Experimental Study on Electrostatic Spraying Technique Effects of Gasoline Combustion Characteristics

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Keywords: Electrostatic spray, Combustion Characteristics, Gasoline.

Abstract. The combustion characteristics of gasoline, set up a test-bed combustion technology based on electrostatic spray, the combustion chamber along the axial position of the gas temperature and the variation of the combustion chamber flue gas composition of the key position of the test. Experiment iron drum simulation of the combustion chamber of 50cm and 80cm in diameter and height, respectively, in the longitudinal uniform on one side of the barrel with a straight line 10cm away from play a number of hole; Santana 3000 fuel injection enables fuel atomization; needle electrode and the electrostatic generator gasoline to bring the static. When the injector spray out of petrol continued to burn so that the thermocouple and the exhaust gas analyzer probe is inserted into the through hole to the metal pail each height of the center, respectively, to test the barrel along the axial position of the gas temperature before and after to bring static variation of gas composition and key positions. Experimental results show that the electrostatic spray combustion technology can significantly improve the thermal efficiency of gasoline combustion and improve flue gas emissions, the use of electrostatic spray combustion technology, near the nozzle temperature increases can be achieved in about 18%; HC emissions decrease can reach more than 60%, decrease of CO emissions can be achieved in more than 58%, the increase of CO2 emissions can be achieved more than 52%, NOX emissions decrease can reach more than 45% percent, a new idea for energy saving.

Introduction

The combustion mode of the current gasoline engine is spray combustion. However, the atomization condition of gasoline is very poor because of low temperature and slow air flow rate when the gasoline engine is starting, warming up or idle speed, so the gasoline engine consumes a lot of energy with serious emission. Even if the gasoline is in its medium working condition with large air intake, high rotation and good atomization, the gasoline remains to combust incompletely and there is still room for improvement. It is found in the research that the surface tension and viscosity resistance of liquid are two major resistances against the atomization but the charging liquid can decrease the surface tension and increase the internal and external pressure difference so as to improve the atomization [1-2]. The electrostatic spray technology means the charging liquid flown out from the nozzle where a static generator is equipped to charge the liquid with thousands of watts static electricity makes the liquid column surface extremely unstable and even splits into ions or droplets under the effects of surface tension, electrostatic force and gravity. This technology can improve the atomization of the droplets significantly so as to achieve the purpose of improving combustion [3-4].
Morio Jido [5] studied the electrostatic spray of kerosene under 0.06Mpa injection pressure on the purpose of improving the spray condition due to the spray form of charging kerosene droplets changing along with the charged voltage and electrode shape. Robert E Hetrick [6] designed an intake port injector for gasoline engine and studied the electrostatic spray under 0.275Mpa injection pressure, discovering the spray cone angle after the gasoline is charged increases significantly along with the increase of the charging current. Wen Jianlong [7] studied the electrostatic spray and combustion of the diesel under 0.25Mpa injection pressure and the result showed the charging diesel spray narrowed the particle size distribution, making the diesel burn more fully but emit much less. The above researches all indicate that the charged fuel can improve the atomization and combustion effect in case of the low and stable injection pressure. We made use of a test-bed to measure the change rule of the gas temperature in the axial direction and the flue gas composition at the key positons in the combustion chamber with the charged or uncharged fuel so as to study the rule [8-9] that the static electricity imposes on the spray combustion characteristics in the pursuit of a new concept for energy saving and emission reduction.

**Experimental apparatus and measuring method**

**Experimental apparatus**

The Figure 1 shows the experimental apparatus which mainly consists of air compressor, oil tank, pressure valve, fuel injector, solenoid valve power supply of the fuel injector, drum, bracket, electrode, electrostatic generator, etc. The air compressor offers a certain pressure to the gasoline to ensure the gasoline flows continuously. The pressure valve keeps the gasoline pressure in the channel constant. As the core part of the experiment, the fuel injector of Santana 3000 which is fixed on the bracket can amortize the gasoline into droplets by injecting it via four nozzles on the needle valve of the injector. As far as we know, the fuel injector usually injects intermittently on the gasoline engine and the closing and opening of the needle valve is controlled by the ECU through the solenoid valve. So we add a 12V power supply to the solenoid valve to make the fuel injector inject constantly. To make sure the gasoline can combust in a stable manner, the gasoline combustion is simulated in a combustion chamber in the experiment with a steel drum (see the Figure 2) covering the injector. The drum is 50cm diameter and 80cm high, with several holes on a longitudinal line with interval of 10cm between each other (these holes shall be distributed on a line and the aperture is about 18mm). When the gasoline sprayed out of the injector combusts constantly, the probes of the thermocouple and the exhaust gas analyzer will arrive at the center of each plain at different heights through the holes to detect the gas temperature along the axial position in the drum and the change rule of the gas composition in the key positions. Besides, two needle electrodes shall be installed on the drum bracket near the fuel injector so that the gasoline can be charged with enough electrostatic charge [10-11] when it is sprayed out.

In addition to the experimental apparatus mentioned above, the experiment also applied the high precision temperature measuring instrument (Temperature measurement ranges from $-50^\circ C$~$1300^\circ C$) of Shanghai Yulai Instrument Co., Ltd., thermocouple, HNA-500 exhaust gas analyzer and auxiliary materials like asbestos.
Measuring method

Firstly, connect all the equipment as shown in the Figure 1, switch on the air compressor (gasoline pressure stabilized at 1.5kg/cm²), tank valve and solenoid valve of the fuel injector (keep the needle valve open as well) so that the gasoline in the tank sprays out of the injector constantly [12]. Ignite the amortized gasoline at the injector nozzle and the gasoline will keep combusting [13]. Get the probes of the thermocouple and exhaust gas analyzer to each center of the drum through the holes in one side of the drum and detect the temperature and change rule of the flue gas (including CO, HC, CO2, NOX, etc.) at different height of the drum (the temperature can be read from the high precision temperature measuring instrument and thermocouple and the exhaust gas concentration from the exhaust gas analyzer). When the above processes are done, connect the electrostatic generator with the needle electrodes installed near the fuel injector. Switch on the electrostatic generator, impose 20KV high voltage and detect the change rule [14-15] of the temperature and the flue gas (including CO, HC, CO2, NOX, etc.) at each center of different heights of the drum during the combustion of the gas charged with electrostatic electricity.
Results and analysis

The experiment is completed under the conditions of 35 OC ambient temperature, 70% average relative humidity, 20KV needle electrode voltage and 1.5kg/cm2 oil pressure. The results is as shown as in the Figure 3~Figure 7.

The Figure 3 shows the differences of the gas temperature at the center along the axial direction when the charged or uncharged gasoline is combusting constantly in the combustion chamber. It is obvious that the combustion of the charged gasoline occurs much closer to the nozzle, showing a temperature about 18% higher than the combustion of the uncharged gasoline; the temperature drops sharply near the steel drum combustion chamber at the end of the spray-cone. So the combustion zone is enlarged and better for full combustion due to the combustion more approaching to the nozzle.

The Figure 4 shows the change rule of the HC emission along with the time at the outlet of the combustion chamber when the charged or uncharged gasoline is constantly combusted. The HC emission drops as apparently as by more than 60% during the electrostatic spray combustion, which means the gasoline combats more fully with this technology.

The Figure 5 and 6 represent the change rule of the CO and CO2 along with the time at the outlet of the combustion chamber respectively. From the figure it can be observed that the CO emission drops as sharply as by more than 85% while the CO2 emission increases as apparently as by more than 52% when the electrostatic spray combustion is applied, which is also an evidence that shows the technology makes the combustion better.

The Figure 7 is the change rule of the NOX emission along with the time at the outlet of the combustion when the charged or uncharged gasoline is constantly combusted. The electrostatic spray combustion technology decreases the NOX emission as significantly as by more than 45%, which indicates the oxidation reaction of N in the fuel is inhibited efficiently in the electrostatic spray combustion.

Figure 3. Gasoline combustion temperatures at different positions on the axial line.
Figure 4. HC emission along with the time.

Figure 5. CO emission along with the time.

Figure 6. CO\textsubscript{2} emission along with the time.
Conclusions

According to the combustion characteristics of gasoline, we set up a test-bed combustion technology based on electrostatic spray combustion technology and studied the change rule of the gas temperature along the axial position in the combustion chamber and the flue gas composition of the key position in the combustion chamber. The result shows that the technology can improve the efficiency of gasoline combustion and emission of flue gases, making the temperature near the nozzle drop by about 18\%, the HC emission drop by more than 60\%, CO emission drop by more than 58\%, CO2 emission increase by more than 52\% and NOX emission drop by more than 45\%.

References


