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Characteristic Analysis on Energy Waveforms of Point Sparks and Plamas Applied a Converting Device of Spark for Gasoline Engines

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Abstract

Background/Objectives: This research analyzes waveforms of surge and discharge voltage in the plasma ignition and point ignition through realization of plasma spark by self-producing a plasma generator apparatus. **Methods/Statistical Analysis**: The components including batteries, ignition pulse generator (self-produced), pencil type ignition coil, iridium ignition plug, and nonresistance ignition plug were used in the experimental device. The experimental method involved assessing the gap change of the ignition plug and the engine rotation count by setting the range of measurement from 1,200 rpm to 5,200 rpm. By connecting an additional device, impedance value increased due to the influence from the internal elements and components. **Findings:** The plasma ignition discharge energy discharges plasma completion from 0.75 to 1.5 ms to show that the point and plasma have different energy characteristics and when the ignition plug gap is increased, the energy characteristics of discharge voltage increased. However, the starting point of the discharge responded 2.5 ms faster compared to the point ignition due to the plasma discharge point delay of 0.75 compared to the point ignition. By connecting an additional device, impedance value increased due to the influence from the internal elements and components. This helped to find the cause behind the relatively delayed 3rd phase amplification's plasma discharge starting point in comparison to the point ignition. **Application/Improvements:** We believe that better result will be drawn when the electrode diameter and formation are re-engineered with the optimized volume change of plasma produced between the ignition plug electrodes.

Keywords: Charging Voltage, Converting Device, Discharging Voltage, Ignition Engine, Plasma

1. Introduction

The ignition technique used in the gasoline engine must produce spark by stabilizing energy transferred from the 2nd phase coil of the ignition to the plug electrodes. The most important element in the gasoline engine is incorporating a precise control technology which maximizes the combustion performance by transferring spark from the minimized combustion state[1,2]. Out of the three elements of combustion, ignition technology is one of the most important elements and more attention has been given to this subject of study[3]. Although the gasoline engines are faced with difficult regulations including the California Fuel Efficiency Regulation that requires the application of technology to control the exhaust emission, the technologies that improve fuel efficiency also has features that control harmful exhaust emission as well[4,5]. The point ignition technology used for the gasoline engines

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have been continuously generating problems such as miss fires while attempting to improve the high-compression, swirl, and tumble state[6,7]. To advance new technologies to cope with this problem, studies focusing on plasma ignition are increasing rapidly worldwide[8]. When assessing the studies pertaining to ignition technology, studies focusing on high-compression, high capacity, and acceleration are being widely facilitated and studies concentrating on the application of plasma in engines are continuously expanding[9]. Figure 1 shows results including the high voltage, microwave, and laser plasma. Out of these various plasma application studies, the plasma realization can be most easily accessed through high voltage and depending on how the circuit and the components are engineered, the production of plasma can vary. However, the plasma characteristic research through the waveform analysis with the self-produced generator is not being assessed in this research. Therefore, this research aims to display the performance results of the surge and discharge voltage from the point ignition and plasma ignition through spark generated from the self-produced plasma generator for gasoline engines.

2. Experimental Devices and Methods

To achieve the ignition system for 1.6 L gasoline engines as shown in Figure 2, the test equipment was self-produced and the components including 12 V battery, ignition pulse generator (self-produced), pencil type ignition coil, iridium ignition plug, and non-resistance ignition plug were used. The pulse generator calculated the engine rotating speed through the frequency variable element. The duty rate of frequency and pulse designed to control the ground signals through the transistor switching and the increased high voltage from the ignition coil is designed to produce point and plasma ignition between the electrodes of the ignition plug. By creating a circuit that can increase internal circuits, the plasma generator is designed to charge 14k V to 19k V for direct discharge to plasma. The plugs developed by B company, was used as

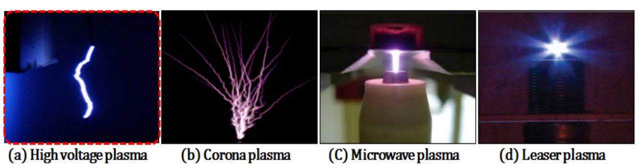


Figure 1. Kinds of plasma ignition.

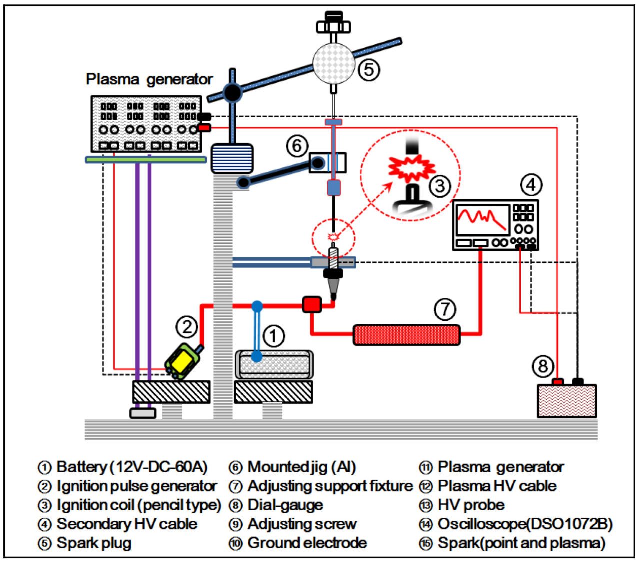


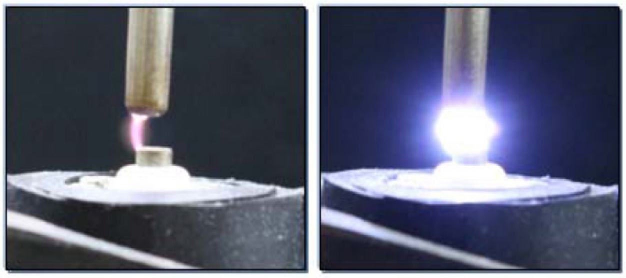
Figure 2. Schematic of copied device using in ignition system for an SI engine.

a component for the ignition plug and the RG cable was used for the signal transfer for the plasma production to minimize noise signals. Table 1 displays the specifications of the products used in the testing equipment.

The test method involves calculating the pulse duty with engine rotating speeds from by setting the ignition plug gap to 1.0 mm, 1.5 mm, 2.0 mm. This was considered the base test for ignition production. Plasma discharge signals were compared with the base by setting the amplify signal ratio of the plasma generator to (500:1) using the high voltage probe. Moreover, the measure domain for the gap change and engine rotating speed of the ignition plug was set from 1,200 rpm to 5,200 rpm to facilitate the test and the ignition plug gap was set from 1.0 mm, the standard suggested by the B Company, to 2.0 mm, a safe range

Table 1. Specifications of copied device using in ignitions system for an SI engine

No.	Items	Specifications
1	Generator	- Frequency: 14Hz to 1,000Hz
2	Ignition coil	- Pencil
3	Spark plug	- Iridium
4	Oscilloscope	- Sampling speed: 1GSaps
5	Dial gauge	- Accuracy: 0.01mm
6	Adjust screw	- 0.1mm*50mm
7	High voltage cable	- RG 58 AU/probe
8	Battery	- 12V_DC-60Ah



(a) Point ignition(spark) (b) Plasma ignition(spark)

Figure 3. Shapes of real ignition through an experimental device.

Table 2. Experimental conditions of points and plasmas ignition

No.	Condition items	Set up for conditions
1	Engine speed	From 1,200rpm to 5,200rpm, 400rpm unit
2	Plug gap	1.0mm, 1.5mm, 2.0mm
3	Ignition type	Point(base)/Plasma
4	Manufacture	B(iridium plug)

of gap for the assessment of energy change in plasma. The test factors were set similarly following this method and about 10 counts of assessment with less than 5% error of the data results were normalized Figure 3 is a picture that shows the actual realization of point ignition and plasma ignition and Table 2 displays the actual test conditions.

3. Experimental Results and Discussions

Figure 4 shows the waveform detected from the secondary side of the point ignition coil used in the ignition start simulator for gasoline engines. The graph compared the voltage to the ignition time and this study results were achieved by setting the point ignition plug gap at 0.1 mm, 1.5 mm, 2.0 mm. Ignition pulse duty rate of the test results were set to 7:3 (On:Off) and the trigger position of the 2nd phase waveform was set at 0.0. In addition, the reliability was assessed through 128 (1/sec) for the accuracy of the test results. The symbols indicated in the graph were classified as A (1.0 mm surge voltage), B (1.5 mm surge voltage), C (2.0 mm surge voltage), D (discharge voltage), E (point of ignition completion) for assessment.

Figure 5 shows test results generated by adding the plasma generator following the same conditions and

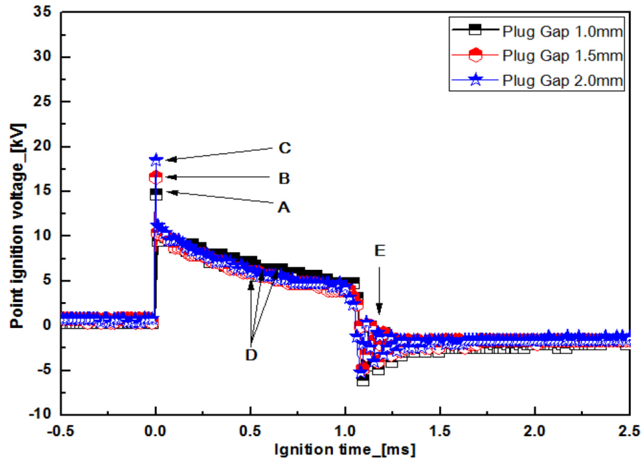


Figure 4. Results of point ignition from 1,200rpm to 5,200rpm.

installment methods in Figure 5. The plasma voltage was compared to the ignition time and the symbols indicated in the graph are classified as A (Initial 1st phase charge voltage), B (1st phase surge voltage), C (2nd phase charge voltage), D (2nd phase surge voltage), E (+discharge voltage), F (high voltage charge point), G (maximum plasma spark), H (-discharge voltage) for assessment. The test results with the use of plasma generator showed that before the generation of plasma discharge, with the plug gap is set at 1.0 mm, 1.5 mm, and 2.0 mm, A displayed 2.0 mm <1.5 mm<1.0 mm in order, the results disagreeing with the point ignition. The surge voltage results showed 1.0 mm (29 kV)>1.5 mm (27 kV)>1.0 mm (15 kV) in order, which increased 13 kV on the average compared

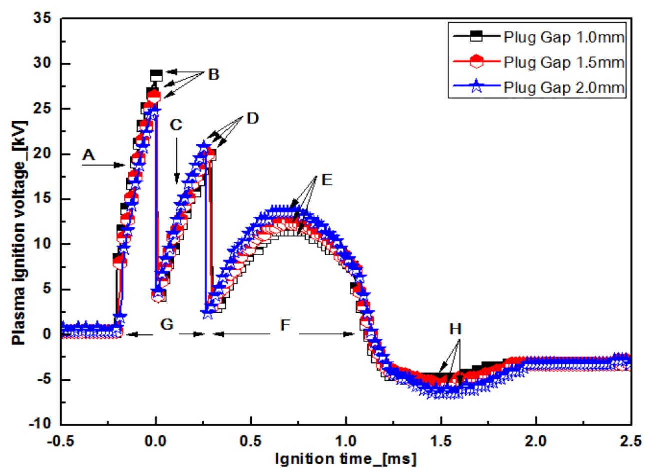


Figure 5. Results of plasma ignition from 1,200 rpm to 5,200 rpm.

to the point ignition. In the case of plasma ignition, it was examined by the process of charging 3rd amplification through inner circuit of plasma generator from high-voltage (14 kV to 19 kV) generated in 2nd coil and the reason which it has shown against the surge voltage waveform of point ignition from the energy lost as increasing the gap of ignition plug's gap. At the point of C and D, the pre-discharge (spark) was created after the point B completion, and subsequently it transformed into 2nd phase charge and at point D (2nd phase surge voltage), it showed results opposite to that of point B. The cause of the trend decreased more than B-point (First phase surge voltage) by energy generation through pre-discharge in the process of converting 2nd charge was examined. The cause of the opposing results derived from the 1 phase and 2nd phase surge voltage was identified by analyzing the size of the 2nd phase surge voltage 1.0 mm (20 kV)<1.5 mm (21 kV)<2.0 mm (22 kV) in order. For point E, the exchange constituent were different from the energy constituent of the point ignition results and the size of the discharged energy, in accordance to the plug gap, were 1.0 mm (11 kV)<1.5 mm (12.5 kV)<2.0 mm (15 kV), which showed differentiated signals. Furthermore, in the H point (negative discharges), the constituent of the discharge energy (spark) in the E point transformed in the opposite direction, showing reversed results. As a result, some of signal constituent of the spark, generating the actual plasma discharging energy, were converted to ground since the energy maximized by wrongfully designed diameter of plug electrode. The reason of incidence of delaying phenomenon of converting ground from remained plasma constituent was confirmed. For F and G points, as it was the most important point for discharge voltage production, the results showed that G point of discharge production, without the surge charge between the F (1 ms) and G (0.5) points occurred equivalent to the point of the previous point ignition. The cause was that the energy consistent of the surge and discharge constituent was strong compared to the plasma spark point ignition. Although the volume of the spark was maximized, the point of spark production was relatively delayed due to the addition of the internal element in the plasma generator.

Figure 6 shows result that is needed to reassess the 128 (1/sec) averaged results that compare the point ignition characteristics and plasma ignition characteristics which were the most important constituents from Figure 4 and 5. When assessing the point ignition, the point that had an influence on the ignition performance was identified as point 4. In the case of plasma, it resulted in 5 points,

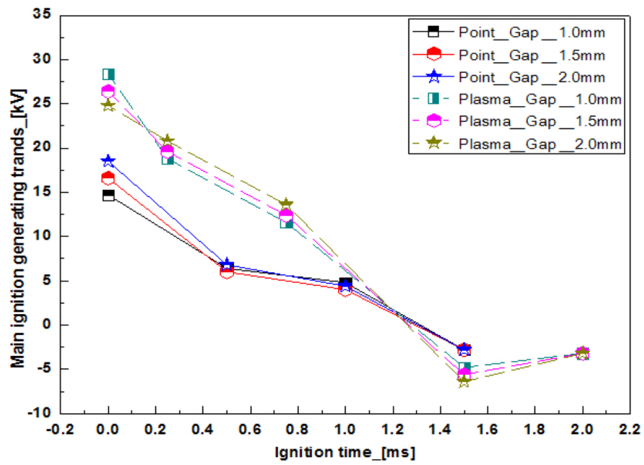


Figure 6. Main result of trends in point and plasma ignitions from 5,200 rpm

which meant 1 point was produced compared to the previous point ignition method. As a cause, in the case of point ignition, the size of the surge voltage from 0.0 ms point increased depending on the gap and from 0.5 point, the same performance was maintained to 1.5 ms point to complete the ignitions which were the identified results. As the cause, the performance of the high energy discharge related to the low voltage, maintained the characteristics until the ignition of high voltage energy constituent from the 2nd phase ignition coil became completed and this was clearly confirmed. However, in the case of plasma ignition, results showed that the ignition energy performance slightly changed from 0.0 ms point to the completion point of 2.0 ms due to the differences in the frequency characteristics of point ignition.

Figure 7 shows the numerical values in order to assess the differences in characteristics at the actual point where the spark of the point ignition and plasma ignition occur. In the discharge energy of the point ignition, low voltage spark becomes completed from 0.0 ms to 1.0 ms and even though the point plug gap is changed, the same results were seen. The plasma ignition discharge energy discharges plasma completion from 0.75 to 1.5 ms to show that the point and plasma have different energy characteristics and when the ignition plug gap is increased, the energy characteristics of discharge voltage increased. However, the starting point of the discharge responded 2.5 ms faster compared to the point ignition due to the plasma discharge point delay of 0.75 compared to the point ignition. By connecting an additional device, impedance value increased due to the influence from the

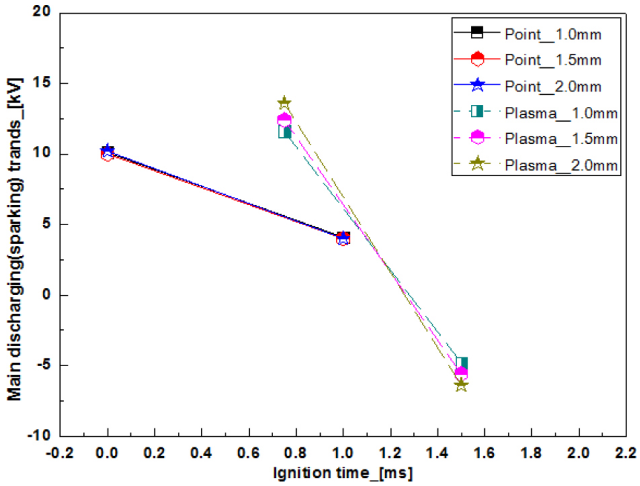


Figure 7. Main result of discharging voltages between point and plasma from 5,200 rpm

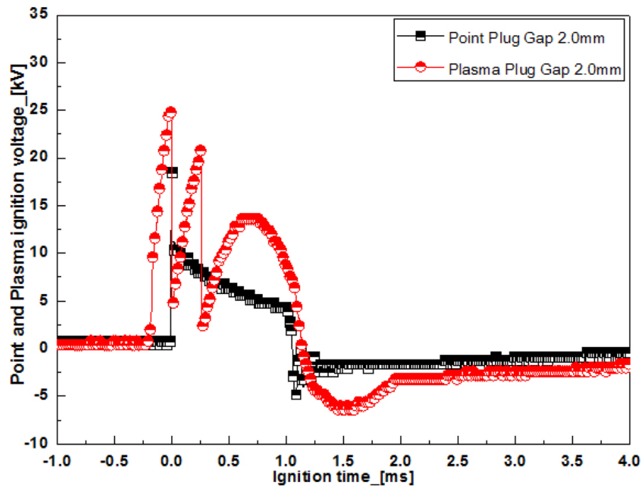


Figure 8. Comparison with performances of point and plasma ignition from 5,200 rpm.

internal elements and components. This helped to find the cause behind the relatively delayed 3rd phase amplification's plasma discharge starting point in comparison to the point ignition. Therefore, the necessity of considering the ignition point revision of the plasma delay phenomenon was realized.

Figure 8 show the numerical figures assessed from 5,200 rpm engine rotation count to compare the point and plasma ignition in the Red zoon of the engine. The final results pertaining to the point and plasma ignition displays that better energy performance compared to the point ignition can be obtained from using it parallel with the control circuit and finding a solution to advance the delayed time of the plasma ignition through the testing data from the gasoline engine's maximum rotation count. Moreover, the more reliable results can be expected if the plasma created between the ignition plug and electrode redesigns the electrode diameter and form by maximized the volume change of spark.

4. Conclusions

The following conclusion was obtained from the test results which consisted of realizing plasma spark from the existing ignition system in order to expand the lean condition range of combustion.

- From the result of experimenting the performance of point ignition at 5,200 rpm, as the gap of ignition plug is increasing or designed bigger, the height of secondary side of ignition coil was influenced by the magnitude of the plug gap, and as a result, the phenomenon of the increase 1.0 mm (15kV) < 1.5 mm (17 kV) < 2.0 mm (19 kV) in order, was confirmed. In the case of discharging voltage, secondary discharging energy was influenced, even if the gap is changing.
- From the result of experimenting plasma ignition, the numerical value of the discharging voltage of surge-voltage was changed against the point ignition as the plug gap is increased in the process of initiating the plasma ignition. Furthermore, discharging energy generated the maximized plasma energy by creating AC-related energy.
- From the result of evaluating the time of plasma discharge, the time starting from 0.75 ms delayed against point ignition to the completion of plasma was generated 0.25 ms faster than the point ignition. Moreover, in the light of the characteristics of delayed discharge of the plasma, the time of the increase of impedance value was changed, according to the characteristics of the inner circuit and element in the generator.
- From the last result regarding point and plasma ignition, it can be available in the gasoline engine's maximum revolution domain, however, the additional experiment should be implemented by re-designing the control circuit which can advance the delayed time of the plasma ignition. In closing, better performance of the plasma generated between ignitions of plug electrodes, can be achieved by re-designing the diameter and appearance of the electrode as well.

5. References

1. Kim K, Choi D. Ignition performance of high-efficiency plasma applied a generating amplification device with high voltages. KSAE. 2015; 10(79):694–8.
2. Hohenverg GF. Advanced approaches for heat transfer calculations. SAE. 1979; 790825:2788–806.
3. Arun S, Solomon P. Plasma-jet ignition of fuel sprays in a rapid compression machine. SAE. 1988; 880205:1–15.
4. Kim K, Kim H, Choi D, Ahn J, Kwon B, Kim S. Study on plasma performance of piezo-ceramic using ignition oscillator copied device for gasoline engine. Fall Conference Proceedings of KSAE; 2014. p. 29–30.
5. Kim H, Kim K, Choi D. Fundamental study of a plasma generating for gasoline ignition applying AC power. Indian Journal of Science and Technology. 2015; 8(21):1–5.
6. Jaworek A, Krupa A. Corona discharging from a multipoint electrode in flowing air. Journal of Electrostatics. 1996; 38:187–97.
7. Song J, Seo Y, Sunwoo M. A study on the effects of ignition energy and discharge duration on the performances of spark ignition engines. Transactions of KSAE. 2001; 9(6):40–6.
8. Moon S. Recent trend in eco-car policies and vehicle development in Japan. Auto Journal of KSAE. 2012; 34(11):50–4.
9. Ryu HW, Park JS, Yoo HS, Kim MH. Combustion characteristics ignited by plasma jet igniter in constant volume vessels shaped like conventional engine chamber. Fall Conference Proceedings of KSAE; 1999. p. 79–86.