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異なる重力環境における被覆導線の過電流着火現象の差異の解明

Clarification of Overload Ignition Phenomena of Insulated Electric Wire in Microgravity and Normal gravity

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1. Introduction

Ensuring the safety of crews is one of the most important issues during manned space activities. The overload ignition of electric wires is the most likely cause of potential electrical fire accidents in spacecraft [1)]. Previous experimental works [2,3)] have found that the overloaded wire can be ignited under a lower electric current in microgravity than in normal gravity. In this study, a 2-dimensional numerical model are utilized to clarify the differences in ignition phenomena between microgravity and normal gravity.

2. Methods

Previous experiments [3)] for overload ignition of electric wires were conducted under a direct current power supply in a closed chamber. To ensure the ignition during a short-term microgravity environment, laboratory wire samples have been used. The electric wire sample consists of polyethylene (PE) insulation and nichrome core wire which has high flammability and high electrical resistance, respectively. In this study, the numerical model is under a two-dimensional Cartesian coordinates system to represent the cross-section of the experimental chamber. Single-step finite rate reactions were employed for both solid phase pyrolysis and gas phase combustion [4,5)]. The ignition criterion in the simulation is that the local volumetric heat release rate exceeds 32,000 kW/m^3 based on the heat release by stoichiometric reaction of pyrolyzed ethylene and air at the auto-ignition temperature.

3. Results

Figure 1 shows ignition positions which is the distance between the wire surface and the ignition point as a function of applied current value. In zero gravity (0G) case, the ignition can occur away from the wire under low to medium current, and the ignition position becomes farther as the current increases. On the other hand, ignition occurs near the wire surface with a high current supply. In low and medium current cases, as the hot pyrolyzed ethylene gas diffuses into the air, the spontaneous exothermic reaction continues, then ignition happens. In contrast, with a high current supply, the high heating rate leads to a high ejection velocity of pyrolyzed ethylene, which promotes the diffusion of the hot ethylene into the cold air (cooling) and further inhibits the exothermic reaction in the gas phase away from the wire. Meanwhile, after complete pyrolysis of PE insulation, the exposed core wire with excessive Joule heat can ignite the surrounding mixture. The ignition mode that occurs in the gas phase away from the wire is defined as “spontaneous ignition” and the other ignition mode near the wire surface is defined as “wire assisted ignition.” It was also confirmed that the trends of these ignition positions were in good agreement with the experimental images.

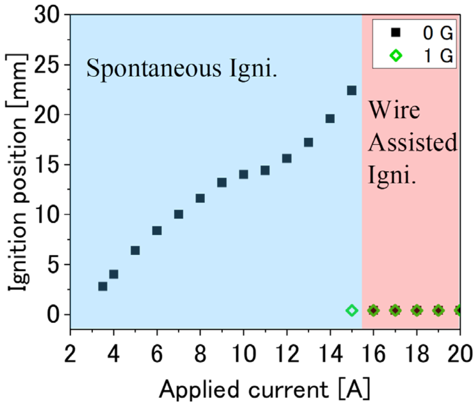

Fig. 1 Ignition position from the wire surface

In normal gravity (1G) case, the wire assisted ignition happens with a high current, but ignition does not occur below medium current. It is due to the cooling of the pyrolyzed ethylene gas by natural convection and blowing away by the upward buoyant flow. This phenomenon happens in 1G even when the initial ejected velocity of ethylene gas is slow with a low heating rate. Thus, spontaneous ignition is less likely to happen in 1G.

4. Conclusion

In this study, how the overload ignition phenomenon of insulated wire differs between 0G and 1G are investigated. By numerical simulations, two ignition modes in 0G have been found. One is the “spontaneous ignition” caused by the continuous exothermic reaction in the gas phase, and the other one is “wire assisted ignition” which is exposed core wire with excessive Joule heat ignites the surrounding gas. Further, the spontaneous ignition is likely to happen only in 0G, especially under low current supply, which indicates the uniqueness of ignition risk in space.

References

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