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酸素濃度の変化がアルミニウム粉塵爆発に与える影響
Effect of oxygen concentration on aluminum dust explosions.

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1. Introduction

In order to promote planetary exploration activities and space planet habitation, it is necessary to consider measures to prevent and mitigate dust explosions in environments different from those on the Earth[1)]. The reason for this is that the presence of aluminum oxide in the lunar regolith[2)] suggests that aluminum may be used as a resource in space. Aluminum powders are used in a variety of applications on the earth, such as in the steel industry, paints and 3D printers. However, aluminum powder has the highest reported number of dust explosion incidents among metal powders and catastrophic damages[3)]. In addition, the spacecraft cabin atmosphere design space is decided with varying volume percent oxygen and total pressure[4)]. Three main matters are taken into account, one of which is the flammability limits of the material. From this, the knowledge of how these two parameters change the combustion characteristics is essential for safe space operations. In view of the above, the objective of this study is to determine the effect of oxygen concentration on explosion of aluminum powder clouds. In the present study, the minimum explosible concentration (MEC) of aluminum powder was investigated experimentally. A chemical reaction analysis was also carried out to investigate the influence of oxygen concentration on flame structure.

2. Experimental set up

A few modified version of the experimental apparatus according to JIS Z8818 was used to enable experiments with gas mixtures. Measurements were made in accordance with JIS. When the flame propagated up to 100 mm above the discharge pole, determine that an explosion has occurred. The test was repeated five times at the same concentration and the maximum concentration at which non explosion occurred was set as the MEC. Aluminum powder (Toyo Aluminum K.K.) with a median diameter of 22 μm was used. The initial pressure in the explosion cylinder was set at 1 atm and the oxygen concentration varied from 10 vol% to 50 vol% by nitrogen dilution.

3. Results and discussion

The MEC values of aluminum powder for different oxygen concentrations obtained in this experiment is shown in **Fig. 1**. The vertical axis in this graph is the aluminum dust concentration, which is the amount of powder loaded into the explosion cylinder divided by the explosion cylinder volume. The MEC tended to become smaller as the oxygen concentration increased. The MEC varied significantly between 10 and 15 vol% oxygen concentration, with a large value at 10 vol%. Then a gradual decrease in MEC values was observed between 21 and 50 vol% oxygen concentration, although the amount of change was small. This indicates that the effect of oxygen concentration on the MEC is greater under low oxygen conditions, but less so under high oxygen conditions.

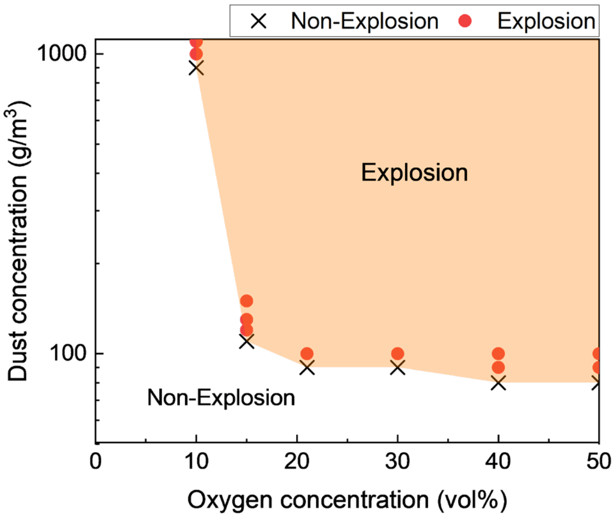

Figure 1. The MEC of aluminum/nitrogen/oxygen mixtures

Numerical analysis was also used to investigate how the aluminum flame changes when the oxygen concentration is varied. The analysis software used was cantera [5] and the reaction mechanism was an aluminum combustion model [6]. Calculations were carried out at an initial pressure of 1 atm, an initial temperature of 300 K and a dust concentration of 100 g/m^3, with the oxygen concentration varied as in the experimental conditions. The effect of oxygen concentration on flame structure is shown in **Fig. 2**. The adiabatic flame temperature and the mole fraction of the final product, Al_2O_3(l), are equal under different oxygen concentrations. This is probably the result of the same amount of aluminum reacting without excess, as all reactions were carried out under dilute conditions. However, the temperature rapidly increases and the flame thickness decreases with increasing oxygen concentration. The combustion model used included 12 elementary reactions, of which R1（$AlO+O_2=AlO+O$）, the direct reaction between aluminum and oxygen,

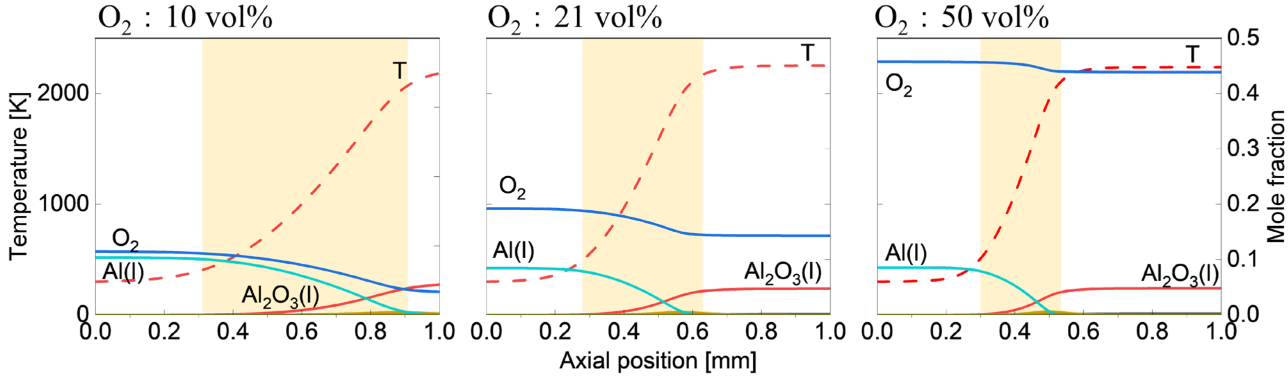

Figure 2. Aluminum flame structures (O_2 : 10, 21, 50 vol%)

was found to have the highest reaction rate. As the oxygen concentration increases, the peak value of the reaction rate of R1 tends to increase, indicating that the reaction between aluminum and oxygen is more accelerated.

4. Conclusion

In this study, the effects of oxygen concentration on MEC and flame structure were investigated using experiments and a chemical reaction analysis. The results demonstrated that the MEC decreases with increasing oxygen concentration. A numerical analysis using an aluminum combustion model shows that the chemical reaction rate increase with increasing oxygen concentration. An oxygen concentration of 10 vol% is considered to be a difficult condition for flame propagation due to the small reaction rate.

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