Modeling and Control of Pre-chamber Initiated Jet Ignition Combustion Systems

Ruitao Song
Advisor: Dr. Guoming Zhu

Abstract

Turbulent jet ignition (TJI) combustion is a promising concept for achieving high thermal efficiency and low NOx (nitrogen oxides) emissions. It has the potential to be used in next-generation internal combustion engines.

For optimizing the TJI combustion system and developing the associated model-based TJI control strategies, a control-oriented TJI combustion model with satisfactory accuracy and low computational effort is usually a necessity. In this research, a control-oriented TJI combustion model is firstly developed for a rapid compression machine (RCM) configured for TJI combustion. Then, the RCM model was extended to an engine model for the Dual-Mode (DM) TJI engine at Michigan State University. A two-zone combustion model based on the newly proposed parameter-varying Wiebe function is proposed. Since the engine uses the liquid fuel, a pre-chamber air-fuel mixing and vaporization model are also developed. The simulation results show a good agreement with the experimental data. The relative simulation error of the in-cylinder pressure is less than 8%.

To achieve stable combustion with high thermal efficiency and low engine-out emissions, an optimal combustion phasing controller is developed for the DM-TJI engine. Traditional open-loop map-based control becomes less favorable in terms of calibration effort, robustness to engine aging, and especially control accuracy for the DM-TJI engine due to the increased number of control variables over spark-ignition engines. In this research, a model-based feedforward controller is developed. A feedback controller is designed based on the linear quadratic tracking control with output covariance constraint. The proposed feedforward and feedback controllers show a better performance than a group of baseline controllers through a series of dynamometer engine tests.