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98 A Study on Electrostatic Charging Characteristics in Vehicle Fuel Systems

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Abstract

As the friction between two mated materials generates electrostatic voltage, vehicles (particularly those operated in cold climates) accumulate an electrostatic voltage due to the fuel flow in the fuel line, air flow outside of the vehicle, etc. In this study, investigation into the electrostatic discharge characteristics has been carried out in the fuel systems of gasoline engines depending on the environment temperature. For the experiment, conventional fuel filters (paint coated steel case) and specifically manufactured testing equipment have been prepared. The experimental results indicate that an accumulation speed of electrostatic voltage depends on the surrounding temperature, and new methods of testing procedures are required compared to SAE standards.

Keywords: Electrostatic charge, Electrostatic discharge, Fuel filter, Air filter, Surface

1. Introduction

In compliance with the worldwide trend in which the high pressure direct injection engine (GDI, HSDI) prevails, it is inevitable that a high pressure and high speed fuel feeding system be adopted. Especially in the case of the fuel filter, as the voids become dense to improve the performance of the filter, the fuel contacting area and relative contact speed increase greatly. Consequently, concerns over the static electricity accumulation and discharge in the fuel system are becoming intensified. Moreover, in line with the recent trend of modularization, the fuel filters are built in the fuel tank. In this case, the evaporated fuel gas completely fills the space formed by the consumption of fuel in the tank, and the resulting electrostatic discharge in the fuel filter can cause a very dangerous situation. In advanced countries, this circumstance is controlled by the regulation requiring that the level of static electricity accumulated during a certain period of time in the vehicle fuel system under an environment in which it can be easily generated (especially the electrostatic potential level measured at the edge of the fuel system) be maintained at a stable level.

In the test standards of advanced countries (SAE and EPA recommended code) applied to domestic vehicles, the situation is simply required to be left at specific test temperature (-30℃) for a certain period of time (about 48 hours). Then if the static electricity is not accumulated over the designated level (30KV), it is deemed to have passed the test requirement. However, through this study, it was observed from the continuous electrostatic voltage level measurement results that discharge and re-accumulation of static electricity occurred during the testing time period depending on the surrounding conditions. Hence, it was recognized that errors occur if the electrostatic voltage stability is evaluated only with the above test standards. Therefore, it was found that the domestic automobile manufacturers demanding the automobile component suppliers to provide components that are in compliance with the test standards of advanced manufacturers must apply more subdivided test standards in order to prevent the danger of electrostatic discharge in the vehicle fuel system. This study proposes a methodological testing method for domestic automobile component manufacturers to cope with global outsourcing by subdividing the following conditions further for evaluation: the dangerous conditions that cause frequent electrostatic discharge in the fuel system; the potential electrostatic discharge condition that can continue electrostatic potential accumulation with even a small amount of charge; and, the safety condition against static electricity under which self discharge amount exceeds the amount of accumulated electrostatic charge so that no further accumulation of electrostatic charge is achieved

2. Measurement of Static Electricity Generation in Fuel System

2.1 Testing Methods and Configuration of Testing Devices

Fig. 1 shows the configuration of a fuel system that generates the same fuel flow condition as that of the fuel system in an actual vehicle. Operation of the actual fuel system was performed in a low temperature chamber by changing its temperature- ambient temperature (relative humidity lower than 10%), -15°C, -30°C and -45°C, in order to eliminate the effect of humidity in the air, and the state of insulation between the chamber and the fuel system was checked before operating the fuel system.

In an actual vehicle, the static electricity is generated when the fuel flows. However, for the experiment, considering the danger of ignition, the fuel system was operated by using the aero hydraulic oil with viscosity characteristics (approx. 0.2 cts at the ambient temperature), which guarantees fluidity at low temperature, similar to those of vehicle fuels, which was selected among the hydraulic fluids that can easily separate electrical charges in accordance with the SAE regulation.

This test was performed to prevent electron emission through a conductive vehicle fuel hose and to measure the net amount that the electrostatic charge generated from the component itself (fuel filter unit). As presented in Fig. 2, the portions of fuel hoses directly connected to the filter unit were replaced with approximately 10cm long insulated hoses at the front and rear ends, and all the remaining portions were replaced by conductive fuel hose so as to measure only the amount of static electricity generated in the filter unit, thereby avoiding the possible effect by another flow.

Not only during the winter season but also in the dry weather of spring, the electrostatic discharge in vehicles frequently occurs. Considering this, necessary conditions were provided to allow the electrostatic generation to take place easily even at the ambient temperature so that it can be compared to the status of static electricity accumulation in the low temperature conditions. For the test at ambient temperature, a separate air dry system to completely remove the humidity in the chamber was installed so as to provide an environment that can maintain relative humidity close to 0% at the ambient temperature. A precise flow meter was installed to compensate the flow rate change caused by the change in the fluid viscosity due to the temperature change, and to minimize the deviation in the static electricity generation according to the flow rate change at each test temperature.

In addition, real-time measurement of electrostatic charge accumulation was executed to observe the change in the electrostatic charge accumulation, and the discharge flame and discharging noise were also observed during the open air discharge. Cameras and lighting device were installed in the chamber for the observation. Also, a vibration isolating pad was installed at the sensor securing place to avoid the effect of vibration that might be generated in the chamber during the operation of the compression pump for the refrigerating machine.

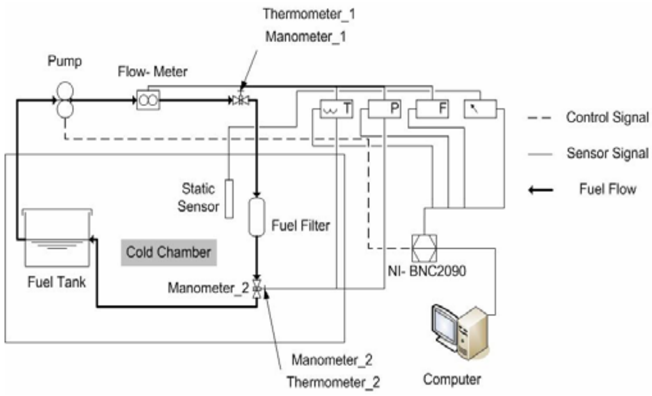

Fig. 1. Fuel System Electrostatic Test Bench

2.2 Measurement of Generated Amount of Electrostatic charge from the Fuel Filter

During the experiment, the amount of electrostatic charge generated from the fuel filter was measured by maintaining the relative humidity at 0% and by changing the temperature [-37℃, -30℃, -15℃, 0℃ and ambient temperature (20℃)]. Fig. 3 shows the change in the amount of the electrostatic charge according to time at -37℃. As indicated in Fig. 3, instantaneous discharge occurred following the generation of static electricity of about 10KV at -37℃, and then static electricity was charged again. It was found that the same amount of electrostatic charge was measured after some time passed. From Fig. 4 to Fig. 6, it was found that instantaneous discharge did not occur frequently, however, the electrostatic potential level was approximately 8~10kV through the balance between the generated amount of electric charge and the leaked or naturally dissipated amount of electric charge. Fig. 7

illustrates the comparison of electrostatic potential levels according to the change in the test temperature. It was found that the electrostatic charge accumulation increased as the temperature became lower. The electrostatic potential levels at -37℃ and -30℃ were very close to each other, so that it is expected that even if the test is performed at a lower temperature, there will be no significant difference. It is thought that this is due to the fact that the characteristics of static electricity generation were related with the humidity, and the influence by the humidity is little at the temperatures of -37℃ and -30℃, at which the moisture in the air completely froze, so that similar electrostatic potential level was observed.

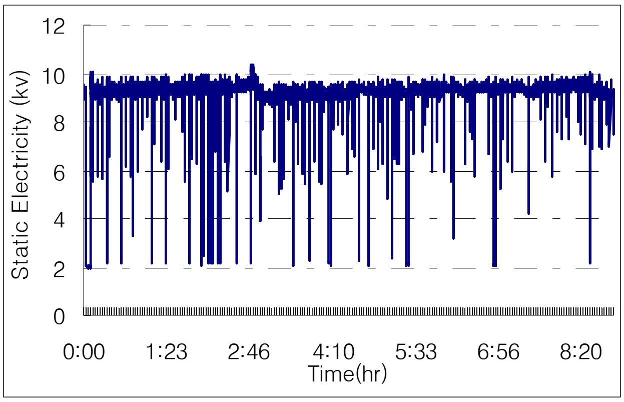

Fig. 2. Electrostatic Level at -37℃

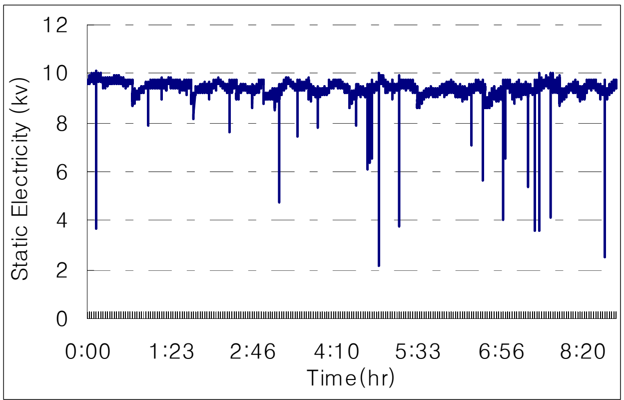

Fig. 3. Electrostatic Level at -30℃

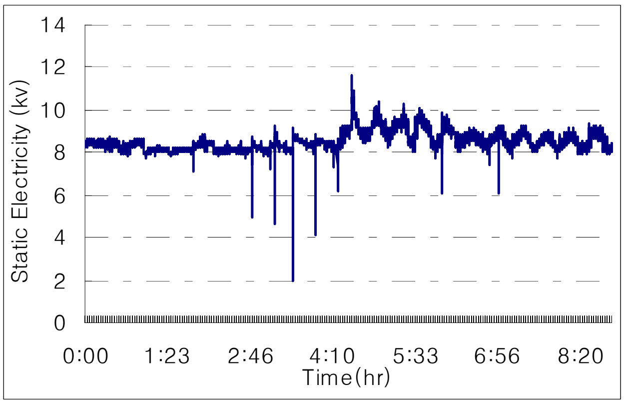

Fig. 4. Electrostatic Level at -15℃

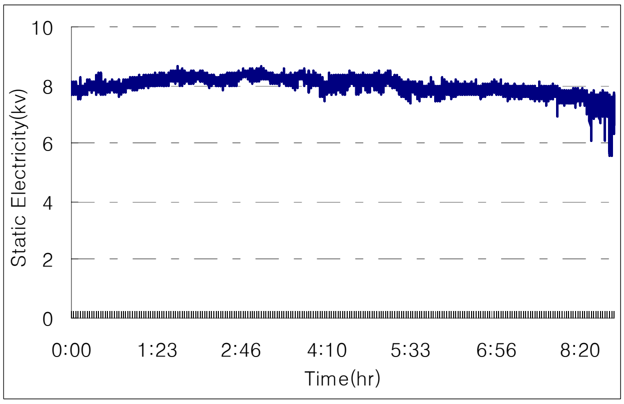

Fig. 5. Electrostatic Level at 20℃ (Dry Condition)

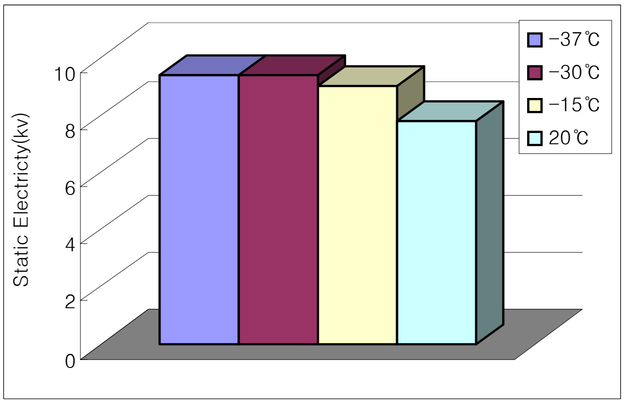

Fig. 6. Electrostatic Level Change According to Temperature Change

2.3 Verification of Electrostatic Discharge Phenomenon due to the Electrostatic Potential Accumulated in the Fuel System

Fig. 8 to Fig. 10 show the results of the test that was performed to observe how the flame was generated, using the grounded parts at the fuel inlet and the fuel filter body at the ambient temperature with humidity of 0%. From Figs. Fig. 8 and Fig. 9 it can be seen that the flame became stronger at lower temperature. So, like the result of the previous test, the possibility that the electrostatic discharge will occur at the lower temperature is great.

In case of grounding to the earth, the electrostatic potential level became 0KV in the adjacent area of the grounding point, and thus the safety could be secured. In this case also, however, a considerable amount of electrostatic charge existed in the corner areas except for the grounding points. However, when the grounding wire was closely located to these areas, a weak flame occurred (See Fig. 11). This signifies that even if the filter is grounded and its electrostatic charges are completely discharged, it can still accumulate static electricity in the other surrounding areas. This implies that, if the surrounding condition is unfavorably formed, there exists the possibility of an accident to take place caused by the electrostatic discharge even though the fuel filter is grounded.

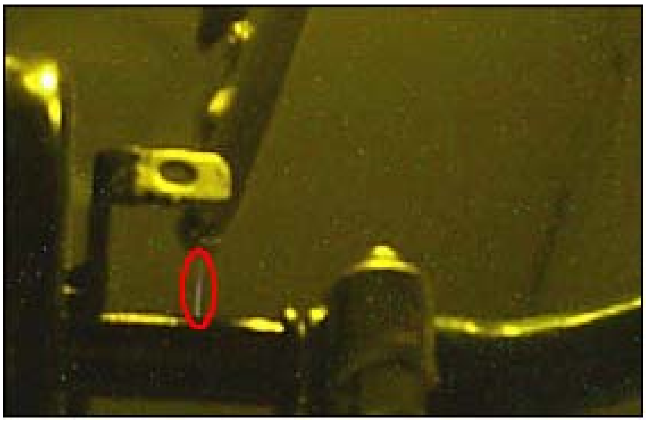

Fig. 7. Electrostatic Discharge at 20℃

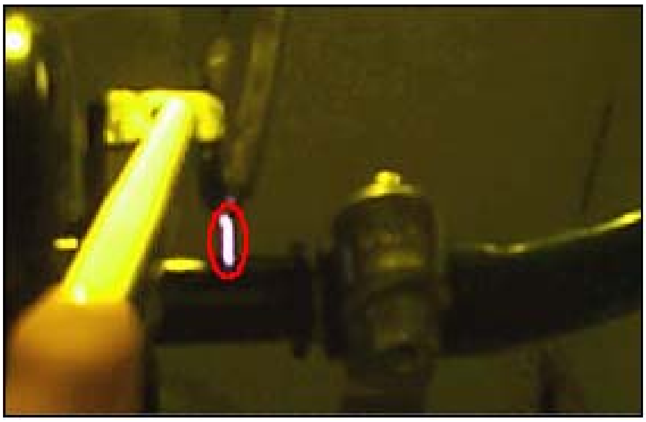

Fig. 8. Electrostatic Discharge at -30℃

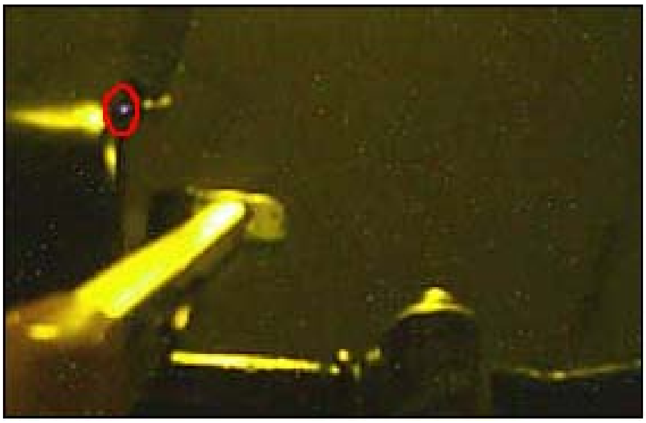

Fig. 9. Electrostatic Discharge at 20℃ (Grounded Condition)

3. Accumulated Electrostatic Potential Level during Actual Driving

3.1 Testing Methods and Configuration of Testing Devices

Electrostatic potential sensors were installed on the fuel filter, vehicle surface and air filter of an actual vehicle and the accumulated electrostatic charge at each point was measured while driving the vehicle.

The test conditions were as follows: ambient temperature was below -1℃, and humidity was lower than 18%. Fig. 11 through Fig. 13 show the test performed by installing the sensors.

Fig. 10. Electrostatic Measuring at Fuel Filter

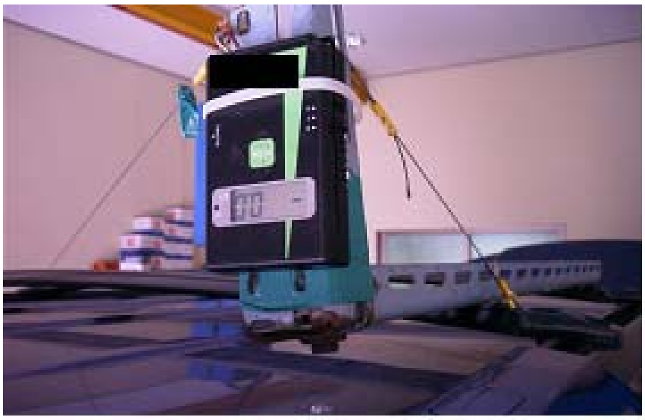

Fig. 11. Electrostatic Measuring at Vehicle Surface

Fig. 12. Electrostatic Measuring at Air Filter

3.2 Result of Measurement

Fig. 14 shows the measurement of the velocity of wind around the vehicle during actual vehicle driving. Fig. 15 through Fig. 17 present the electrostatic potential level at each point, measured on a real-time basis. As indicated in Fig. 15, even in the fuel filter, which is essentially grounded, the electrostatic potential level of approximately 1kv was observed. Thus it was found that the amount of accumulated charges is larger than the self discharging amount. Fig. 16 specifies that the static electricity accumulation on the vehicle surface increased as driving time passed due to friction between the air and vehicle surface, and thus the electrostatic potential level rose steadily from 1.5kv to 3.5kv. This means that the amount of electrostatic charge accumulated on the vehicle surface by various reasons surpasses the amount of charges discharged through the tires by the effect of grounding to the earth. In this circumstance, it is understood that satisfactory grounding effect is hardly expected even if the parts of fuel system are grounded to the vehicle body. The ungrounded air filter made of a non-woven cloth material, demonstrated a high level of electrostatic potential, from 4kv to 13kv. Such high level of electrostatic potential generated in some components may become a reason for the increase in the electrostatic potential level of the vehicle body. And it may also increase the grounding level of the vehicle components (especially the fuel system components) that discharge the static electricity to the vehicle body as a grounding system, and cause a dangerous discharge condition.

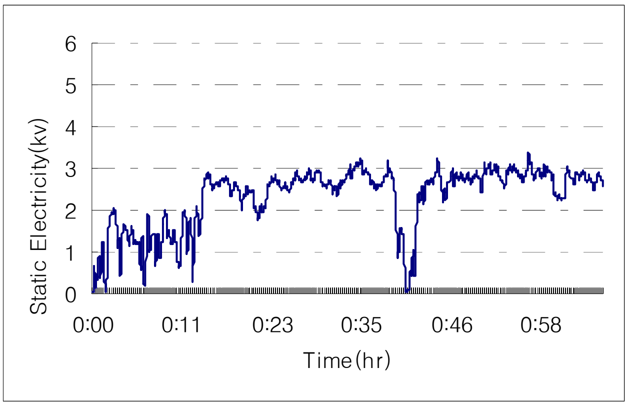

Fig. 13. Wind Velocity Profile around Test Vehicle

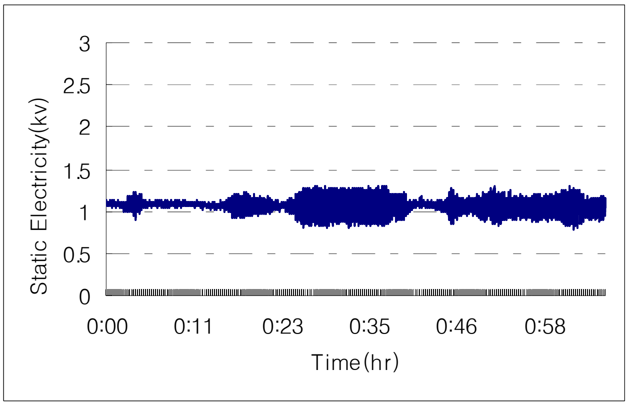

Fig. 14. Electrostatic Level of Fuel Filter

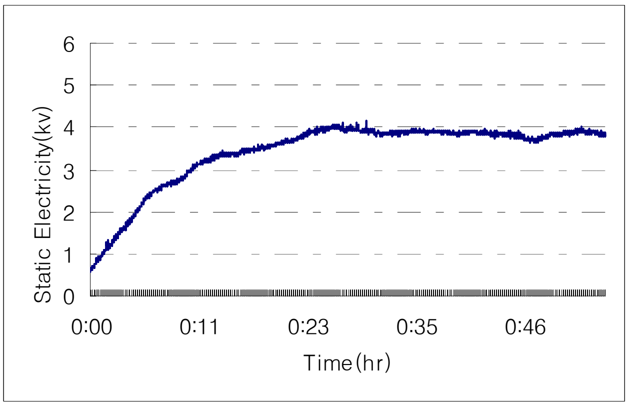

Fig. 15. Electrostatic Level of Vehicle Surface

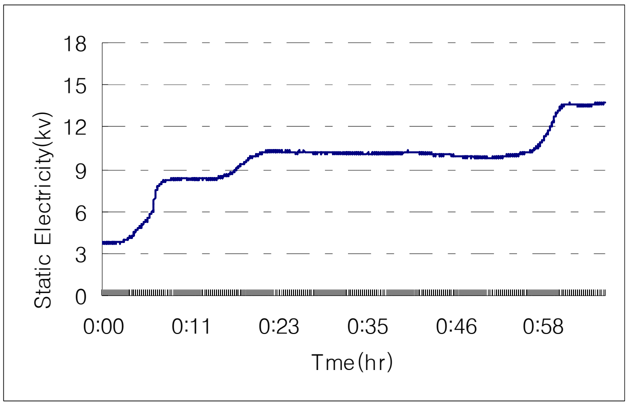

Fig. 16. Electrostatic Level of Air Filter

4. Conclusion

This study has evaluated static electricity accumulation characteristics in order to prevent the latent possibility of accident that may occur due to the discharge of accumulated static electricity in the parts of vehicle fuel system (fuel filter), and has presented methodological test practices with the following conclusions.

1) It was verified that when the vehicle is driven for a long time under low temperature and humidity, static electricity is accumulated in each part of the vehicle, and even though the fuel filter is grounded, if the discharge condition is developed, the occurrence of flame by discharge may possibly cause an accident.

2) The actual test result shows that even though allowable electrostatic potential level at -30℃ is 30kv in the SAE1645 regulation, the discharge may occur at a much lower electrostatic potential level of 10kv.

3) The parts of the vehicle fuel system are grounded to the body of the vehicle to prevent the static electricity discharge. However, according to the test result, in normal vehicles, the electrostatic potential level of the vehicle may increase owing to other parts having a high accumulation tendency of static electricity, depending on the surrounding conditions (temperature, humidity, wind velocity, etc.). Also, it was found that since the effect of grounding the parts of the fuel system to the vehicle body was insufficient, it may cause static electricity to be accumulated.

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