EXPERIMENTAL INVESTIGATION OF IN CYLINDER HC CHARACTERISTICS DURING THE FLAME PERIOD BY USING GAS CHROMATOGRAPHY TECHNOLOGY

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Abstract

In this study, Ricardo Engine that is a single-cylinder research engine was used. Emission concentrations in the engine cylinder were investigated experimentally during flame period on expansion stroke. Model GSD-10 fast response gas sampling system was used to sample gas in the cylinder. This gas sampling system basically consists of two main units; a high speed operated electro-magnetic gas sampling valve and a high speed exciter designed to provide the exciting current to it. In the study, the high speed gas sampling valve was mounted to the gas chromatograph instrument directly and samplings were done at intended crank shaft angle continuously. The electro-magnetic valve lift time was controlled by setting a time-lag from the TDC reference point of the engine crank angle. This time-lag was set by using angle value of the crank pulse. Crank pulses were provided crank pulse generator. The generator consists of a slit disc to be mounted on the engine shaft exit and a photo electric pick-up. it was designed to generate the crank pulse (360 pulses/rev.) and the reference pulse (1 pulse/rev.) These pulses were provided to the valve controller, and then were amplified and shaped. Experiments were repeated for three different compression ratios (r=6-7-8). In cylinder gas samples were taken for 10-15 degree intervals after spark plug ignited the mixture in the cylinder. Samples were taken during the flame period which was approximately 60 degree of crank shaft angle after the spark plug ignited. In this study, Agilent 7890A Gas Chromatography system was preferred to analyses HC component of the sampled gas from the engine cylinder. GC-FID (Flame Ionization Detector) analysis method was used to investigate hydrocarbon components. Response time of hydrocarbon components were listed. HC components variation with respect to crank shaft angle was plotted. The effect of compression ratio was analyzed and all results were plotted. The relationship between the engine parameter and the combustion mechanism in the cylinder were discussed.

Keywords: Gas Chromatography, Gas Sampling, Emissions in cylinder, Ricardo Engine

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1. Introduction

The developments in industry and technology and the increase in the numbers of industrial establishment and vehicles develop life-quality of human being, however they cause environmental pollution and in order to prevent environmental pollution, Research and Development (R&D) studies are required. Nowadays, global warming is the one of the most important problems. The particle and gaseous emissions from internal combustion engines contribute this problem as the one of the main source. For this reason, during the design of internal combustion engines, emissions must be considered. The contribution of internal combustion engines on the greenhouse effect and global warming are required to decrease by strict regulations. Therefore, before making structural variations during the development stage of an engine, the fundamental bases must be determined clearly. In order to minimize the cost of prototypes/models, the behavior of combustion and combustion products must be understood. The combustion in cylinder is the only source for mechanical power of an engine. Consequently, the studies for investigation and improvement of combustion and emission behavior in-cylinder contribute automotive technology.

To produce further information regarding the source of exhaust hydrocarbons from engines, a parametric study of both exhaust and in-cylinder hydrocarbons has been carried out in a CFR engine operating at 1000 rpm on isooctane. Samples of the gas near the cylinder wall of the engine were taken over a complete engine cycle using a rapid [1]. It was seen that, crevice volumes were the major source both the in-cylinder and exhaust hydrocarbon observed in those experiments. M.Peckham and N. Collings has been developed a fast-FID sampling technique to study top-land crevice out-gassing from the moving piston of an SI engine. The removal of wall HCs has been dedected during the exhaust stroke from the probable scrolling effect produced by the rising piston scalping unburned material from the cylinder wall [2]. In another study, a fast- response FID technique has been used to study the concentration of hydrocarbon concentration of hydrocarbon material at four different locations in a firing SI engine. In this way, wall effects could be noted by moving the probe position without stopping the engine and directly comparing with hydrocarbon levels in the bulk gas [3]. In a similar manner, instantaneous in-cylinder and engine exhaust port HC concentrations were measured simultaneously using a fast response flame ionization detector concentrated on the post flame period [4]. HC concentration development during the post-flame period was discussed. Comparison was made of the post-flame in cylinder and exhaust port HC concentrations under different engine operating conditions, which gives a better understanding of the mechanism by which HC emissions form from crevices in SI engines [4]. The fast-response flame ionization detector has become a widely used instrument for time-resolved hydrocarbon measurements in internal combustion engines. In an important study, the characteristics and working experience of fast- response FID instrument were reviewed [5]. In particular, the sampling system and its performance for isolating the pressure pulsation in in-cylinder and in engine exhaust measurements were described. Results from different applications were given in this study to illustrate the utilities of the instrument [5]. The use of a fast flame-ionization detector (FID) system for measuring hydrocarbon (HC) levels in spark ignition engine cylinder was described in another study [6].

2. Experimental Setup

All experiments were carried out on a single cylinder Ricardo E6 variable compression ratio engine. The engine was coupled to a D.C. dynamometer with DV-300 control module to provide free motoring and firing capabilities. The controller operates on 480 VAC, three phase power, and the control module converts the AC electrical supply to 300 VDC power. The control module is wired to a General Electric, 20 horsepower, 33 ampere, and direct current motor/generator dynamometer with a rated maximum speed of 3000 revolutions per minute. Under fired engine conditions, the dynamometer maintained the speed within ±5 rpm of the set conditions. A flywheel is connected to the crankshaft in order to reduce cyclic variability and speed variations, cause by the intermittent combustion events. The specifications of Ricardo E6 engine are listed on Table 1.

Table.1 Engine specifications

Cylinder Diameter	76,2 mm
Stroke	111.1 mm
Displacement Volume	0,507 lt
Maximum Revolution number	3000 rpm
Maximum Power	9,4 kW
Maximum Cylinder Pressure	150 bar
Fuel	Gasoline
Static Ignition	25 ^{o} BTDC
Compression Ratio	6-7-8
Coolant Temperature	30 ^{o}
Engine Speed	1200 rpm and 1560 rpm
Load	%75 - %50

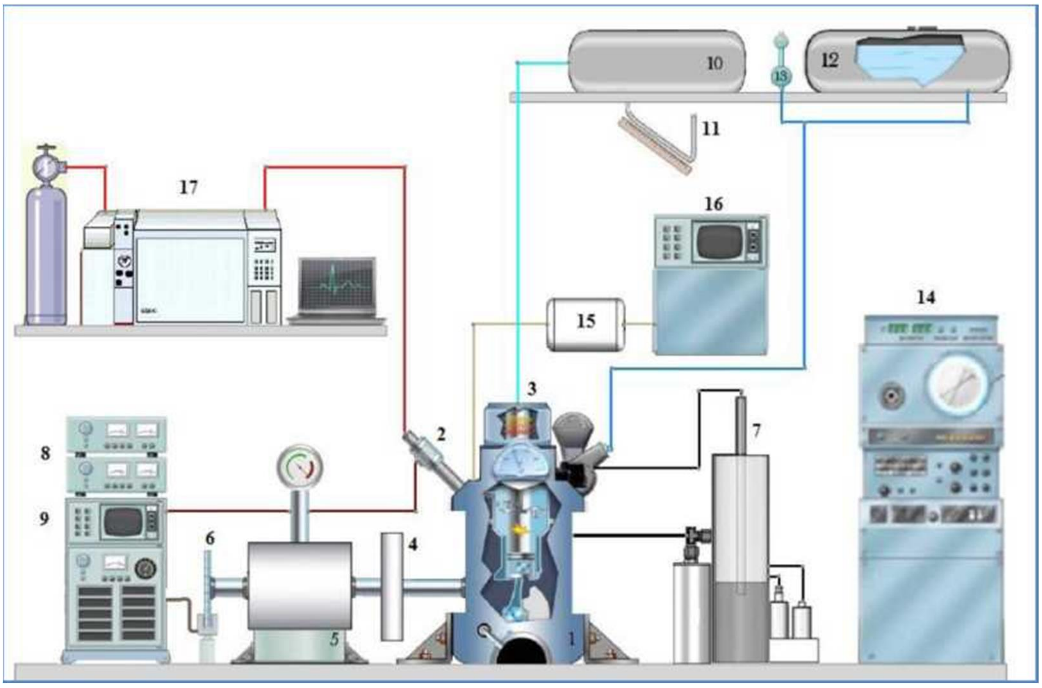
Engine cylinder gases were extracted during the combustion period by using high speed gas sampling system. Model GSD-10 gas sampling system basically consist of two main units; a high speed operated eletro-magnetic gas sampling valve and a high speed magnet exciter designed to provide the exciting current to it. For its auxiliary instruments, the following units are optionally available;

Å A sampling valve controller which enables the sampling valve to operate at the desired timing.
Å A crank pulse generator which provides the crank angle information to the controller.
Å A valve motion dedector which monitors valve lift wave-forms or performances of the sampling valve.

Accordingly, the high speed gas sampling system, model GSD-10 is complete with;

1. Electro-magnetic gas sampling valve, needle type or poppet type.
2. High speed magnet exciter.
3. Sampling valve controller.
4. Crank pulse generator with one slit disc.
5. Valve motion detector
6. Rack

The sampling valve controller provides the control signal to the exciter. The controller can amplify and shape pulse signals from the photo electric pick up mounted on engine shaft. In the case of four cycle engine, this unit has additional function which the TDC reference pulse can be divided into V. The valve lift time of the sampling valve is controlled by setting a time-lag from the reference TDC point. The generator consists of a slit disc to be mounted on the engine shaft and a photo electric pick-up, and is designed to generate the crank pulse (360 pulses/rev) and the reference pulse (1 pulse/rev). these pulses are provided to the valve controller, and then are amplified and shaped. The detector detects the lift of the sampling valve and gives voltage output. The schematic layout of the experimental setup is shown in Fig.1.



Number	Device
1	Ricardo E6 Single Cylinder Research Engine
2	Electromagnetic Sampling Valve
3	Intake air conditioner
4	Flywheel
5	Dynamometer
6	Slit Disk/Photo Electric Reader
7	Cooling Water Tower + Water Pump + Heat Exchanger
8	2 x Oscilloscope
9	High-Speed Gas Sampling Device
10	Orifice and Air Tank
11	Inclined Manometer
12	Fuel Tank
13	Glass Measuring Tube
14	Ricardo E6 Single Cylinder Research Engine Control Panel
15	Exhaust Silencer
16	Capalec Gas Analyzer
17	Gas Chromatography Equipment + Data Logger + Gas Tubes

Fig.1. Schematic layout of the experimental installation

To analyze the hydrocarbons, Agilent Gas Chromatogram system was used. The GC-FID specifications are represented in Table.2

Table.2 GC-FID Specifications

Device		**Agilent 7890A Gas Chromatography**
Detectors		**FID - TCD**
Method		**Automatic injection (continuous line connection)**
Oven Temperature		**30°C (Before analysis, Cold case)**
Columns		**Hayesep-D-5 30m, D=0.320 mm, Film=0.25^m**
Carrier Gas		**Helium @18 PSI Dry Air**
Temperature Program	**1.**	**Starting from 30 °C and wait 8 minutes. Then temperature rising to 60 °C with using 40 °C/min heating rate and wait 15 minutes.**
	2.	**Starting from 60 °C and use 50 °C/min heating rate. The final temperature is raised to 250 °C.**
	3.	**Finally, wait 13 minutes at 250 °C.**
Sample input		**~ 100 ml/min**

3. Results and Discussions:

Unleaded gasoline was used as the fuel for this set of experiments. Data acquisition began after the engine coolant temperature and lubricating oil temperatures have stabilized at 85 °C and 70 °C respectively. A sample chromatogram which was taken from the engine operation state of 6 compression ratio, 900 rpm and 20 CSA advance ignition, is given in Fig.2.

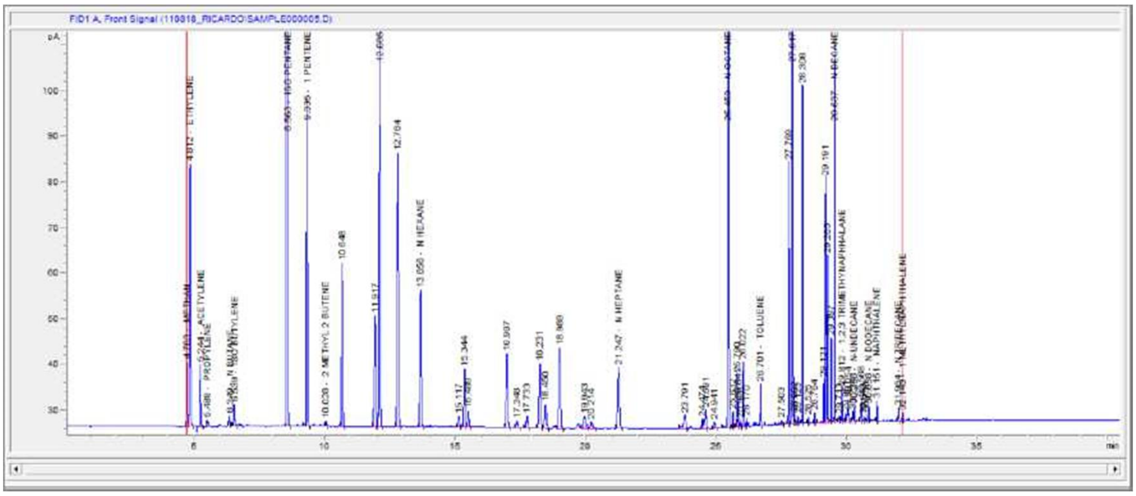


Fig.2. Chromatogram illustration of FID

As seen from Fig.2, there are many HC peaks exist in the chromatogram. These peaks are very clear and segregated. Analyze of hydrocarbon period cut off at the GC time which is 32 minute. After this GC time there are no HC component occur. After spark plug, Behavior of Ethylene and Acetylene in the cylinder is given in Figure.3. For different engine speed, iso-pentane distribution with respect to crank angle is shown in Fig.4.

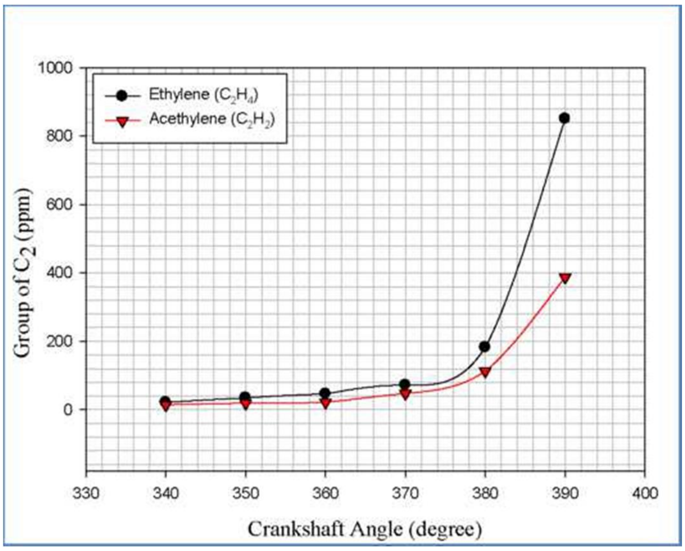


Fig.3. Change of Group of C_2 with respect to Crankshaft Angle at compression ratio r = 7 and N = 900 rpm

At the end of the flame period, hydrocarbon component of ethylene reaches 823 ppm. This result show that the heavy hydrocarbon components chemical degradation to light hydrocarbon components during the flame period in the engine cylinder.

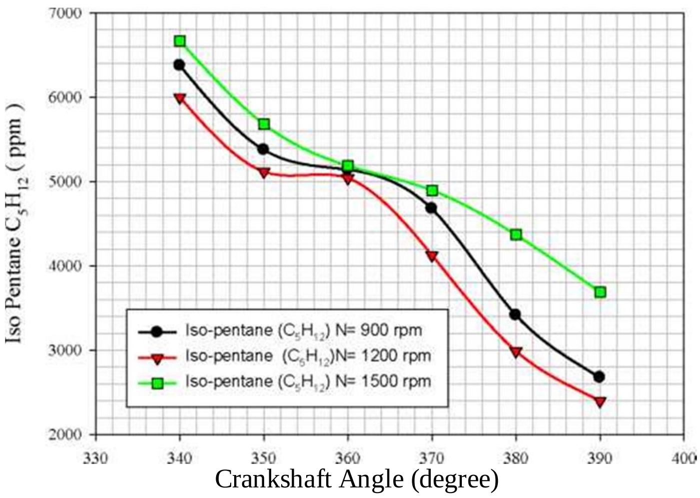


Fig.4. Change of iso-pentane with respect to Crankshaft Angle at compression ratio r = 7 and N = 900, 1200 and 1500 rpm

When the spark plug ignited, iso-pentane is higher than 6000 ppm for both engine speed. While the engine is running at 1200 rpm, iso-pentane amount level is seen lower than the other engine speed at the beginning of the combustion. For both engine speed, iso-pentane tends to decrease with respect to crank angle in the cylinder. Change of C_5-C_8 wrt crank shaft angle at the compression ratio r = 8 and engine speed N=1200 rpm is given in the Fig.5.

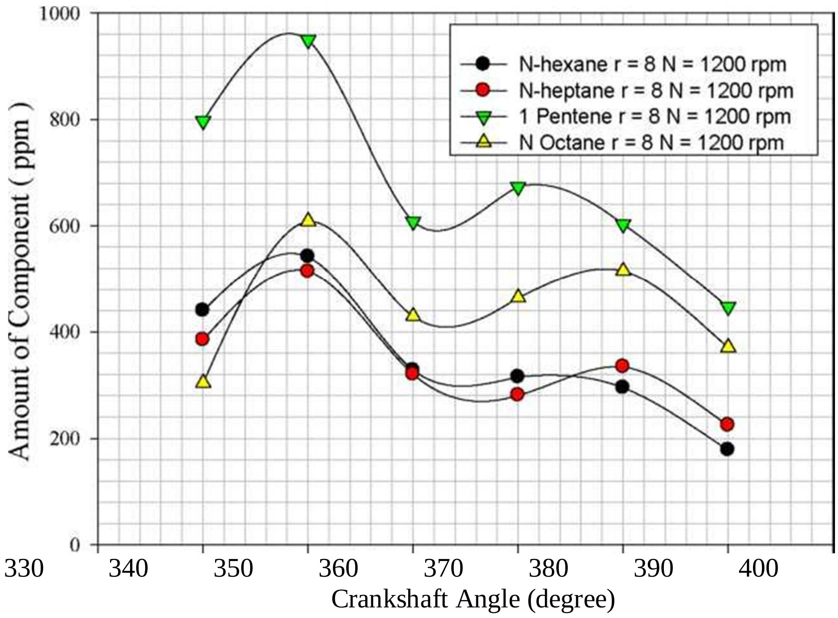


Fig.5. Change of C_5-C_8 with respect to Crankshaft Angle at compression ratio r = 8 and N = 1200 rpm

N-hexane (C_6HI_4), N-heptanes (C_7HI_6), 1 Pentene (C_5HI_0) and N-octane (C_8HI_8) components are given in the Fig.5 respectively. After spark plug ignited, similar trends are seen for both HC component. At 370 crank shaft angle, there is a peak point for both components. This point may be a secondary chemical degradation point. This result must be concluded with the pressure and temperature data at the same crank shaft angle.

4. Conclusion

In this study, high speed electro-magnetic sample and gas chromatogram system were used. There are some results of in-cylinder HC component with respect to crank shaft angle during the flame period. Instantaneous HC component concentrations were analyzed simultaneously by using GC-FID technology. It is seen that the heavy HC components amount (as N-octane) tend to decrease during the flame period. On the other hand, light HC components (as ethylene) amount tends to rise during the expansion stroke. And there is a peak value at the end of the combustion. This expected result show that the chemical degradation occurs between the HC components during the combustion.

5. Acknowledgements

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