学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Spherical flame propagation behavior of pulverized coal particles and ammonia in a turbulent environment.
(微粉炭とアンモニアの乱流混焼場における球状火炎伝播特性)

The aim of the present study is to clarify the flame propagation behavior of pulverized coal particle clouds for mixing combustion of low ignitability coal and ammonia. The unique experimental apparatus was developed for the experiments on pulverized coal combustion, ammonia combustion and coal-ammonia mixing combustion in a turbulent environment. The experiments on spherical flames propagations were performed by using a spherical-inner shape closed vessel. The turbulent flow field in the vessel generated by counter-rotation of two identical fans. A linear relationship between fan rotational speed, N and turbulence intensity, u' was obtained from particle image velocimetry (PIV) measurements. The turbulence was considered homogeneous, and there was no regular bulk motion in the center of the combustion vessel. A dispersion system was designed to disperse the pulverized coal particles into combustion field. The pulverized coal was dispersed homogeneously in the combustion field by 300 kPa dispersion gas. Dispersion flow was not influencing the flame propagation behavior.

Using the present experimental apparatus, the pulverized coal clouds showed no flame propagation by using air as the ambient gas. Therefore, diluted oxygen (40 vol% O2 and 60 vol% N2) was used as the ambient gas to achieve flame propagation. To make a qualitative comparison, the ammonia and mixing combustion also used the similar ambient gas. However, to validate the results from present experimental methods, the experiment of ammonia-air mixture also performed to compare the present results to the previous research results that available in the literature.

Common bituminous coal (namely C5) and low ignitable coal (namely TW, KK and UL) with different fuel ratio were tested in the present study. In the coal combustion of C5 coal for various coal concentrations and turbulence intensities, the turbulence intensity has a significant effect compared to the effect of coal concentration. This is due to the effect of turbulence heat transfer. Turbulence heat transfer increased the volatile release rate, thus increased the flame propagation velocity. Flame propagation capability of low ignitable coal for various coal concentrations and various turbulence intensities also clarified.

Ammonia-air and ammonia-O_2N_2 premixed combustion experiment were performed for various equivalence ratios and turbulence intensities. Flame propagation probability limit for the ammonia-air mixture in various turbulence intensities was clarified. Flame propagation behavior of ammonia-air in the quiescent environment was obtained and showed good agreement to the previous study in the literature. Flame propagation velocity for ammonia-O_2N_2 mixture was obtained and compared to the characteristics of ammonia-O_2N_2 flames in the mixing combustion.

Mixing combustion of coal-ammonia-O_2N_2 mixtures was experimentally studied for the C5, TW, KK and UL coal for various turbulence intensities. The coal concentration was set to 0.6 kg/m^3 and the equivalence ratio of ammonia-O_2N_2 is 0.6. Without ammonia addition, the KK and UL coal were not sustaining flame propagation, while TW coal was sustained flame propagation only in the high turbulence intensities. The ammonia as an energy carrier was increased the flame propagation velocity of C5 coal in mixing combustion about five times. In addition, ammonia flame increased the ignition capability of low ignitable coal. Ammonia flame increased the volatile release rate of the coal particles, thus flame propagation velocity increases. Therefore, TW, KK and UL coal sustained the flame propagation in various turbulence intensities. Turbulence intensity has a significant effect on flame propagation velocity of mixing combustion, similar to the coal combustion. Based on the lower heating value (LHV), with ammonia addition, coal particle can be saved around 20% (weight %). The findings of the present study contribute to the fuel cost reduction and the improvement of energy security by being able to utilize low ignitable pulverized coal particles.