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学 位 論 文 内 容 の 要 旨

博士の専攻分野の名称　　博士（工学）　　氏名　Xia Yu

学 位 論 文 題 名

Turbulent flame propagation behavior and mechanism of solid particle cloud/ammonia co-combustion

(固体粒子群とアンモニアの混焼における乱流火炎伝播挙動とメカニズム)

Solid particle cloud/ammonia/oxidizer co-combustion has immunes potential since it can decrease green-house gas emissions and improve energy security from the viewpoint to step into a carbon free society. Flame propagation velocity is a fundamental property for evaluating the flame stabilization performance of combustion of fuels in combustors. The present research aims to clarify the solid particle cloud/ammonia co-combustion turbulent flame propagation characteristics and mechanism. To achieve this aim, four types of experiments were performed, including pure ammonia turbulent combustion, pure solid particle cloud turbulent combustion, the solid particle cloud/ammonia/oxidizer turbulent co-combustion, and silica particle cloud/gas-fuel mixing-combustion experiments. The experiments were conducted by using a unique constant-volume turbulent combustion chamber.

In pure ammonia turbulent combustion, it was found the effects of diffusional–thermal instability and the turbulence are important factors for affecting the turbulent flame propagation velocity of ammonia combustion. In pure solid particle combustion, it was found, for the quasi-monodispersed particle clouds, the flame propagation velocity increased with the increase in the turbulence intensity and the decrease in the quasi-monodispersed particle size. However, the particle concentration has little effect the flame propagation velocity, which is unique in a turbulent flow field. In the combustion of turbulent polydispersed particle cloud, the particle–particle agglomeration and the agglomeration break-up in the turbulent flow field affect turbulent flame propagation.

In pulverized coal particle cloud/ammonia co-combustion, it was discovered the turbulent flame propagation velocity of co-combustion is higher than that of the pure pulverized coal combustion and whether the turbulent flame propagation velocity of the co-combustion is higher than that of the pure ammonia combustion is dependent on the equivalence ratio of the ammonia-oxidizer. In ammonia-lean cases, the turbulent flame propagation velocity of co-combustion is larger than that of the pure ammonia co-combustion. In ammonia-rich cases, the turbulent flame propagation velocity of the co-combustion is lower than the pure ammonia combustion. In stoichiometric condition, both are almost same. This unique feature was

explained by a mechanism including three competing effects proposed by the authors. In an ammonia lean condition, the positive effects, which are the strong radiation from the luminous flame and the increment of the local equivalence ratio by the addition of volatile matter, are larger than the negative effect, which is the heat absorption by the unburned particles in the preheat zone. In an ammonia rich condition, the effect of the increment of the local equivalence ratio by the addition of the volatile matter turns into a negative effect. Consequently, the negative effects overcome the positive effect in an ammonia rich condition resulting a lower flame propagation velocity of the solid particle fuel/ammonia co-combustion.
To furtherly validate the proposed three effects, the silica particle cloud/ammonia mixing-combustion and silica particle cloud/acetylene/air mixing-combustion, and PMMA particle cloud/ammonia co-combustion experiments were conducted. It was found that the turbulent flame propagation velocity of the silica particle cloud/ammonia/oxygen/nitrogen mixing combustion is lower than that of the pure ammonia combustion irrespective to the ammonia equivalence ratio. Therefore, the heat sink effect from the unburned particles is validated. Moreover, the turbulent flame propagation velocity of the silica particle cloud/acetylene/air mixing combustion was lower than that of the pure acetylene/air combustion. Therefore, the radiation effect from the soot particle on the co-combustion takes a minor role on the flame propagation of co-combustion for small-scale flame. It may have an important effect on the large-scale flame. Further, in PMMA particle cloud/ammonia/oxygen/nitrogen co-combustion, the same turbulent flame propagation phenomenon with pulverized coal particle cloud/ammonia/oxygen/nitrogen co-combustion was observed. Therefore, in solid particle cloud/ammonia/oxidizer co-combustion, the turbulent flame propagation mechanism is mainly controlled by the heat sink negative effect from the unburned particles in the preheat zone of the flame front and the local equivalence ratio increment effect by the volatile matter released from the solid particles in the preheat zone of the flame front.
Based on the experimental results obtained by the present research, the turbulent flame propagation mechanism of solid particle cloud/ammonia co-combustion were clarified.