

Study on Performance Characteristics of Ignition Device using in High Voltage Piezo Electronic Ceramic

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Abstract

Background/Objectives: This research involves the production of testing device that simulates the gasoline engine ignition devices and an ignition system with the application of high voltage piezoelectric ceramic aimed overcome the limitations of the existing ignition devices. **Methods/Statistical Analysis:** The experiment was conducted by using a high voltage to the piezoelectric ceramic as a way to overcome the limitations of the conventional ignition device. The experiment was configured the same as the number of revolutions of the engine by varying the duty ratio of the pulse, the ignition time was used as the duty ratio of 8:2 (on:off). **Findings:** As applying piezo electrode ceramic of high voltage, it might be confirmed to increase the secondary voltage comparison with existing ignition system which generating high energies. It also, the energies changed as variable pulses frequencies were indicated the increasing trends proportionally according to distance of ignition plug gaps. Thus, saving capacities of surge voltage were considered to be stable when returning at piezo electronic ceramic because discharged energies were also increased no matter how surge voltage was high size. **Application/Improvements:** As the changed size of energies, it was expected to be more clear realization for lean combustion than conventional ignition device.

Keywords: Discharging Voltage, Misfire, Plasma Ignition, Point Ignition, Spark Engine

1. Introduction

Today, more attention is drawn to downsizing trying to increase efficiency, output, and product miniaturization conditions¹. The internal combustion is divided into mechanical technology and electronic technology and the latter is applied in 6:4 ratios. Furthermore, the ongoing trend shows that the compound elements with the use of control systems are continuously being modified². Instead of studying the fragmentary parts of the engine technology, this research aims to apply technologies, including new technologies that can employ changes to the entire system.

Currently the gasoline engine technology is faced with difficulties stabilizing the power generation because

of instability in the ignition within the combustion chamber due factors including high compression ratio, eddy reinforcement, and lean air-fuel ratio. As the environmental regulations become more demanding, more focus had been given to the development of low fuel consumption technologies, including lean combustion. This created ongoing problems including flare misfires in the engine combustion chamber and decrease in outputs, and there is a need for improvement^{3,4}.

The ignition technology, which is a core variable to engine control should be considered for enhancing fuel efficiency, output and performance, and decreasing harmful exhaust gas. Aside from the current point ignition technologies, a new application technology that can generate better performance and level of safety should be studied and developed^{5,6}.

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When looking back at the previous studies, fundamental test using current amplification equipment, visualization tests with emphasis on combustion flames, plasma application test for the development of LPG air mixing system, plasma jet plug study for the realization of the lean combustion can be found. However, there were no nation studies thus far that concentrate on the gasoline engine and its precise application. Furthermore, national and international automobile and component companies have been continuously facilitating research studies and they have been suggesting the need for high efficiency ignition systems such as laser ignition and plasma ignition^{7,8}.

Therefore, this research involves the production of testing device that simulates the gasoline engine ignition devices and an ignition system with the application of high voltage piezoelectric ceramic aimed overcome the limitations of the existing ignition devices; these were developed to analyze performance levels. This study aims at assessing the possibilities of the influence in the discharge when it is implemented according to the spark gap and its application to the gasoline engine.

2. Testing Device and Methods

2.1 Testing Device

Figure 1 schematic diagram shows the installation of the ignition system for gasoline engines and piezoelectric ceramic plasma generator to assess the performance of the existing point ignition method and the plasma ignition method. Table 1 displays data of the main components and measuring equipment.

Within the point ignition system, the ignition circuit was designed using the fundamentals of producing the frequency clock pulse from the NE555-P type element by receiving the power supply from the battery. Furthermore, the clock pulse was produced to generate high voltage spark in the ignition coil from controlling the (-) signal to generate high voltage. The plasma ignition system was designed to use the fundamental idea of charging the voltage in piezoelectric elements to create the discharge phenomenon and the circuit was produced in a bridge form to allow increased spark generation in the ignition plug point. In addition, as shown in Figure 2, the ignition plug used the iridium ignition plug which is sold locally by D Company and secured the spark signals from the second side phase of the ignition coil using an oscilloscope and high voltage probe.

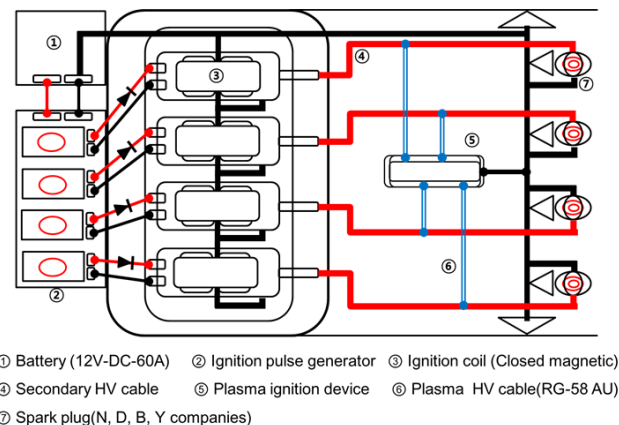


Figure 1. Schematic diagram of ignition system.

Table 1. Specification of part components for experiment

Item	Specification
Battery	- Voltage and Current : DC 12V 200Ah - Temperature: -40 °C to 70 °C
Ignition pulse generator	- Temperature: -25 °C to 85 °C - Measured at 1 ± 0.1kHz
Ignition coil	- Primary : 1.0 to 1.3, Secondary 6,000 to 30,000
Spark plug	- Heat range : 5 to 11.5 - Performance : 70%
Oscilloscope	- Sampling speed : 1GSaps - Bandwidth : 70MHz

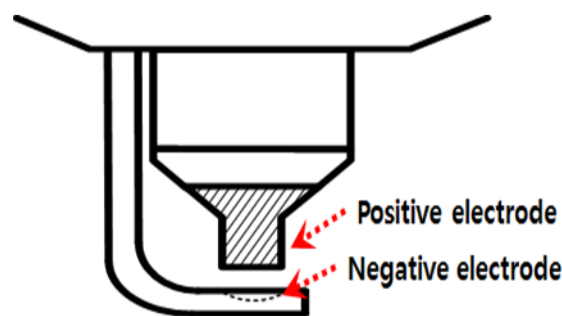


Figure 2. Structure of ignition plug.

2.2 Test Methods

As displayed in Table 2, the engine rotation range was set from 800 rpm to 5,200 rpm in 400 rpm units and to allow spark creation from the engine rotation range, the ignition starting simulator was set from 13.3 Hz to 86.6 Hz in 6.6 Hz units to control the adjustable resistance and to simulate the engine rotation range. In the actual

gasoline engine, 5,200 rpm or higher generates instable electronic controls, and thus, domain over 5,200 rpm was not suggested.

Furthermore, the gap was set from 1.0 mm to 2.0 mm in order to analyze the varying levels of ignition performance in each of the ignition plug gap. The reason behind setting the maximum gap limit at 2.0 mm is because any gap over that limit is exposed to the risk of damage occurring in the components from the high voltage of the simulator. Therefore, this standard was set to prevent the latter problems.

Table 2. Specifications of experimental condition

Engine speed (rpm)	Plug gap (mm)	Ignition type	Company
from 800 to 5,200	1.0	Point/	D
with 400 unit	2.0	Plasma	

3. Results and Considerations

This study assessed the second stage waveform of the existing ignition methods and a plasma ignition method that uses the high voltage piezoelectric ceramic, and further, it analyzed the influences derived from the ignition plug gaps.

3.1 Plug Gap 1.0 mm Test Results

This study involved each section of the second stage waveform of the existing ignition methods and plasma ignition methods and as a result, it showed similar tendencies in all of the sections. Only the results from minimum rotating speed of 800 rpm to maximum rotating speed of 5,200 rpm sections were presented.

Figure 3 shows the surge voltage characteristics according to the ignition plug gap of 1 mm and engine rotating speeds. As demonstrated in the figure, the 800 rpm surge voltage analysis results show the following: About 16.0 kV high voltage in the second side phase of existing point ignition method and about 31.2 kV voltages in the plasma ignition method. In addition, analysis of the 5,200 rpm surge voltage shows the following: About 16.0 kV of high voltage in the second side phase of the existing point ignition method and 32.8 kV voltages in the plasma ignition method.

The electrode of the ignition plug used in this study projected the structure of becoming thinner as it approached the top side of the insulator, and therefore, it showed an advantage in the performance of generating plasma compare to the existing ignition. Even though the surge voltage increased using the plasma ignition method, the size of the discharge voltage increased as well and the charging ability of the surge voltage returning from the high voltage piezoelectric ceramic stabilized. Also, in the plasma ignition method, it showed -0.25 ms as the starting point where the voltage became filled and it momentarily stores the high voltage generated from the ignition coil. Moreover, discharge was initiated in the transistor off state.

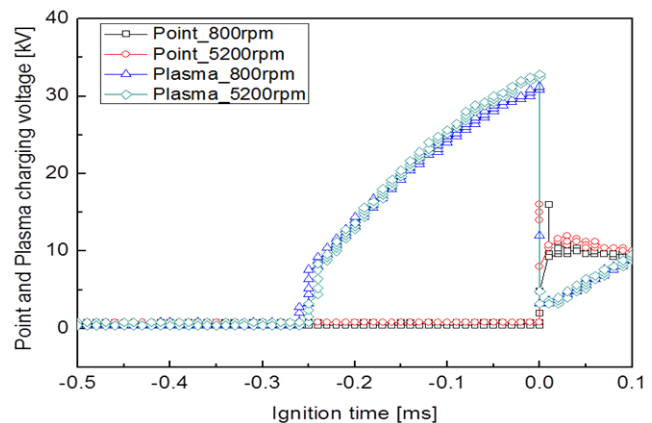


Figure 3. Surge voltage characteristics according to engine rotating speed and spark plug gap 1.0 mm.

Figure 4 shows the discharge voltage characteristics according to the ignition plug gap of 1 mm and engine rotating speeds. As shown in the figure, the point of spark discharge occurred in from 0.0~1.8 ms and the existing ignition method showed a discharge delay phenomenon in which it gradually decreased from 10.0 kV point of 0.0 ms. On the contrary, plasma ignition method displayed lower voltage starting point compared the point ignition method, showing similar phenomenon as exchange period 1. This displayed a fast movement of electrons derived from the energy volume increase created in the plasma ignition which was higher than the energy volume creation in the point ignition.

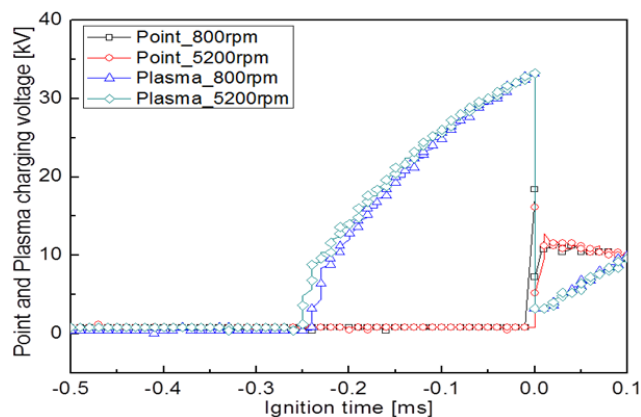


Figure 4. Discharge voltage characteristics according to engine rotating speed and spark plug gap 1.0 mm.

3.2 Plug Gap 2.0 mm Test Results

This studied each section of the second stage waveform of the existing ignition methods and plasma ignition methods and as a result, it showed similar tendencies in all of the sections. Only the results from minimum rotating speed of 800 rpm to maximum rotating speed of 5,200 rpm sections were presented.

Figure 5 shows the surge voltage characteristics according to the ignition plug gap of 2.0 mm and engine rotating speeds. As demonstrated in the figure, the 800 rpm surge voltage analysis results show the following: About 18.0 kV of high voltage in the second side phase of existing point ignition method and about 33.2 kV voltage in the plasma ignition method. In addition, analysis of the 5,200 rpm surge voltage shows the following: about 18.4 kV of high voltage in the second side phase of the existing point ignition method and 33.2 kV voltage in the plasma ignition method.

As mentioned in the plasma gap 1.0 mm analysis results, the electrode of the ignition plug used in this study projected the structure of becoming thinner as it approached the top side of the insulator, and therefore, it showed an advantage in the performance of generating plasma compare to the existing ignition. Even though the surge voltage increased using the plasma ignition method, the size of the discharge voltage increased as well and the charging ability of the surge voltage returning from the high voltage piezoelectric ceramic stabilized. Also, it showed -0.25 ms as the starting point where the voltage became filled and it momentarily stores the high voltage generated from the ignition coil. Moreover, discharge was initiated in the transistor off state.

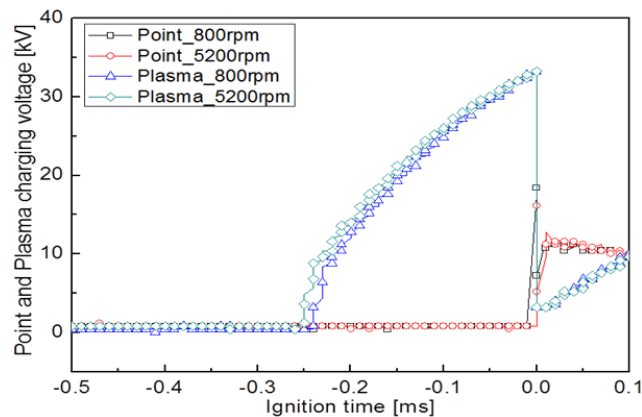


Figure 5. Surge voltage characteristics according to engine rotating speed and spark plug gap 2.0 mm.

Figure 6 shows the discharge voltage characteristics according to the ignition plug gap of 2.0 mm and engine rotating speeds. As shown in the figure, the point of spark discharge occurred in from 0.0~1.8 ms and the existing ignition method showed a discharge delay phenomenon in which it gradually decreased from 10.0kV point of 0.0 ms. On the contrary, plasma ignition method displayed lower voltage starting point compared the point ignition method, showing similar phenomenon as exchange period 1. As mentioned in the 1.0 mm test results, the increase of energy volume created in the plasma ignition was greater in comparison to the point ignition.

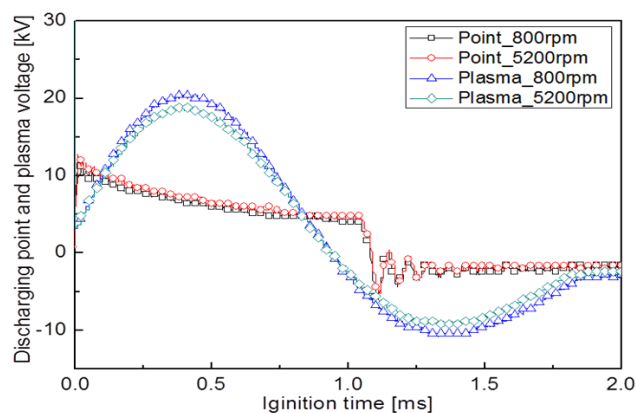


Figure 6. Discharge voltage characteristics according to engine rotating speed and spark plug gap 2.0 mm.

3.3 Test Results of All Section

Figure 7 and 8 shows the surge voltage and discharge voltage according to the engine rotating speed from 800 rpm to 5,200 rpm (ignition cycle f: 13.3Hz~86.6Hz) and this is to compare and analysis the performance

of all sections, not a specialized domain of rotation performance.

After analyzing the surge voltage, when the plug gap was set to 1.0 mm, the second side phase of the existing point ignition method maintained constant voltage at 16.0 kV and plasma ignition method maintained constant voltage around 32.0 kV. Moreover, when the plug gap was set at 2.0 mm, only the size of the voltage increased compare to the existing point ignition and no significant characteristics were found. However, an instable surge voltage was identified because the filling ability of the high voltage piezoelectric ceramic could not be smoothly invigorated. Although the size of the energy in the surge voltage increased in the plasma ignition method, it is expected that the volume changing phenomenon will occur in the discharged energy.

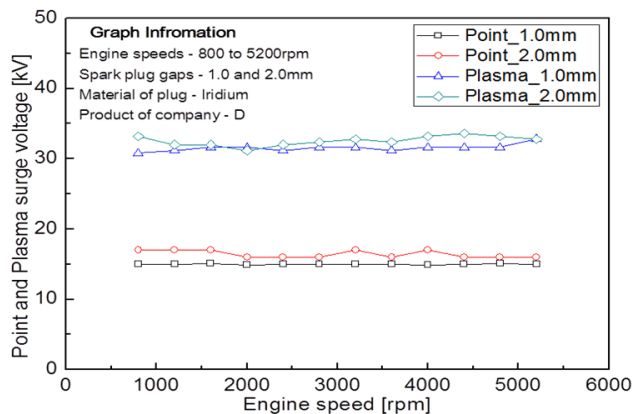


Figure 7. Result of point and plasma ignition performance to surge voltage.

Result analyzing the discharge voltage, when the plug gap was set to 1.0 mm, the existing point ignition method maintained constant voltage at 6.5 kV and plasma ignition method maintained constant voltage around 17 kV. Also, when set to 2.0 mm, it maintained constant voltage at 6.0 kV and the plasma ignition method maintained constant voltage around 14.5 kV. The latter can be considered as the characteristics of the ignition plug used in the study and when the surge voltage of about 30.0 kV is produced, the filling ability and discharge ability of the plasma ignition method is created in similar fashion.

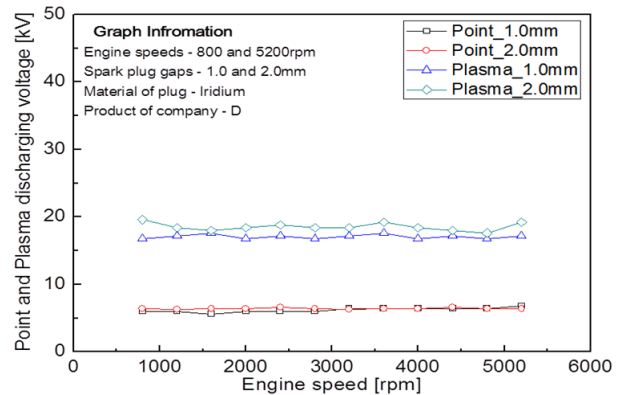


Figure 8. Result of point and plasma ignition performance for discharge voltage.

4. Conclusions

By using the gasoline engine ignition starting simulator, the ignition performance of the plasma generator with the application of high voltage piezoelectric ceramic was assessed and the following are the results.

- In the plasma ignition method, the surge voltage increased about 2 times compared to the existing point ignition method and through this, increasing in ignition performance was identified.
- Through the high voltage piezoelectric ceramic, the efficiency of the energy transferred to the plug became enhanced.
- By assessing the AC signals at the point of discharge, the energy volume created in the plasma ignition increased more than the energy volume created in the point ignition.
- In all sections, the surge voltage of the plasma ignition device maintained about 30 kV and discharge voltage improved about 2~3 times compared to the existing point ignition method.
- It is considered that if a more stabilized circuit and internal mechanical performance of the ignition plug is complemented, the instable spark discharge created in the second side phase will improve to be used efficiently in the engine rotation sections.

5. References

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