

Estimation on the Location of Peak Pressure at Quick Start of HEV Engine Employing Ion Sensing Technology

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ABSTRACT

In this paper an estimation method on location of peak pressure (LPP) employing flame ionization measurement, with the spark plug as a sensor, was discussed to achieve combustion parameters estimation at quick start of HEV engines. Through the cycle-based ion signal analysis, the location of peak pressure can be extracted in individual cylinder for the optimization of engine quick start control of HEV engine. A series of quick start processes with different cranking speed and engine coolant temperature are tested for establishing the relationship between the ion signals and the combustion parameters. An Artificial Neural Network (ANN) algorithm is used in this study for estimating these two combustion parameters. The experiment results show that the location of peak pressure can be well established by this method.

INTRODUCTION

One of the most important strategies to reduce fuel consumption and emissions of HEVs is engine off idling. By canceling of unnecessary idle state, engines avoid operate in a condition of zero power output, and about 5%~10% fuel consumption can be reduced^[1]. However, an aftermath of frequent start or restart of engines with high cranking speed comes forth subsequently. Depending on the driving cycle, the configuration of the powertrain and the control strategy, engines used in HEVs might be required to start and stop for many times. These start or restart processes of HEV engines, comparing with the cold start processes of engine used in traditional vehicles, are more transient, both engine speed and load changed more dramatically during these processes^[2]. And it is more difficult to control these processes accurately on HEV engines.

Generally speaking, on traditional vehicles, spark advance timing is crucial for engine efficiency and emission optimization^[3]. Through the adjusting of spark advance timing, different cylinder pressure variation process and different location of peak pressure will be

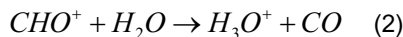
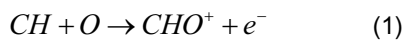
achieved which means different heat release process. As concern as the start progress of engine, an important way to reducing cold-start hydrocarbon emissions and heating up the catalyst during a cold start is achieving a postponed LPP by retarding a spark time to raise an exhaust temperature and heating up a catalyst. But too late ignition will lead to bad combustion such as partial burn and misfire^[4]. Today, spark advance values are optimized empirically and stored in tabular form in the engine control unit. The drawback of this method is that it is not possible to achieve a closed loop control the LPP and adjust the spark advanced angle in real time for optimize the start progress of IC engine^[5]. Thus, real time LPP estimation is crucial for the start progress of engine, especially for the HEV engine which start progress is highly transient.

A possibility of location of peak pressure estimation can be achieved by employing the spark plug as an ion sensor. Since 1990s, there has been a greater interest in the ionization sensing technique for spark ignition (SI) engines^[6]. The advantage of utilizing ionization sensing over crankshaft velocity fluctuation measurement for 100% misfire detection at all speeds and loads as required by OBD-2^[7]. This is especially the case for engines with more than 4 cylinders. The spark plug as ionic current sensor does not require any additional space or expenses. Generally, the combustion of fuel inside the engine cylinder produces ions and free electrons. A current can be generated and detected by locating two electrodes in the combustion chamber and applying a low DC potential difference between them.

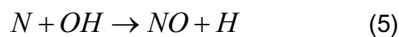
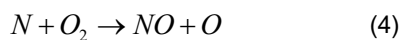
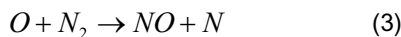
This paper discussed a method of cycle-based combustion parameter estimation utilizing flame ionization measurement at engine start phase. The ion signal, along with engine speed, engine coolant temperature, spark advance and manifold absolute pressure, is used as the input variable of an Artificial Neural Networks (ANN) algorithm, and the location of peak pressure are estimated to provide a possibility of close loop control of quick start of HEV engine^[8].

BASIC THEORY OF ION SENSING TECHNILOGY

Ion current signals have long been investigated as a combustion diagnostic tool. The ionization process during combustion of fuel in the cylinder is basically composed by a complex set of thousands of chemical reactions^[9]. Generally speaking, this process can be divided mainly into two phases by the essential mechanism of the ionization process in different periods^[10]. The first phase of an ion current signal which arose by the combustion is defined as the "flame front phase". This phase is related to the combustion process in the flame kernel. It depends on the front flame propagation and the ion probe position within the combustion chamber. The source of the current during this phase is mainly related to chemical-ionization processes as Equation (1) and (2):



The second phase is defined as the "post flame phase". The ionization during this phase is due to the high temperature inside the combustion chamber. And the most dominative ion production mechanism in this phase is the slow forming Nitric Oxide by means of the extended Zeldovich mechanism^[11] as Equation (3), (4) and (5):



The ionization during this phase is due to the high temperature inside the combustion chamber. Since the temperature and the pressure are closely related, the ionization signal follows the pressure signal near the peak.

EXPERIMENT METHOD

The schematic diagram of the test bench is shown in figure 1. A motor servo control system was installed on the gasoline PFI engine test bench to crank the engine and start the engine at different cranking speeds. The on

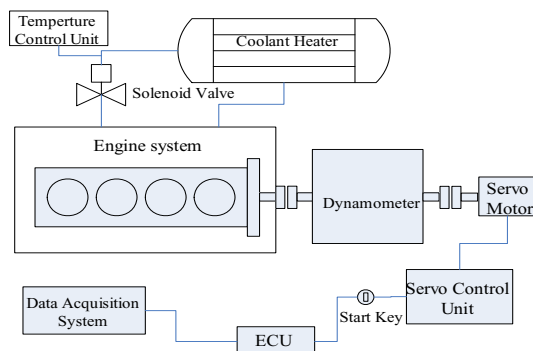


Fig.1 The schematic diagram of the test bench

off of the motor is triggered by the start key which is also connected the electronic control unit (ECU) to

control the beginning of the injection and ignition of the engine.

The engine used in this test is from Shanghai Maple Automobile Company, and the ECU is calibrated by UEAS. The engine specifications are given in table 1.

TABLE I
SPECIFICATIONS OF THE ENGINE

Engine	JL479QA
Bore and Stroke	78.7×77.0 mm
Compression Ratio	9.8
Cylinder Number	4
Ignition Sequence	1-3-4-2
Fuel Injection Type	PFI
Fuel Type	93# Gasoline
Ignition Coil	1-4, 2-3

In this study the first cylinder is used as the object for the research of the quick start progress of HEV engine. All the engine operation parameter collected from both ECU and other sensors are for the 1st cylinder only.

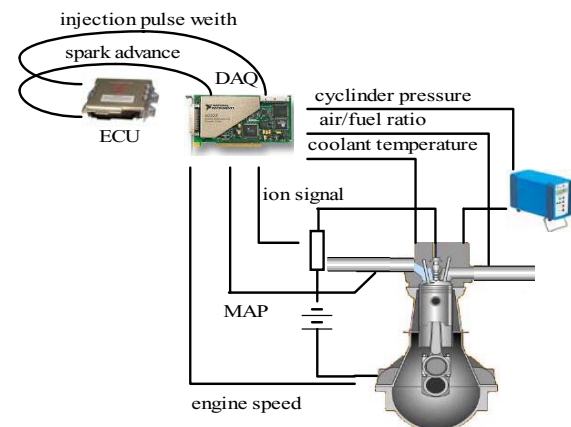


Fig.2 The schematic diagram of engine DAQ system

By the observation of the cylinder pressure signal of this cylinder, the LPP variation during quick progress will be achieved, and will be estimated through the variation of ion signal and other signals. The schematic diagram of the engine operation parameters achieving system of the 1st cylinder is shown in Fig.2.

COMBUSTION PARAMETER ESTIMATION METHOD

Fig.3 is the variation of the cylinder pressure and ion signal of first 4 cycles at two teams of start progress at same conditions with a cranking speed of 400rpm, and coolant temperature is 20°C. From the 1st cycle it can be seen that the cylinder pressure of the first cycle of these two teams of start progress are almost the same, as well as the ion signal. The 2nd, 3rd and 4th cycle show that the variation of ion signal is well corrective with the cylinder pressure. And the peak position of the ion signal is always near LPP.

Generally speaking, there are two peaks in a ion signal, one is at "flame front phase" and the other one is at "post flame phase", but not always two peaks can be seen because these two peaks superimpose with each other