Biofuel, a form of renewable fuel, has promising future, especially as the alternative fuel for transportation. Biofuel is usually blended with petroleum fuel and used in flex fuel engines. Since the characteristics of biofuel are quite different from those of the petroleum based fuel, it is very important to optimize the combustion properties for biofuel engines under different fuel blends. This research focuses on biofuel content detection and combustion control of biofuel engines under different biofuel contents.

The first part of this research is the utilization of the ionic polymer-metal composite (IPMC) material as a sensing element of a flow and fluid property sensor for flex fuel engines. It is motivated by the IPMC’s intrinsic sensing characteristic that an IPMC beam is capable of producing an electric signal closely correlated to its mechanical movement due to the redistribution of mobile ions inside the IPMC material. The IPMC beam is modeled as multiple rigid elements connected by rotational springs and dampers in this study. The fluid properties are estimated by using the least-squares approach based upon the developed finite element model. The proposed estimation scheme was validated in experiments under different fluid media, and it was found that the estimated fluid properties have fairly good agreement with their actual values. This research is very important for automotive applications where the characteristics of the fuel blend need to be identified in real time.

The second part of the research is targeted at the optimal tracking control of the desired air-to-fuel ratio (AFR) based upon adaptively estimated biofuel content for internal combustion engines equipped with the lean NOx trap (LNT) aftertreatment system. The biofuel content is adaptively estimated based upon the oxygen sensor signal. The engine system was approximated by a third order linear system. A linear quadratic optimal tracking controller was developed to track the desired engine AFR during the LNT regeneration period. The robust stability of the closed loop system with the biofuel content estimation is guaranteed over the entire biofuel content range by using the robust stability criteria for the LPV (linear parameter variation) system, where the biofuel gain and the engine speed are considered as the variable parameters. Several adaptive control schemes were studied through simulations, and then the selected control strategies were evaluated through dynamometer tests for a lean burn spark ignition (SI) engine. The best performance was achieved by the gain-scheduled adaptive scheme.

The third part of the research is detection of the combustion phase and estimation of biodiesel content using traditional knock sensors. Existing approaches for the combustion phase detection of a diesel engine are mainly based upon the high cost in-cylinder pressure sensor. This study focuses on developing a method to estimate the point of 75% of mass faction burned (MFB75) by using the traditional knock sensor signal. It was observed through experiment data that the knock signal can be correlated to MFB75 location well. Therefore, an MFB75 estimation method was proposed based upon the integrated knock signal over every crank angle. The proposed approach was validated using the experimental data and provided accurate estimation of MFB75 consistently. In addition, the study also demonstrates the feasibility of using the knock sensor signal to provide a secondary estimation of fuel content.