Electric-Field Assisted Fuel Atomization

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Fuel injection technology is employed in most combustion systems, such as internal combustion engines or oil burners. It has been well known that atomization plays an important role in combustion efficiency and pollutant emissions — specifically, that a finer fuel mist allows a more efficient burn of the fuel, resulting in fewer harmful emissions. This is attributed to a fact that combustion starts from the interface between the fuel and air (oxygen). If we reduce the size of the fuel droplets, we increase the total surface area to start burning, boost the combustion efficiency, and improve the emission.

There are a couple of new techniques in development to reach this goal. For example, Delphi Company in its long-term project plans to develop a new fuel injector that utilizes a high pressure of 200 bar to reduce the size of fuel droplets to 25 μm in diameter. This injector, called Delphi Multec™ Direct Injection Gasoline Spray Stratified Injector, requires substantial changes of the fuel lines in vehicles as the current vehicles can only sustain a fuel pressure less than 3 bars [1].

Another possible technique is the electrostatic atomization, which makes all fuel droplets negatively charged [2-6]. The droplet size will be small if the charge density on the droplets is high. In addition, since the negatively charged droplets are repulsive to each other, no agglomeration could occur. Unfortunately, up to date, electrostatic atomization technology has not been employed on any fuel systems, not to say on vehicles. The main reason is that the electrostatic atomization technology requires special fuel injectors with a very high voltage directly applied on. Shown in Fig.1 is a typical such fuel injector for the electrostatic atomization [6], which is completely different from any existing fuel injectors employed on vehicles now. It requires a high voltage directly applied on the nozzle. The emitter cathode emits negative charges to pass the fuel to the anode, while it cannot move down to close the nozzle in order to stop the spray. To employ such a fuel injector on vehicles is not an easy task.

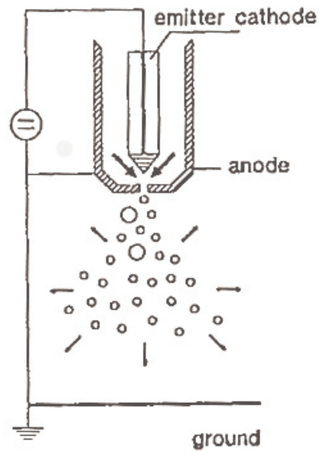

Fig. 1 The fuel injector for electrostatic atomization. The high voltage needs to be applied directly on the nozzle.

The new technology reported here is novel and unconventional since it does not need to change the existing fuel injector. In fact, the developed device is just an add-on for the current existing fuel injectors and it can be used with all current fuel injectors on vehicles. Our experiments, in fact, were conducted with an Accel fuel injector (Fig.2) , which is widely used on many automobiles. Our invention does not try to provide negative charges to fuel droplets as in the electrostatic atomization. Instead, our invention lets the fuel pass an electric field to have its viscosity reduced. When the viscosity of the fuel is reduced, the size of the sprayed droplets is reduced, too [7,8].

Fig.2 The Accel high impedance fuel injector used in our experiment.

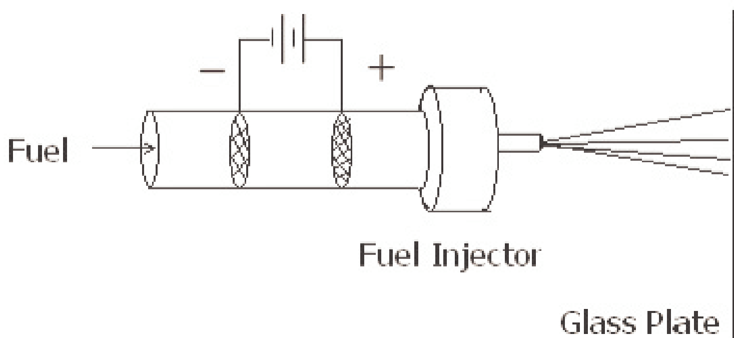

Fig.3 The experimental setup. The fuel flows through two metallic meshes before it reaches the fuel injector. A voltage is applied on the two meshes to produce an electric field around 1kV/mm in the space between the two meshes.

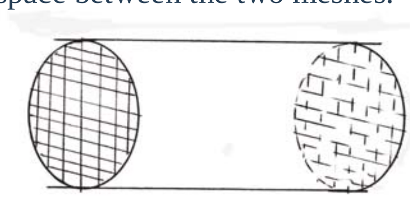

Fig.4. Two copper meshes are inserted inside the fuel line.

The experimental setup is in Fig.3. As mentioned before, the fuel injector was an Accel high impedance fuel injector (Fig.2). Inside the fuel line were inserted two copper meshes (Fig.4), on which a voltage is applied to produce a strong electric field, about 1kV/mm, in the space within the two meshes. We also arranged the anode is close to the fuel injector, so that the produced electric field was opposite to the fuel flow direction. In the experiment, we let the fuel take about 15 seconds to pass the electric field. One fuel spray lasted for about 4 milliseconds. The droplets were collected by a plate, which was covered with a layer of oxidized magnesium. Once the droplets were collected, the plates were scanned by a high-resolution scanner and the droplet size distributions were then analyzed by computers.

Our glass plate is a square, about 10cm x 10 cm, which is large enough to collect all droplets in the spray. Shown in Fig.5 is a typical recording of collected droplets. While this method is slower and more time consuming than the optical scattering technique, it is certainly much more reliable than any other methods: It provides no ambiguity. Every droplet in the spray is recorded and physically measured.

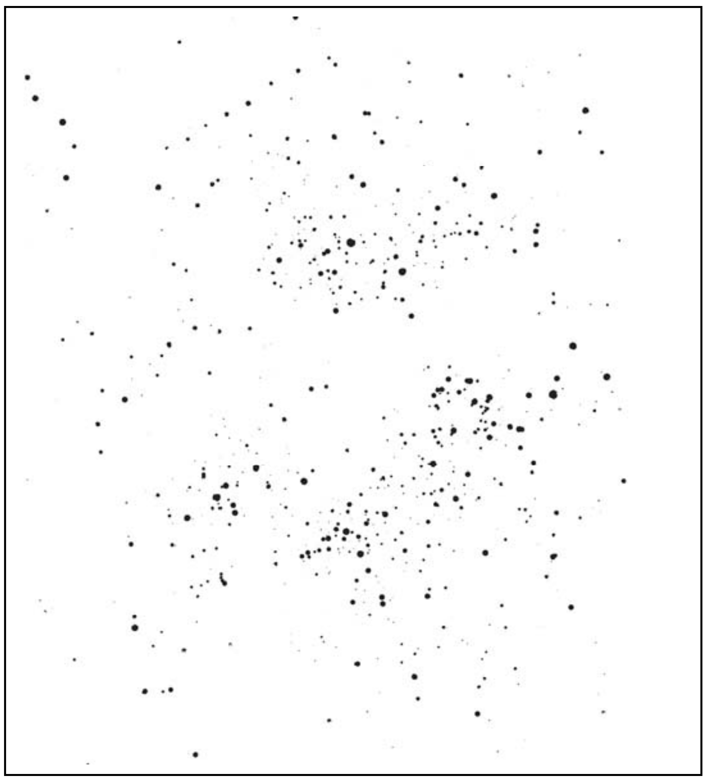

Fig.5 A typical plate with collected sprayed droplets.

The statistical results for the diesel fuel are in Fig.6, while the results for gasoline with 20% ethanol are in Fig.7. All of them are averaged over many tests. It is clear from both figures that a strong electric field reduces the droplet size in the atomization process.

For the experiment with diesel, the fuel pressure was 200 lb/in^2 (psi), the electric field was about 1.0kV/mm. The fuel took about 15 seconds to pass the electric field. The effect on diesel fuel is very significant. For example, the number of droplets of radius below 5 μm was increased from 5.3% to 15.3%. This was a factor of three. It is also clear from Fig.4 that the electric field made most droplets to have radius below 40 μm. If such a device is applied on a diesel vehicle, the fuel mileage will be increased by 15-30% and the emission will also be greatly improved.

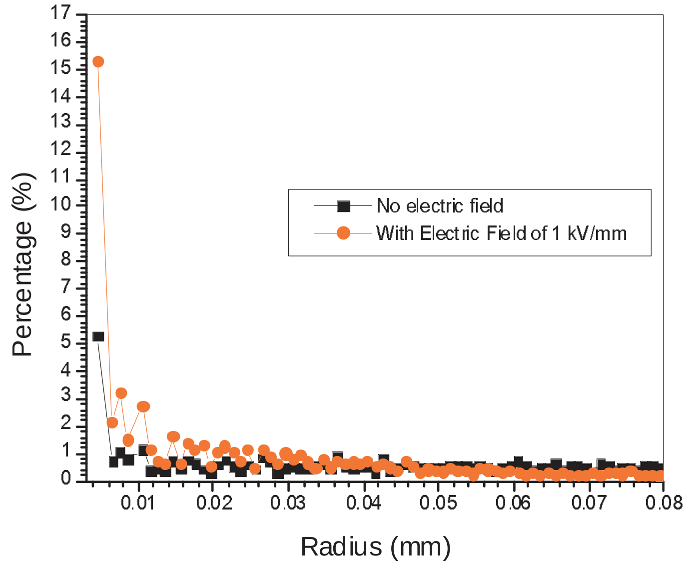

Fig.6 The size distribution of diesel fuel in the atomization with or without electric field applied. The fuel pressure was 200 psi. The electric field was 1.0kV/mm. The fuel took about 15seconds to pass the electric field.

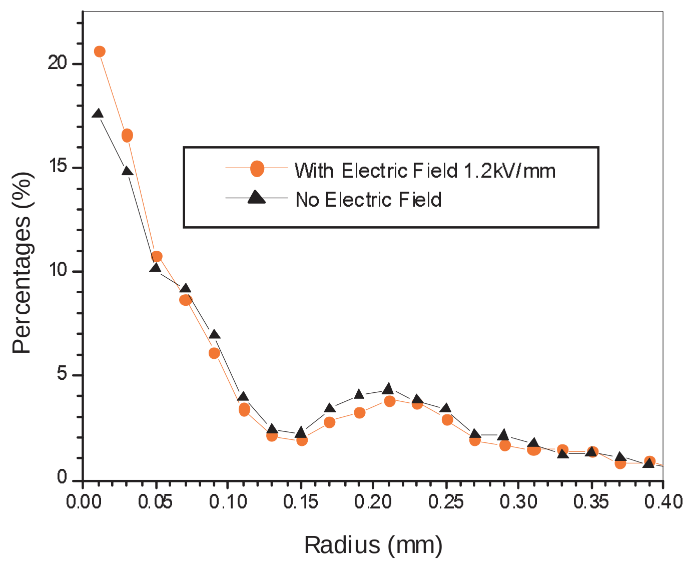

Fig.7 The size distribution of gasoline (with 20% ethanol) in the atomization with or without electric field. The fuel pressure was 110psi. The electric field was 1.2kV/mm. The fuel took about 15 seconds to pass the electric field.

In the experiment with gasoline (with 20% ethanol), the fuel pressure was 110psi, the electric field was 1.2kV/mm, and the fuel took about 15 seconds to pass the electric field. The effect on gasoline is also significant. For example, the number of droplets with radius of 10 μm was increased from 17.6% to 20.7%, an increase of 20%. If such a device is applied on a vehicle, the gas mileage will be increased by 5-10% and the emission will also be greatly improved.

References

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