Implementation of Advanced Fuels and Combustion for Internal Combustion Engines

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Advanced engine designs for transportation has shown significant reduction in engine-out emissions while simultaneously achieving gains in fuel efficiency by using Low Temperature Combustion (LTC) modes and feedback control of the combustion processes. The work of this group has considered the difficulties encountered in using these combustion modes through implementation of advanced control methodologies, novel sensor techniques as well as expanding usage of fuels such as bio-fuels and hydrogen. The methods used to obtain the lower combustion temperatures include lean mixtures and high levels of exhaust gas recirculation. For example, LTC modes such as Homogeneous Charge Compression Ignition (HCCI) and Partially Premixed Compression Ignition (PCCI) engines show real gains in reduced engine out emissions with improved efficiency. However, implementation of these advanced combustion modes presents combustion timing and stability issues due to stronger dependence of these advanced combustion modes on the physical and chemical properties of the fuel, inlet temperature, and inlet composition than traditional diffusion burning (“diesel” type) modes. Progress in these advanced combustion modes requires a “smart” engine capable of sensing heat release patterns and adjusting combustion system parameters. Hence collaborative work between several researchers at Missouri S&T are considering the required combustion analysis, nonlinear control, sensor development and fuel property issues surrounding the implementation of several LTC modes. Analysis methods currently considered are based on surface accelerations for use on both conventional and premixed auto-ignited combustion types that can robustly indicate combustion characteristics. Surface mount accelerometers are being used to indicate combustion characteristics needed for closed loop engine control but which have minimal structural influence. Acceleration frequency bands are being identified where the structural characteristics has the most influence (i.e. structure resonant modes), thereby allowing indication of other surface acceleration frequency bands which are minimally affected by the structure and more indicative of the combustion behavior. Active control necessitates an advanced control strategy such as adaptive neural networks which we have shown can function satisfactorily even when the dynamics of the engine combustion process are unknown. A near optimal nonlinear adaptive controller using Approximate Dynamic Programming (ADP), based on a phenomenological LTC engine model is being developed. The conceived controller would reduce cyclic variability in start-of-combustion, limit pressure rise rates and control to maximize efficiency through control of heat release pattern phasing. With advanced control algorithms, low-cost sensor technologies need to be developed before robust control of auto-ignited combustion can be achieved on a production scale. Interferometer based sensors packaged in small fiber optics are being developed for the high temperature and pressure combustion chamber environment with response times on the order of microseconds. Finally, advancing the application of advanced LTC modes to enable the use of bio-fuels or hydrogen has become increasingly important for energy security. Consequently, the distinct characteristics of hydrogen combustion in engines are being investigated using advanced simulation techniques to examine more efficient and cleaner operating strategies (e.g., dual-fuel operation).