PROPOSAL

ESTIMATION OF INTERNAL CYLINDER PRESSURE IN A HOMOGENEOUS CHARGE COMPRESSION IGNITION ENGINE THROUGH TORQUE ESTIMATION

Submitted to

The Engineering Honors Committee

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ABSTRACT

Homogeneous Charge Compression Ignition (HCCI) is a combustion mode in which a homogeneous mixture of fuel and air auto ignites in the combustion cylinder of a Diesel engine. HCCI is a new technology that has proven to be very promising in reducing levels of NO_x and Particulate Matter emissions that a Diesel engine produces. However, since this technology is still new, there are many problems that exist in successfully implementing HCCI in Diesel engines in the field. One of these problems is that there is currently no way to control the combustion timing when utilizing HCCI. The inability to control this process is the main purpose of this research project. The outcome that is anticipated from this research is the development of a practical way of estimating the pressure inside the cylinder. Since the combustion process is initiated due to critical pressure and temperature conditions, the ability to know the pressure inside the cylinder is the first step in controlling combustion.

INTRODUCTION

Homogeneous Charge Compression Ignition (HCCI) is a technology that has been developed in response to EPA legislation. The regulations will take effect in the year 2007 and will require the severe reduction of diesel engine emissions, more specifically Nitrogen Oxides (NO_x) and Particulate Matter (PM). This deadline is quickly approaching, creating urgency among researchers to further understand and control this new technology. NO_x and PM are both created during the combustion process of a typical Direct Injection (DI) Diesel engine. Fuel is injected into the cylinder at Top Dead Center (TDC) during the compression stroke. The increase in temperature and pressure in the cylinder causes spontaneous combustion. NO_x is formed due to high combustion temperatures and PM is formed due to large fuel droplets being partially burned or unburned and escaping through exhaust. The implementation of HCCI in a DI Diesel engine significantly reduces these emissions. One means of implementing HCCI combustion is to create a homogeneous mixture of fuel and air outside of the cylinder that is drawn into the cylinder during the intake stroke. This method reduces emissions by reducing the combustion temperature and allowing for a more complete combustion due to increased surface area and more uniform distribution of the fuel droplets. One disadvantage of HCCI is the inability to control combustion timing since a homogeneous fuel and air mixture exists in the cylinder during the entire compression stroke. The inability to control combustion timing can cause early combustion or cylinder misfire. Both of these conditions are undesirable in any engine. One way to control the combustion timing is to know the pressure inside the cylinder during the compression stroke (combustion pressure). The combustion pressure can be measured in a research lab using pressure transducers, however due to expense of equipment, reliability issues, and short life span it is almost impossible to implement this technique in vehicles. The purpose of this research project is to create an algorithm to accurately estimate the combustion pressure in a conventional DI Diesel engine implementing HCCI through the measurement of crankshaft angular velocity. This will be done using a method that has been utilized in direct injection engines, but never with HCCI combustion. (See Figure 1) Being able to accurately estimate the in-cylinder pressure of an HCCI Diesel engine will be a giant step towards further understanding and increased control of this new technology. Gaining control over HCCI combustion will help reduce harmful emissions and increase the efficiency of this promising method of fuel delivery.

OBJECTIVES

The main objective of this research project is to create an algorithm to estimate the combustion pressure of a DI diesel engine utilizing a new HCCI method. This will be achieved through the measurement of in-cylinder pressure and crankshaft angular velocity. Crankshaft velocity fluctuations can be used to estimate the net torque which is directly related to the combustion pressure. Therefore, working backwards through a series of algorithms will allow for the accurate estimation of combustion pressure when the crankshaft angular velocity is known.

METHODS OF PROCEDURE

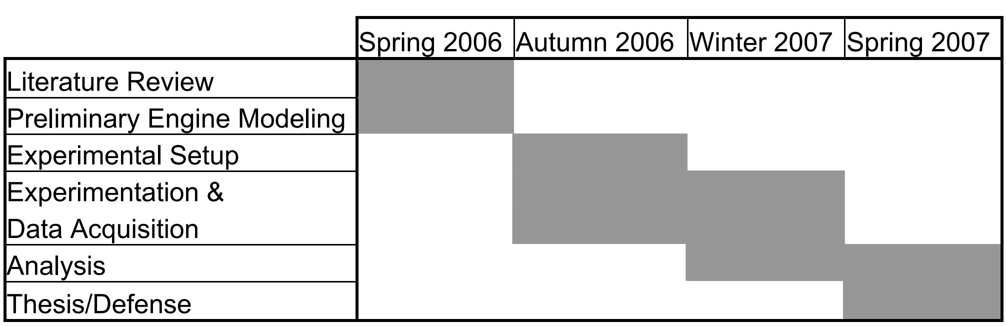
The first phase of this research project will take place during Spring Quarter of 2006 and will consist of a rigorous literature review. Topics that will be studied include, but are not limited to, HCCI theory, previously used methods for torque and combustion pressure estimation, frequency domain analysis, and other topics covered in ME 482 and ME H680. The knowledge gained from both of these classes will play an integral part in this project. Additional study and preliminary work in the kinematic and dynamic modeling of the engine crankshaft will also take place during this phase. (See Figures 2 & 3) This work will result in the development of a Simulink-based simulator of the kinematics and dynamics of a four-cylinder engine, to better understand the relationship between combustion pressure, shaft torque, and shaft angular velocity.

Due to co-op obligations during the summer, the next phase will take place during Autumn Quarter of 2006 and will consist of preparing the experimental setup at The Ohio State University Center for Automotive Research (CAR). (See Figure 4) The method of HCCI that will be studied uses an external fuel atomizer that is a fairly new technology created by researchers at CAR. This atomizer is coupled to the engine intake system and creates sub-micron sized droplets of fuel in the air stream resulting in a nearly homogeneous mixture. The experiments will take place in a VM Motori, 2.5 liter, 4-cylinder, diesel engine mounted to an engine dynamometer in a test cell at CAR. Devices for a few of the important parameters will also be installed. Crankshaft angular velocity fluctuations will be measured using an optical encoder mounted to the crankshaft of the engine. The pressure inside the cylinder will be measured with glow plugs that have built-in pressure transducers. Another part of this step will be to study preliminary combustion pressure and crankshaft torque estimation algorithms that can be implemented in engine simulations. Gaining an understanding of these algorithms for the estimation of the combustion pressure using the torque estimation methods will be critical in analysis of experimental data.

The next phase is the experimental and data acquisition phase which will take place simultaneously most likely during Winter Quarter of 2007. The data collected from experimentation will be analyzed using statistical methods and frequency domain methods for proper torque and therefore combustion pressure estimation.

The final analysis and preparation of a thesis and oral defense will occur during Spring Quarter of 2007, the quarter in which I will graduate.

SCHEDULE



CAPABILITY

This project will utilize knowledge gained from a diverse course load both completed and in progress this spring quarter of 2006. Engine modeling will use kinematics and dynamics concepts as well as knowledge to be gained from ME482 to further develop a practical numerical algorithm. Also, the knowledge to be obtained from ME H680 will also be implemented in the complex signal processing methods required to complete this research. The main class that has inspired me to do this work was a technical elective taken Spring Quarter of 2005. ME 694 a Powertrain Laboratory taught by Dr. Soliman at CAR showed me how state of the art and interesting work like this could be. This class also taught me a great deal more about engine theory than I already knew.

Most importantly, this research experience is a great opportunity for me because of my strong desire to work in the automotive industry. I already have co-op experience in an engine testing lab at the Lubrizol Corporation. This experience has taught me a great deal about the basics of engine testing, trouble shooting, and analysis. I will return for one last co-op rotation this Summer Quarter of 2006. During this rotation I will have the opportunity to expand my knowledge by working in the diesel engine lab. The main purpose of this lab is to test the effects of engine oil and fuel additives on diesel engine emissions. I believe that this will give me an upper hand as I proceed with this research opportunity.

REFERENCES

1. L. Garzarella and M. Ghisolfi, "Experimental and Theoretical Analysis of HCCI Engines with External Mixture Formation". M.S. Thesis, Politecnico di Milano, June 2005.
2. B. Lee, G. Rizzoni, Y. Guezennec, and A. Soliman, "Engine Control Using Torque Estimation" SAE Technical Paper No. 2001-01-0995.
3. N. Cavina, F. Ponti, G. Rizzoni, "Fast Algorithms for On-Board Torque Estimation", SAE Technical Paper 1999-01-0541, 1999 SAE Transactions, Vol. 108, Journal of Engines, Section 3, pp. 738-745.
4. D. Lee, G. Rizzoni, "Detection of partial misfire in IC engines using a measurement of crankshaft angular velocity", SAE Technical Paper 951070, 1995 SAE Transactions, Journal of Engines.

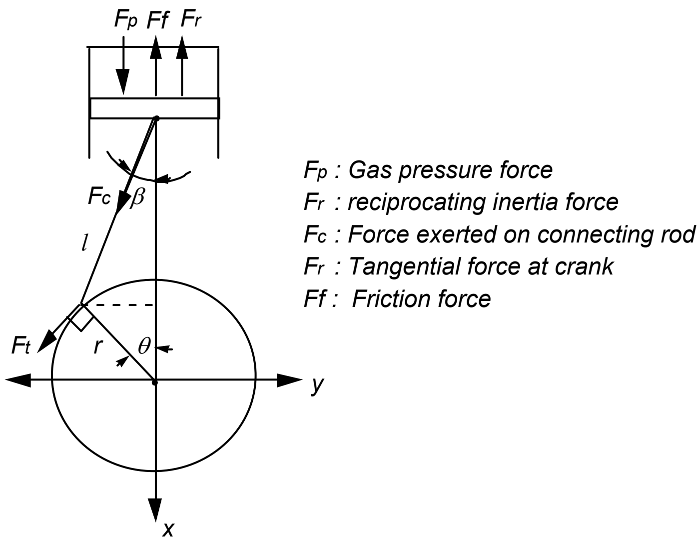


Figure 2 – kinematics of reciprocating engine

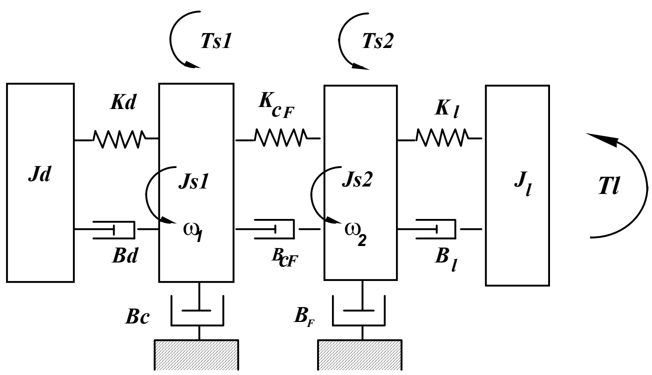


Figure 3 – engine crankshaft dynamic model

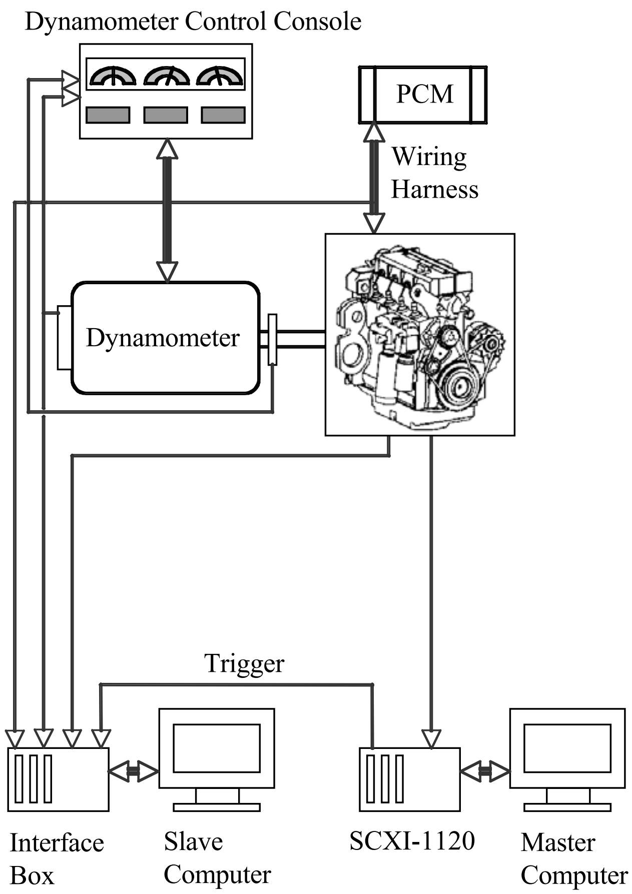


Figure 4 – experimental setup

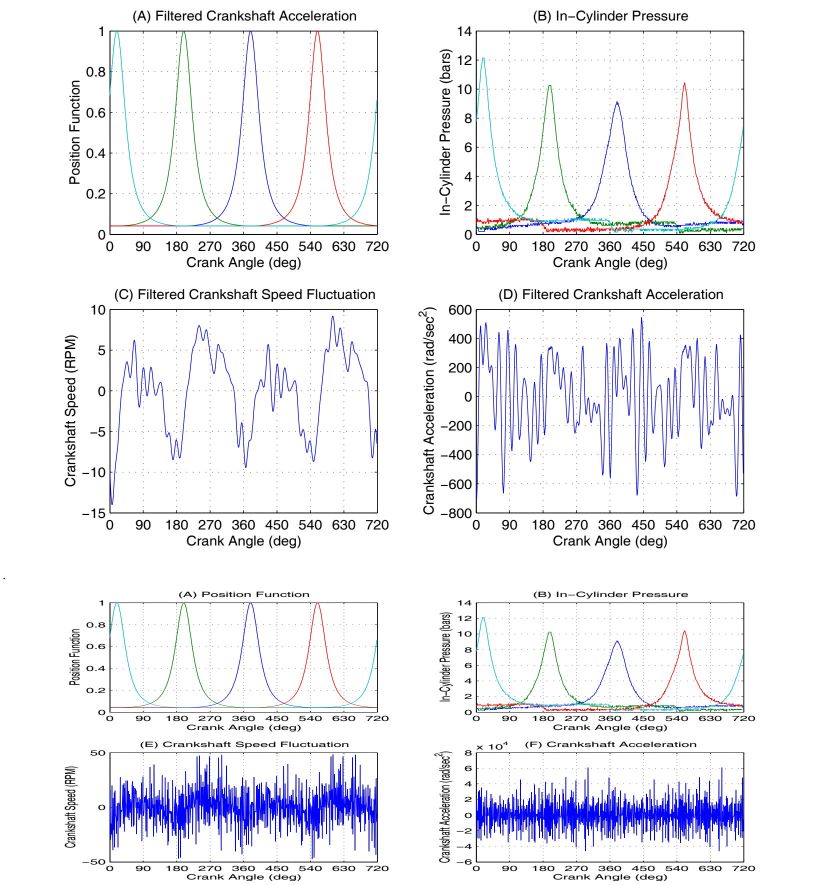


Figure 1 – previous results from gasoline engine