AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING

LEAN-BURN AND FUEL INJECTION OF NATURAL GAS IN SI ENGINES; THEIR EFFECTS ON THE PERFORMANCE, EMISSIONS AND COMBUSTION CHARACTERISTICS

by

Ahmed El-Geushey Fetoh M. Hassaneen
B.Sc. Mechanical (Power) Engineering, 1983
M.Sc. Mechanical (Energy) Engineering, 1990

A Thesis Submitted In Fulfillment Of The Requirements For The Degree
Of **Doctor Of Philosophy**
In Mechanical (Power) Engineering

Supervised by

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Ph.D. Thesis
Name : **Ahmed El-Geushey F.M. Hassaneen**
Degree : **Ph. D.**
Thesis Title : "Lean-Burn and Fuel Injection of Natural Gas in a SI Engine; Their Effects on The Performance, Emission and Combustion Characteristics"

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Statement

This dissertation is submitted to Ain Shams University for the degree of Doctor of Philosophy in Mechanical Engineering.

The work comprised in this thesis was carried out by **Ahmed El-Geushey F. M. Hassaneen** in the period from 10/1992 to 2/1997

No part of this dissertation had been submitted for a degree at any other university.

Date : 25 / 2 / 1997

Signature :
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My dear ***father*** *and my brave* ***mother****, I'm feeling your souls around me everywhere, encouraging me and leading me to every success as you were dreaming.*

ABSTRACT

An experimental and analytical investigation is carried out to study the effects of using the electronic control of air-to-fuel ratio and engine ignition timing in a lean-burn natural gas fueled engine. The effects of that control system on the performance, emission and combustion characteristics are examined.

In the experimental part, an 8-cylinder automotive engine and a complete test rig including a water brake dynamometer equipped with a data acquisition system, high pressure fuel system, air intake system and exhaust gases analyzers were set up. An engine research controller was used to control air to fuel ratio through the control of the pulsewidth of injector opening time and consequently the amount of fuel injected. The controller also used to adjust the ignition timing. A newly developed universal exhaust gas oxygen (UEGO) sensor was used to measure air to fuel ratio and its fluctuations in both rich and lean ranges. The engine exhaust system was also equipped with a 3-way catalytic converter. A piezo transducer (k-6121) and a comprehensive data acquisition system were used to collect and process 300 consecutive in-cylinder pressure-time cycles.

In the analytical part, a heat release model based on the first law of thermodynamics was applied to the ensemble average cycle of the in-cylinder pressure data. The heat transfer to the cylinder wall is included and discussed in the analysis. The heat release analysis is used to estimate the net heat release fraction as a function of crank angle degree. It also provides information about the cyclic variation in the combustion process based on the variation in the IMEP or peak pressure.

The engine performance, emission and combustion characteristics were mapped at a wide range of equivalence ratios (1.05 to 0.6), different spark timings, loads and engine speeds.

It was found that the fuel injection system can maintain the overall air-to fuel ratio much better than in a gaseous fuel mixer system thus resulting in a very stable engine operation. The instantaneous air to fuel ratio variation at lean, steady state operating condition, were found to be much lower than its variation in engines utilizing mixer type fuel system. At 0.6 equivalence ratio, the unburned hydrocarbon in the exhaust, which were primarily made up of methane, incresead to about 13 g/kW-h at medium loads. The oxides of nitrogen, however, were significantly reduced to below o.6 g/kW-h which in some cases was found to be less than that converted in the 3-way catalytic converter. The catalytic converter conversion efficiency was maximum for both hydrocarbon and oxides of nitrogen at a very narrow window of +/- 0.02 equivalence ratio around stoichiometric otherwise the conversion effeciency deteriorated dramatically for NOx in the lean side and for HC in the rich side.

At a fixed spark timing, changing the mixture equivalence ratio from stoichiometric to 0.6 increased both the initial flame (kernel) development time and the rapid burn duration by about 33%. However, at MBT spark timing only the initial flame (kernel) development time increased by about 80%. A correlation was developed for the initial flame (kernel) development time as a function of mixture physical conditions at the time of the spark. The maximum coefficient of variation in IMEP was 5% at 0.6 equivalence ratio which reflects the good stability of the combustion process. The results also identifies a temperature threshold above which the unburned hydrocarbon conversion efficiency of the catalytic converter is higher than 50%.

KEY WORDS

Spark ignition engine
Alternative fuels
Natural gas
Lean-burn
Fuel injection
Performance, Emission and Combustion

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APPENDICES