Announcing the Final Examination of Xin Gu for the degree of Doctor of Philosophy

Time & Location: January 6, 2012 at 8:30 AM in Engineering

Title: NUMERICAL SIMULATION OF CONVENTIONAL FUELS AND BIOFUELS DISPERSION AND VAPORIZATION PROCESS IN CO-FLOW AND CROSS-FLOW PREMIXERS

In order to follow increasingly strict regulation of pollutant emissions, a new concept of Lean Premixed Pre-vaporized (LPP) combustion has been proposed for turbines. In LPP combustion, controlled atomization, dispersion and vaporization of different types of liquid fuel in the premixer are the key factors required to stabilize the combustion process and improve the efficiency.

A numerical study is conducted for the fundamental understanding of the liquid fuel dispersion and vaporization process in premixers using both cross-flow and co-flow injection methods. First, the vaporization model is validated by comparing the numerical data to existing experiments of single droplet vaporization under both low and high convective air temperatures. Next, the dispersion and vaporization process for biofuels and conventional fuels injected transversely into a typical simplified version of rectangular pre-mixer are simulated and results are analyzed with respect to vaporization performance, degree of mixedness and homogeneity. Finally, collision model has been incorporated to predict more realistic vaporization performance.

Four fuels, Ethanol, Rapeseed Methyl Esters (RME), gasoline and jet-A have been investigated. For mono-disperse spray with no collision model, the droplet diameter reduction and surface temperature rise were found to be strongly dependent on the fuel properties. The diameter histogram near the pre-mixer exit showed a wide droplet diameter distribution for all the fuels. In general, pre-heating of the fuels before injection improved the vaporization performance.

An improvement in the drag model with Stefan flow correction showed that a low speed injection and high cone angle improved performance. All fuels achieved complete vaporization under a spray cone angle of 140°. In general, it was found that cross-flow injection achieved better vaporization performance than co-flow injection.

The collision model based on no-time-counter method (NTC) proposed by Schmidt and Rutland which was implemented to replace O'Rourke's collision algorithm improved the results in that the unphysical numerical artifact in a Cartesian grid was removed and the results were found to be grid-independent. The dispersion and vaporization processes for liquid fuel sprays were simulated in a cylindrical premixer using co-flow injection method. Results for jet-A and Rapeseed Methyl Esters (RME) showed acceptable grid independence. At relatively low spray cone angle and injection velocity, it was found that the collision effect on the average droplet size and the vaporization performance were very high due to relatively high coalescence rate induced by droplet collisions. It was also found that the vaporization performance and the level of homogeneity of fuel-air mixture could be significantly improved when the dispersion level is high, which can be achieved by increasing the spray cone angle and injection velocity. In order to compare the performance between co-flow and cross-flow injection methods, the fuels were injected at an angle of 40° with respect to the streamwise direction to avoid impacting on the wall. The cross-flow injection achieved similar vaporization performance as co-flow because a higher coalescence rate induced by droplet collisions cancelled off its higher heat transfer efficiency between two phases for cross-flow injections.

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