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AN EXPERIMENTAL STUDY ON THE EFFECT OF AIR-ASSIST AND WALL-FLOW DISTRIBUTION IN THE SPARK IGNITION ENGINE PERFORMANCE

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ABSTRACT

The purpose of this paper is to present the investigation on the role of the spray characteristics and wall-flow distribution that influenced the subsequent process such as mixture formation, combustion and exhaust emission in gasoline engine. In this study, the effect of the assistant air pressure on the spray formation and atomization was analysed and an air-assist fuel injection adapter was developed to investigate the spray characteristics as well as to measure the wall-flow distribution.

1.0 INTRODUCTION

The development of internal combustion engine now play a dominant role in the fields of power, propulsion, energy and emission control. Concerning the above matter, engine manufacturers have a lot of option in their hands. For the combustion system, they can strived for the leanest possible mixture to give a highly stable combustion with minimum nitric oxide. The exhaust emissions from automotive engines have become a serious environmental problem in the world. Due to environmental problems, emission regulations for the gasoline engine are becoming more stringent. In order to achieve the low emission engine, a lean-burn system is an effective concept of combustion in engine system design. Also, the lean-burn engine fulfills the environmental and legislative requirements for clean emission. It is very important to control the mixture formation and optimal flow conditions for the low emission because the fuel-air mixing process in the engine cylinder has an effect on the combustion process and pollutant formation.

Recently there has been a lot of investigation to obtain the effective of optimum flow condition in the intake manifold on the combustion stabilization and to clarify the influence of engine variables on the combustion process [1-3] and there are many correlation between the mixture formation and engine exhaust emissions [4-6]. Most measurements have concentrated on the structure and development of the liquid spray. In these experimental works, they have a limitation of the measurements on the engine performance, combustion characteristics and pollutant concentration. The stringency of engine emission standards requires a more through investigation of mixture formation, combustion process and the pollutant formation. Therefore, it is necessary to obtain the investigation of fuel atomization and mixture formation in the engine cylinder.

In this work, the effect of air-assist pressure on the fuel atomization and fuel spray behavior were investigated by the image processing method. Wall-film flow of fuel in the intake manifold was measured using the steady flow test apparatus under the same air-assist conditions. Furthermore, the influences of the air-assist fuel injector on the exhaust emission of gasoline engine were investigated under various air-fuel ratios.

2.0 EXPERIMENTAL APPARATUS AND PROCEDURE

2.1 Experimental Apparatus

To observe the fuel atomization of spray with air-assist fuel injection, the experimental injectors were prepared as shown in Fig. 1. The fuel injection adapter was modified for assistant air, which has six holes with straight groove.

In this study, the air-assist adapter was used to compare the formation of fuel-air mixture and the concentration of exhaust emission. The assisted air supplied by compressor is ejected through 6 holes around the injector nozzle tip. The air from the surge tank then passing through the orifice. The heater is used to control air temperature before entering the cylinder head. In order to observe the spray behavior, the analysis system of spray particle motion consists of a Charge Coupled Device (CCD) camera, injection system, light source, and optical apparatus as shown in Fig. 2.

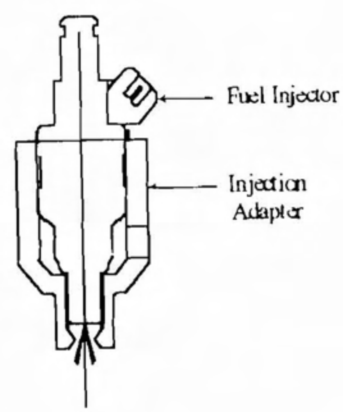

Fig. 1 Air-Assist Injection Adapter

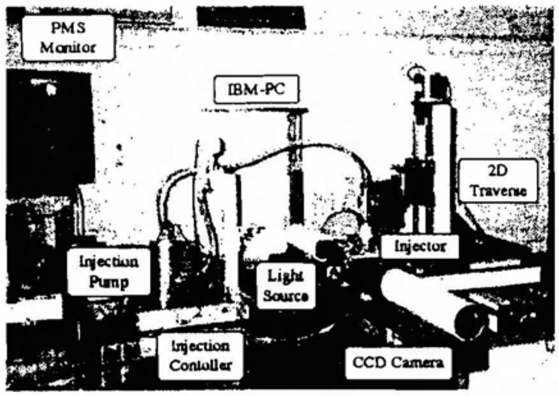

Fig. 2 Spray Particle Motion Analysis System

Fig. 3 shows the measuring device of wall flow of fuel liquid-film. The components of the measuring device of the wall-flow and the schematic of measurement system are shown in Fig. 4. Air was supplied to the engine by air compressor. The steady flow apparatus measured the fuel-film in the wall-flow flowing down along the intake port and manifold with glass tube device.

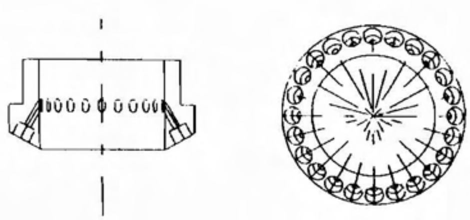

Fig. 3 Wall-Flow Measurement Flow

A schematic diagram of the engine that system is shown in Fig. 5 and the specifications of test engine are listed in Table 1. The engine used is a four-stroke MPI gasoline engine. The experiments were conducted on a four-cylinder gasoline engine coupled directly to an eddy current dynamometer system, and combustion analyzer system was composed of the pressure measuring system, crank angle detector, and data acquisition system. The engine crank angle and engine speed was monitored with magnetic pickup pulses at one-degree intervals.

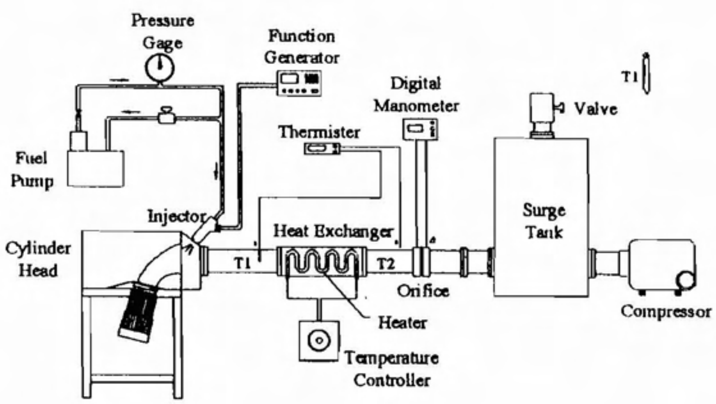

Fig. 4 Schematic Diagram Of Steady Flow Test Rig

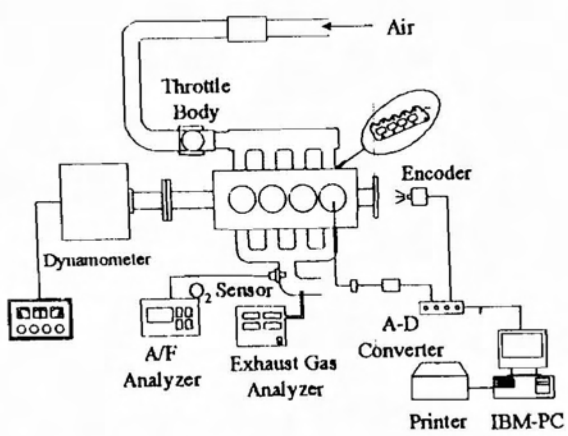

Fig. 5 Schematic Diagram of Test Engine

Table 1 Specifications of Test Engine

Item	Specification
Engine Type	4-Cylinder MPI
Bore x Stroke	81.5 mm x 88.0 mm
Compression Ratio	9.2
No. of Valves	4 (DOHC)

2.2 Experimental Procedure

In order to obtain the spray characteristics and the effect of air-assist injection on the spray behavior and pollutant formation in the engine cylinder, the engine was investigated under the following condition given in Table 2. The engine was water cooled with cooling passages in the cylinder head, around the cylinder and in the exhaust manifold.

The spray behavior of fuel injector was represented by the particle analyzing system. The 50-mm camera lens and CCD camera obtain a magnified image of gasoline spray with air-assist injection. Air-assist effects of fuel spray and pollutant formation in engine were performed at different assistant air pressure as listed in Table 2. Also, the gas pressure, the rate of heat release at each crank angle, represented the combustion characteristics in cylinder.

Table 2 Experimental Conditions

Engine speed (rpm)	1000, 1500, 2000, 2500, 3000
Assist-air pressure (bar)	0.0, 0.3, 0.6, 0.9
Coolant temperature (^{0}C)	30, 40, 50, 60, 70, 80, 90
Air-Fuel ratio	15 ~ 20
Air velocity (steady flow system) (m/s)	0, 18.43

3.0 RESULTS AND DISCUSSION

3.1 Effect Of Assist-Air On The Spray Characteristics

Figure 6 displays the spray characteristics of the fuel injection from the different condition of assist-air pressure by using a spray particle motion analysis system. It shows that the spray width or spray cone angle increase with increasing of the assist-air pressure.

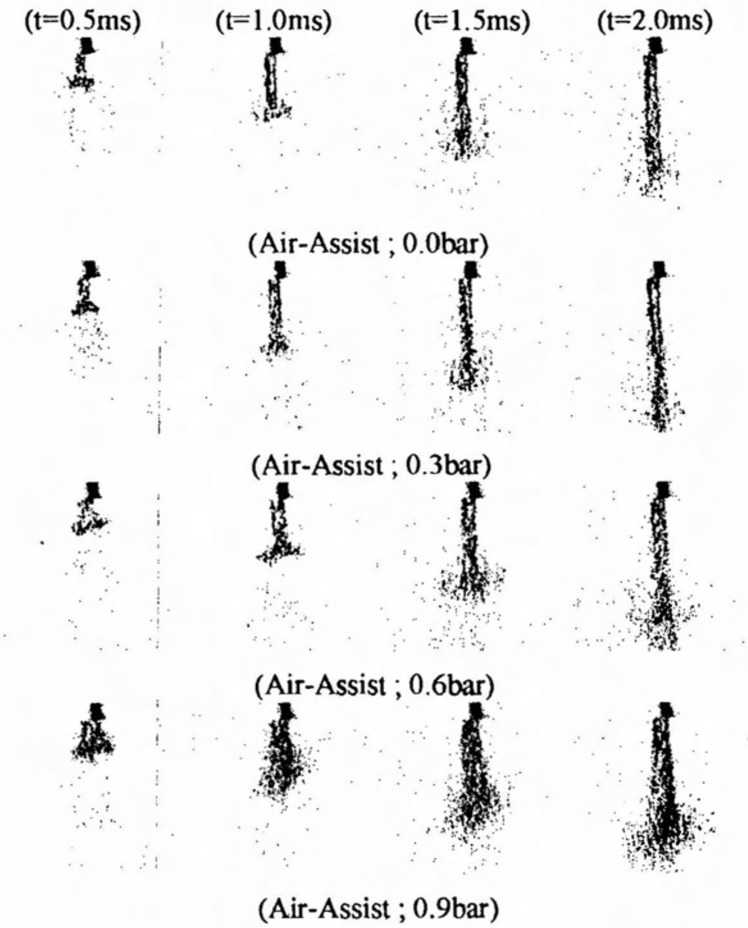

Fig. 6 Images Of Fuel Spray From Nozzle

The SMD from the different sampling position along the spray axis are shown in Fig. 8. The fine SMD droplets are concentrated near the axis position (1) in Fig. 7. These can be explained by the penetration of the droplet initial within the spray are depend on momentum motion. The higher momentum has shorter penetration and give smaller droplet. This fact can be seen clearly in Fig. 6. The smaller droplets lose their velocity more quickly and fall behind the largest one. The fraction of the impact between small droplet and largest droplet cause increase of the SMD in position (2). In addition, it one increases the air-assist pressure will increase the spray angle. It was found that the fuel spray with higher air-assist pressure produce good atomization characteristics. This indicates that the air-assist pressure makes a big contribution to the breakup and atomization process of the spray structure. As a result fine distribution of the SMD droplet was found inside the spray characteristics.

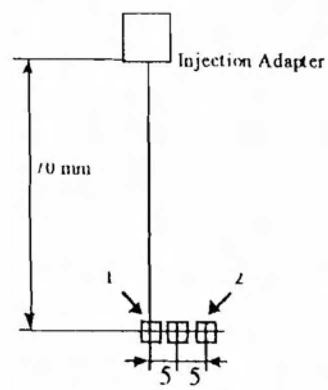

Fig.7 Measuring Section of SM

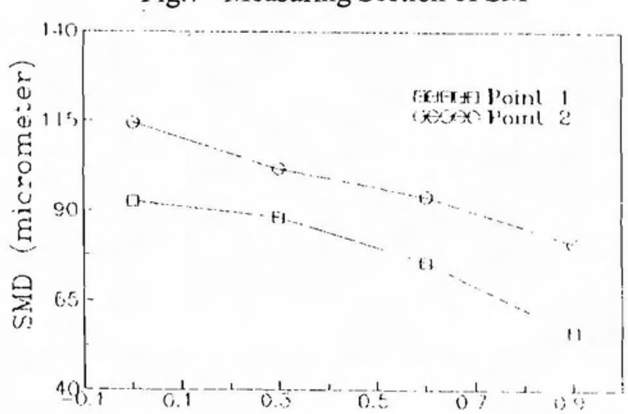

Fig. 8 Effect of Measuring Point on the SMD

3.2 Effect Of The Amount Of Wall-Flow

After passing the cylinder head, the normal, steady and tangential velocity flow of the fuel spray are directed into the wall-flow measurement device in order to characterize the amount of the wall flow in the engine with different of assist-air pressure. In Fig. 9 increasing the assist-air pressure, first reduce the amount the wall flow and then at 0.6 to 0.9 bar, the wall flow for this fuel spray increases. These can be explained by the force disruption process of a fuel spray droplet exposed with the air such as the surface tension and airflow dynamic pressure.

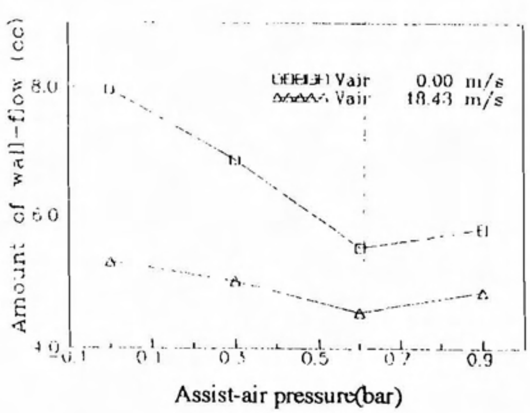

Fig. 9 Total Amount Of Wall-Flow

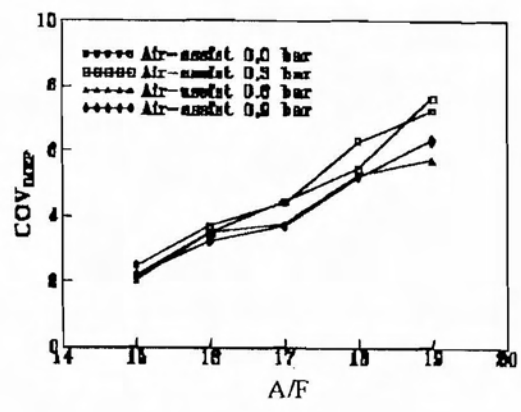

Fig. 10 Effect of Assist Air on COV_{imep}

3.3 Effect Of Assisted Air On The Exhaust Emission

With the basic experimental results, air-assisted fuel injection system is applied to the test engine, so the atomization effect is investigated with the combustion stability as shown in Fig. 10. In this experiment, the coefficient of variation for indicated mean effective pressure (COV_{imep}) is used as the determining standard of combustion stability. The assisted-air injection of fuel spray has influenced upon the variation coefficient of indicated mean effective pressure and combustion stabilization. On the other hand, the effects of air-assistant on the hydrocarbon concentration of exhaust emission are shown in Fig. 11. As shown in the figure, the assist-air injection brings about the hydrocarbon concentration of exhaust emission. Also, the hydrocarbon concentration decreased in accordance with the increase in air-fuel ratio and assisted air pressure.

Figure 12 shows the effect of assist-air pressure on the carbon monoxide concentration of exhaust emission. In this figure, the tendency of carbon monoxide concentration of exhaust emission shows the same trends for all range of air-fuel ratio. The influence of pressurized air at 0.6 bar had a best result in term of the reduction of exhaust pollutant.

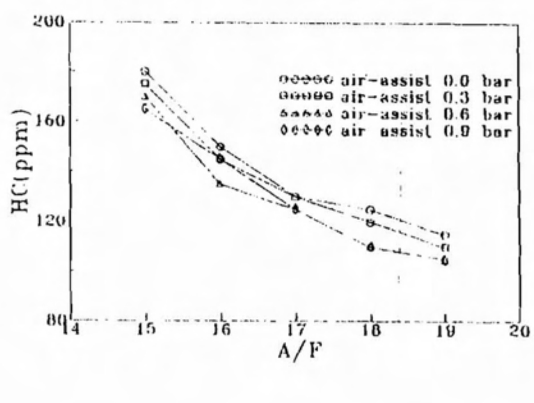

Fig. 11 Effect of Assist Air on HC Concentration

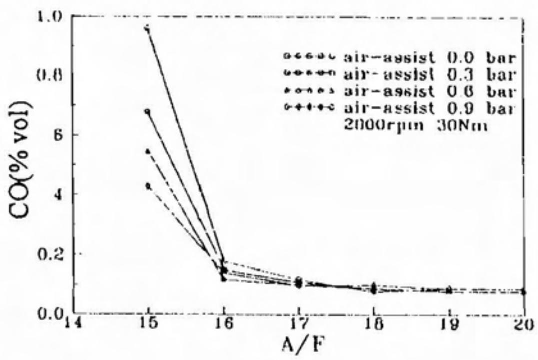

Fig. 12 Effect of Assist Air on CO Concentration

4.0 CONCLUSIONS

In order to obtain the effect of air-assist on the fuel atomization and the formation of exhaust emission in a gasoline engine, the spray characteristics, wall flow, and the concentration of exhaust pollutants were investigated by using the spray analyzing system and combustion analyzer. The following conclusions were obtained from this study.

(1) The SMD of sprays at high air-assist pressure are much smaller than those at lower air-assist pressure.

(2) The air-assist pressures have a great effect on the spray distribution and decrease the amount fuel-film of the wall-flow in the intake system.

(3) At different position in the spray structure the Sauter Mean Diameter (SMD) higher at spray axis.

(4) The pressurized air has a promoting effect in combustion stability and decrease of hydrocarbon and carbon monoxide concentration of exhaust emission.

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