of the air-fuel mixture inside the combustion chamber, so that the energy produced from each mL of fuel can be utilized more optimally. This finding is consistent with previous studies that have also reported that the addition of HHO gas to gasoline engines can extend engine operating duration and reduce specific fuel consumption, in addition to potentially increasing power and torque and improving exhaust emission quality.

In terms of engine temperature, the test results show that the engine temperature after testing with a fuel cell is generally higher than without a fuel cell; for example, at 2000 RPM the engine temperature after testing with a fuel cell reached 104.1°C to 156.7°C, higher than the condition without a fuel cell which ranged from 98.7°C to 122.9°C. This temperature increase is presumed to be caused more by the longer engine operating duration rather than abnormal combustion, since the engine works for a longer period of time at the same fuel volume. This condition needs attention regarding the engine cooling system if the fuel cell is applied for long-term use.

In terms of battery voltage, the test results show a slight decrease in battery voltage after testing, from a range of 12.7–13.1 Volts before testing to 12.0–12.6 Volts after testing. This decrease is reasonable because the battery serves as the current source for the electrolysis process in the fuel cell reactor as well as for the engine ignition system, but the decrease that occurred is still within a reasonable range and does not indicate excessive battery depletion.

The selection of the 180 mL reactor volume for in-depth testing in this study was based on initial observations that this volume provided the most fuel-efficient results compared to the 120 mL and 150 mL reactor volumes that were also planned in this study. A larger electrolyte solution volume is presumed to allow for a larger electrolysis reaction surface area and a greater availability of Na^+ and OH^- ions, so that HHO gas production becomes more stable and sufficient for combustion needs at various engine speed levels. However, this study has not yet presented quantitative test result data for the 120 mL and 150 mL volumes, so a comprehensive comparison of the three reactor volumes still requires further testing in order to objectively determine the most optimal reactor volume.

CONCLUSION

Based on the results and discussion, it can be concluded that the use of a fuel cell with a 180 mL reactor volume in a Pertalite-fueled drive engine using 75 mL of fuel extended the engine operating duration at all tested speed levels (2000, 3000, and 4000 RPM) compared with the engine condition without a fuel cell, with an average increase of approximately 27.5%. The application of a fuel cell also resulted in a higher engine temperature after testing due to the extended operating duration and caused a decrease in battery voltage within an acceptable range. Among the three reactor volume variations considered in this study (120 mL, 150 mL, and 180 mL), the 180 mL reactor volume demonstrated the highest fuel efficiency and was therefore selected as the primary configuration for the main analysis. For future research, comprehensive quantitative testing of all reactor volume variations (120 mL, 150 mL, and 180 mL) is recommended to obtain a more complete and objective comparison and to determine the optimal fuel cell reactor volume for improving engine performance.

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