2010年 03 月 18 日

Department Mechanical and Structural System Engineering	ID	055101	Advisor	Susumu Noda
Name	ODI AKHYARSI			

Title	Experimental and Numerical Studies on Characteristics of Gaseous and Liquid Fuels Combustion in Laboratory-Scale Furnaces

Combustion of fossil fuels still becomes the dominant source of energy for industries. However, the combustion of fossil fuels in combustion systems such as diesel engines and industrial furnaces releases pollutants, such as nitrogen oxides (NOx) and particulate matters, which harm public health and cause atmospheric visibility impairment. The present work is an effort to contribute to the development of knowledge and technology for the reduction of pollutant emission from the confined combustion systems.

The first study is a numerical study regarding fuel split injection, which was found to be able to reduce pollutant emission of diesel engines. The effects of two split-injection parameters, the diesel injection mass ratio and the dwell interval between injections, on the fuel-air ratio and the gas velocity evolution in the chamber were investigated using a computational fluid dynamics (CFD) tool called KIVA-3V. This research was intended to find an optimum configuration for the split-injection scheme in a diesel engine combustion chamber. The splitting of the fuel injection into two pulses can produce a wide flammable area inside the chamber during the mixing-controlled combustion phase, which could be associated with good mixing and distribution of fuel vapor and air inside the chamber, and is believed to contribute to pollutant emissions reduction. Injecting 75% of the total fuel during the first injection and then injecting the rest 25% of the fuel after a 1.0 ms pause was found to produce desirable fuel/air mixing inside the chamber and should reduce pollutant emission effectively. One significant contribution was also made through this numerical study, which is the incorporation of the Enhanced Taylor Analogy Breakup (ETAB) model for the calculation of droplet breakup in KIVA-3V code. The incorporation of the ETAB model increases the capability of the KIVA-3V code in the calculation of droplet breakup for the condition when the Weber number is high.

The complexity of assessing NOx emission characteristics in a real diesel engine case, in which measurements of in-cylinder properties become unmanageable and numerical simulations become inefficient when considering fuel impingement and piston movement effects, led to the idea of investigating NOx emission characteristics in a more approachable apparatus. Therefore, in the second study, the investigation of NOx emission characteristics of confined combustion was conducted with regard to laboratory-scale furnace with coaxial burner system. The study aims to clarify the relationships between operational parameters (i.e. furnace diameter D and combustion air velocity difference ΔUa) with the characteristics of gaseous and liquid fuels combustion. A series of experiments was conducted to capture flame appearances, obtain temperature profiles, and measure NOx concentration at the furnace-exit, for several configurations of fuel, D, and ΔUa. In Addition, numerical simulations using another CFD tool (i.e. ANSYS CFX-10.0) were also conducted, for some of cases, in order to complement the experimental results.

It was found that the flame appearance, temperature profile, velocity profile, and emission index of NOx (EINOx) depend strongly on the furnace diameter D. The results imply that gaseous and liquid fuels combustion can be characterized by the furnace volume. The main reason behind the phenomena is the recirculation vortices that are developed in the larger furnace. The recirculation vortices alter the mechanism of turbulence and mass transport and thus have an effect on the chemical reaction. The temperature measurements reveal that larger values of D and ΔUa lead to lower temperatures, being attributable to the effects of dilution and flame stretch enhanced by the recirculation vortices. The EINOx was well scaled with a parameter $DU_f \Delta Ua$ regardless of the type of the fuel. A normalized EINOx was also found to be inversely proportional to the parameter for both gaseous and liquid fuels combustion. However, the vaporization process in liquid fuel combustion appears to weaken the sensitivity of the normalized EINOx of Jet-A combustion on the parameter $DU_f \Delta Ua$.

By using the gained knowledge on the split-injection scheme in diesel engine combustion chamber and NOx emission characteristics in the laboratory-scale furnaces, one can hopefully design more efficient combustion systems with the required parameters for simultaneously minimizing pollutant emissions.