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論　文　内　容　要　旨

報告番号	甲　先　第　349　号	氏　名	AIZAM SHAHRONI BIN MOHD ARSHAD
学位論文題目	Atomization and Combustion Characteristics of a Fuel-Water Rapid Internal Mixing Injector for Emulsified Fuel Combustion (エマルション燃焼用内部急速混合型油水噴霧ノズルの噴霧特性と燃焼特性)		

内容要

Over the last several decades, emulsified fuel combustion has been a well-known technique that can be used to simultaneously suppress NOx and particulate matter (PM) emissions in practical combustion systems. When water-emulsified fuel is injected into a region already containing hot gases, the flash evaporation of the very small water droplets dispersed in the emulsified fuel results in secondary atomization, thus generating a large number of even smaller droplets. This flash evaporation also enhances the mixing of the fuel vapor with the ambient air and increases the concentration of OH radicals, effectively reducing soot emission. The introduction of water also reduces NO_x emissions because the flame temperature is reduced by the latent heat of the water as well as a dilution effect associated with the generation of water vapor.

However, emulsified fuel combustion has some disadvantages. Emulsification requires the use of expensive surfactants, and temperature lowering in a flame frequently induces unstable combustion. To overcome these disadvantages, our research group has developed a fuel-water rapid internal mixing (RIM) injector incorporated with a small chamber in which the base fuel introduced into the injector is rapidly mixed with water by the swirling flow of air. Because the base fuel would be emulsified during this mixing process, additional emulsification equipment and surfactants are not required. Furthermore, the water content in response to the combustion conditions can be optimized, therefore contribute to the stable operation of combustion furnaces.

In this study, the emulsification and atomization characteristics of an injector were investigated with high-viscosity soybean oil used as base fuel. The internal structure of the droplets discharged from the injector was examined by immersion method and the mechanism of fuel emulsification in the mixing chamber made of transparent acrylic were observed using a high-speed camera. The shadowgraph method was employed to examine the atomization characteristics including the Sauter mean diameters (SMDs) of droplets in sprays, and investigate the effects of gas to liquid ratio (GLR) and viscosity on SMD. Finally, the performance of the RIM injector in terms of the reduction of NOx and PM emissions from a laboratory-scale combustion furnace operating under high-load conditions was assessed.

The experimental results showed that the injector successfully emulsified the base fuel without any surfactants was observed in the mixing chamber over a wide range of water content ratios up to 0.5. Because the water droplets are dispersed in the base fuel, the discharged emulsified fuel classified as a water-in-oil (W/O) type of emulsified fuel. It is evident that as soon as water was introduced, the mixing chamber appeared to fill with a milky liquid. This indicates that the emulsification of base fuel starts immediately after the injection of water into the mixing chamber. As the water content ratio was increased, the SMD of the droplets in the spray increased. This suggest that the decrease in the GLR associated with the increase in the water content ratio influences the deterioration of the atomization. Another factor causing this increase in the SMD is the increase in viscosity resulting from the emulsification. We proposed an empirical formula as functions of GLR and Reynolds number reproducing the deterioration resulting from increasing viscosity. The formula successfully predicts the SMD variation with respect to GLR and water content ratio. Although the emulsification of the base fuel resulted in the discharge of large droplets, the results showed that the nitrogen oxide and particulate matter emissions from a combustion furnace incorporating the injector were found to be reduced simultaneously following the introduction of water even under a high combustion load. The results obtained from combustion tests demonstrate the effectiveness of the injector for the simultaneous reduction of emissions while maintaining the stable operation of combustion furnace.