Research on electrostatic electrification during jet kerosene spraying

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Abstract. Multiple electrostatic electrifications during aircraft fuelling process may cause a fire disaster or explosion, so study on the protection measure for electrostatic electrification is very important for the security of aircraft fuelling. This paper investigated the electrostatic voltage and charge of the fuel nozzle and metal parts during the fuel spraying by self-designed jet kerosene spraying electrostatic electrification test system. The experimental results indicate that the voltage on the fuel nozzle and metal parts is very dangerous for electrostatic safety if they are not reliably grounded.

1. Introduction
There are multiple electrostatic electrifications during aircraft fuelling process, including fuelling streaming electrification in the oil pipeline caused by the pump, and the electrification also appears in contacting separation while fuel flows through the inner side of the pipeline and filter, and spraying electrification arises on the nozzle in a high speed [1-4]. The charge carried by the fuel is difficult to dissipate, it also continues accumulating till an electrostatic discharge occurs to bring out a fire disaster or explosion [5]. So investigation of the electrification during jet kerosene spraying is very important for the security of aircraft fuelling.

A jet kerosene spraying electrostatic electrification test system was designed for studying the electrostatic electrifications of fuel nozzle (grounded or ungrounded, respectively) and metal parts (grounded or ungrounded) during the jet kerosene spraying.

2. Experimental system
Schematic of jet kerosene spraying electrostatic electrification test system is shown in figure 1. Fuel nozzle (3), an isolated metal fixture (2) and oil pipeline (5) are arranged in the airtight container (1) to ensure the security of this test. Three additional grounded fuel tanks are designed as an electrostatic charge relaxation devices, ensuring that the fuel is close to the uncharged state before the next cycle of the test starts. The photo of the actual experimental test system was shown in figure 2.

3. Results and discussion
3.1 Nozzle static voltage during spraying
Schematic diagram of nozzle voltage measurement is shown in figure 3. Figure 4 shows the

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measurement results of nozzle voltage under the conditions of nozzle grounded and ungrounded. We should pay more attention to the maximum electrostatic voltage when analyzing and validating the safety situation of jet kerosene spraying. There is a dangerous threshold for ungrounded nozzle voltage up to 8 kV while the air humidity is 57% RH. And it is also found that the voltage reduced conspicuously when the nozzle was grounded. As we know, the minimum ignition energy of combustible hydrocarbon-air mixtures is 0.2 mJ and the minimum voltage that may cause ignition is 2.5 kV, which is in accordance with the formula:

\[ E = \frac{1}{2} CV^2 \]

Here, \( E \) is ignition energy; \( C \) is the capacitance of the isolated conductor; \( V \) is isolated conductor’s electrostatic voltage.

When isolated conductor has a capacitance of 70 pF. It is concluded that the voltage on isolated conductors like metal nozzle is dangerous to electrostatic safety.

![Figure 1. Schematic diagram of the experiment system.](image1)

![Figure 2. Picture of experimental system.](image2)

### 3.2 Charge of jet kerosene

Theoretically, the metal nozzle electrostatic charge and sprayed fuel charge should be equal and the polarity of them should be opposite. In order to make a comparison between them, we can directly measure the nozzle charge with digital microammeter (6517A).
As shown in figure 5, the charge of nozzle and faraday cage is almost equal, in fact the polarity is opposite, and in order to show the result in this figure, we change the polarity of faraday cage. The test results show that the theoretical analysis fits well with the test results.

3.3 Special charge measurement
The experiments for measuring special charge can be conducted by using metal collecting tank that is a faraday pail instead of faraday cage metal. The schematic diagram of test devices using faraday pail to collect the fuel charge is shown in figure 6. Specific charge of fuel can be gotten through measuring total charge of the charged fuel droplets collected by faraday pail and mass of the JP 8 jet kerosene (its electric conductivity is 180 pS m⁻¹). The results shown in figure 7 indicate that the fuel specific charge decreased obviously when test system was grounded. That is to say the ground technology is an effective measure to prevent electrostatic accidents.
3.4 Isolated conductor

Figure 8 shows the test system of evaluating the isolated conductor electrostatic safety performance, and the test system is mainly composed of the insulation metallic stent and a insulating material for insulation of the stent and pipeline.

The measuring results of voltage shown in figure 9 are conduced under the conditions of the isolated conductor grounded and ungrounded. From figue 9 we can see the voltage has a sharp decline when the isolated conductor is grounded. And we can also know that the isolated conductor which immerses in the fuel has a higher voltage than the one above the fuel level.

![Figure 7. Results of fuel specific charge.](image)

![Figure 8. Measuring device for isolated conductor.](image)

![Figure 9. Measurement results of isolated conductor voltage.](image)

It is observed that the electrostatic charge can be discharged quickly when the isolated conductor is grounded. The charge will be maintained in a stable value, and there is a slow discharge when we immersed isolated conductor in the fuel. That is to say electrostatic accident probability will be greatly reduced when the isolated conductors are thoroughly grounded in jet kerosene spraying environment.
4. Conclusions

1) The nozzle highest voltage can arise to 8 kV when the air humidity is 57% RH. It is concluded that the voltage on isolated conductors like metal nozzle is dangerous to electrostatic safety.

2) Voltage for the isolated conductor can reach only dozens of volts when isolated conductor is grounded and is immersed in the fuel. That is to say, they are safe in respect of electrostatic safety in our experimental conditions.

3) All metal parts on aircraft must be thoroughly grounded before refueling. Isolated conductor parts, such as metal float, should also be grounded. In addition, in order to improve the safety performance of airplane fuel tank, we suggest that the fuel tank should be filled with nitrogen, carbon dioxide and other inert gas during filling operation.

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