Development and Use of PC Based Combustion Analyzer

PC를 사용하는 연소해석장치의 개발에 관한 연구

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요 약

널리 사용되는 IBM-PC를 기본으로 하여 고속도 데이터 처리가 가능한 연소 해석 장치를 개발하였다. 본 시스템은 상용의 A/D 변환기와 C언어를 사용한 소프트웨어 및 PC 인터페이스 보드로 구성되어 있다.

본 연소 해석 장치의 특징은 모든 기능이 모니터 상에서 마우스로 지원되며, PC상에서 타 프로그램을 위한 데이터 변환이 용이하고 메모리의 확장이 기존의 상용 연소 해석 장치에 비해 간편하다.

연구용 단기통 기관실험을 통하여 본 시스템을 검증하였다. 연소실 내의 압력은 크랭크 각도로 0.1°에서 1°의 해상도로 분석할 수 있다.

주요기술용어 : 연소해석장치, A/D변환기, 데이터 처리, 메모리 확장, 연소실 압력

Nomenclature

Symbols

a : crank radius
B : cylinder bore
e : piston pin offset
l : connecting rod length
p : cylinder pressure
r : compression ratio
V : displacement volume
X : mass fraction burned
θ : crank angle(from $-360°$ to $360°$)
$\frac{dp}{d\theta}$: pressure rise rate
$\frac{dQ}{d\theta}$: heat release rate

Abbreviates

A/D : analog/digital
CAS : crank angle speed
IMEP : indicated mean effective pressure
MBT : maximum brake torque
PMEP : pump mean effective pressure
poly : poly tropic coefficient K

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rpm : revolution per minute
TDC : Top dead center(crank angle 0°)

Subscripts
i : i^{th} crank angle
max : maximum value

1. Introduction

To investigate combustion phenomena in the internal combustion engine the cylinder pressure measurement is often used. The most common technique measuring the cylinder pressure is using the piezoelectric transducer.[1] The pressure force in the cylinder is converted to electrical charges by piezoelectric transducer and this charge is also converted to the voltages by the amplifier.[2]

There are many commercial engine data processing systems but they are too expensive and inconvenient.

These days there are many commercial A/D converters operated in the PC environment. Our own developed combustion analyzer is consist of IBM-PC, commercial A/D converter, C-languaged software and the PC interface board. The objects of developing this system are as follows ;

- easy use for engineers who don't major in internal combustion engine
- convenience for handling the memory size
- easiness of data transform
- every function operated by the software

The system was tested using a single cylinder research engine fueled by gasoline and hydrogen. It is possible to compute engine pressure data through this system.

2. Hardware

Fig.1 is the schematic diagram of this system. It is composed of IBM-PC, A/D converter and the PC interfaceboard. Table 1 is the specifications of used A/D converter.[3]

The PC interface card takes charge of two roles ; one is processing the crank angle signal and the other is generating the multi-signal. Fig.2 is the circuit diagram of PC interface board. The crank angle sensor used in this system has the resolution of 3600 pulses per revolution and it is converted to three kinds of signals through the PC interface board.(0.1 degree, 0.5 degree, 1.0 degree) The change of the resolution can be operated by the software.

The A/D converter in this system can't treat the multi-signals at the same time but we used the oscillator signal and our developed digital logic device, so it is possible to manage the multi-signals. Strictly speaking the method of processing the multi-signal is not simultaneous. There are two reasons to use this method. The first, the A/D converter which has the function of sample and hold is expensive, somewhat slow converter rate for the engine speed, and small number of channels. The second, the oscillation time inte-

Table 1 Specification of A/D converter

Model name	DT 2839
Resolution	12bit
Troughput	1 MHz(Single channel) 416 kHz(Multi channel)
Input channel	32 SE
Gain	1, 2, 4, 8

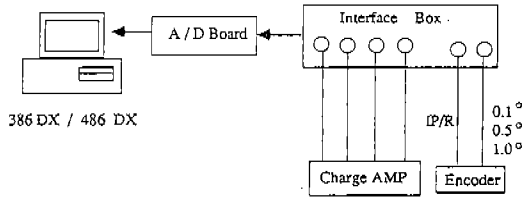

Fig.1 Schematic diagram of PC-based combustion analyzer system

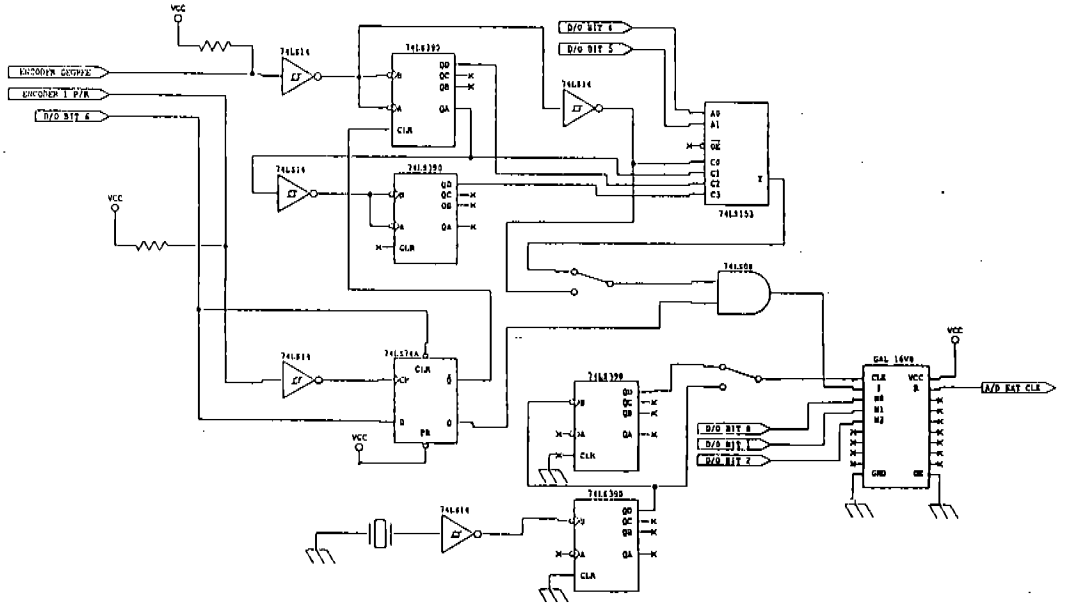

Fig.2 Circuit diagram of the CAS processing board

rval is 400kHz and this is very small time delay in the processing the engine data. For example, at 3000rpm this time delay is below 0.1 degree by the crank angle. Fig.3 is the timing chart of the signals. Equation 1 is the calculation of maximum crank angle speed per one channel measuring the multi signals in this system.

Maximum

$$= \frac{\text{Frequency of Oscillator(4MHz)}}{2 \times \text{Divider(5)} \times (\text{no. of channel} + 1)} \qquad (1)$$

In the acquisition mode the amount of data size is dependent on the RAM memory size of used PC and the maximum throughput rate is approximate 400kHz for multi channels. In the continuous acquisition mode the amount of data size is dependent memory size and the maximum throughput rate is approximate 100kHz.[4]

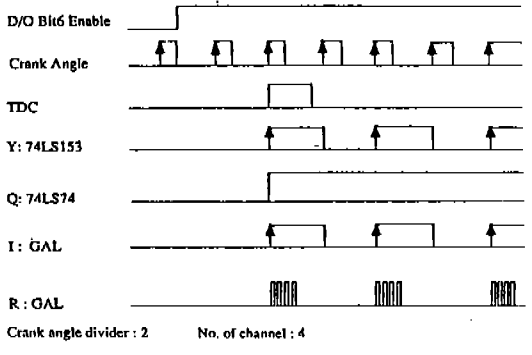

Fig.3 Timing chart of the signals

3. Software

The software in this system is composed of the C-language. This program has three modules ; display module, signal processing module, and data processing module.[1],[5],[6] So it is easy to alter the program for the specific user.

The specification of the program is as follows ;

- Graphics mode : 800×600,256 colors
- User interface, full mouse support, every function operated in the monitor by the mouse.
- Auto TDC correction by the 0.1degree
- Screen hard copy, list output, data output for other package.
- Cursor support

In this system nine kinds of diagrams are offered. They are P-θ, P-V, logP-logV, poly-θ, dQ/dθ, X-θ, dP/dθ-θ, IMEP-cycle and P_{max}-cycle. The functions can be extended easily by altering the data processing module. The values of cycle analysis are IMEP, PMEP, P_{max}, $\theta(P_{max})$, $\theta(dP/d\theta)_{max}$ and $(dP/d\theta)_{max}$. The main equations for the diagrams are as follows. In these equations TDC is 0 degree and crank angle indicates from −360 degree to 360 degree per one cycle.

$$V(\theta)=\frac{\frac{\pi}{4}B^2\cdot(2a)}{r-1}+\frac{\pi}{4}B^2\left[(a+l)\cos\left(\sin^{-1}\left(\frac{e}{a+l}\right)\right)-\left(a\cos\theta+\sqrt{l^2-(e+a\sin\theta)^2}\right)\right] \quad (2)$$

$$P_{mi}=\frac{\sum_{i=360}^{360}P(\theta_i)\left[V(\theta_{i+1})-V(\theta_i)\right]}{\frac{\pi}{4}B^2\cdot(2a)} \quad (3)$$

$$\left[\frac{dP(\theta)}{d\theta}\right]_i=\frac{1}{12}\left[P(\theta_{i-2})-8P(\theta_{i-1})+8P(\theta_{i+1})-P(\theta_{i+2})\right] \quad (4)$$

$$Poly(\theta)=\frac{-\log\left[\frac{P(\theta_i)}{P(\theta_{i+1})}\right]}{\log\left[\frac{V(\theta_i)}{V(\theta_{i+1})}\right]} \quad (5)$$

$$\left[\frac{dQ(\theta)}{d\theta}\right]_i=\frac{1}{k-1}\left[V(\theta_i)\cdot\left(\frac{dP(\theta)}{d\theta}\right)+k\cdot P(\theta_i)\left(\frac{dV(\theta)}{d\theta}\right)_i\right] \quad (6)$$

$$X(\theta)_i=\frac{\sum_{i=-50}^{i}\left(\frac{dQ(\theta)}{d\theta}\right)_i\Delta\theta}{\sum_{i=-50}^{i=50}\left(\frac{dQ(\theta)}{d\theta}\right)_i\Delta\theta} \quad (7)$$

TDC correction is executed by the motoring data. In this system 20 motoring cycles are used for seeking peak pressure and it is corrected by the logP-logV diagram.[1),7)] Fig.4 is the monitor display of this system. The function operates as clicking the corresponding icons by the mouse. There is no need to handle the hardware during the experiment. In the left side window each diagram was displayed. In the right side there are icons for selecting each diagram, cursor, each cycle, hardware information, engine specification and data transform. And in this system printing the diagrams and text data are included.

4. Experiment Results

In the single cylinder research engine this system was used. Table 2 is the specification of this

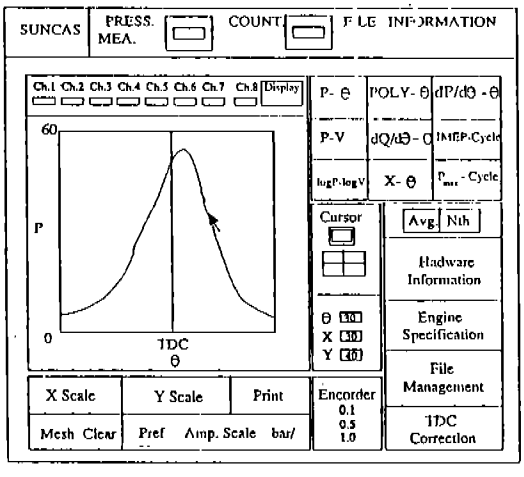

Fig.4 Monitor display of PC based combustion analyzer

engine and Table 3 is the experimental conditions. In this experiment flush mounted type pressure transducer adaptor was used. The pressure transducer is Kistler 6061 and charge amplifier is Kistler 5011. From Fig.5 to Fig.10 the diagrams are showed by this system. The most significant difference between gasoline fueled and hydrogen fueled is rapid combustion of hydrogen. So the combustion process of hydrogen looks like the ideal constant volume combustion in the spark ignition engine.

Table 2 Specification of single cylinder research engine

Model name	TRE-2G
Fuel	Gasoline
Bore * Stroke(l)	85 * 86
Displacement(l)	0.488
Compression ratio	8.5 : 1
Maximum output(hp/rpm)	16/4000
Maximum torque(kg · m/rpm)	3.4/2200
Lubrication system	Dry sump
Cooling system	Water-cooled

Table 3 Experimental test matrix

Ignition timing	MBT
Engine speed	1500rpm
Equivalent ratio	1.0(stoichiometric)
Engine load	Wide open throttle

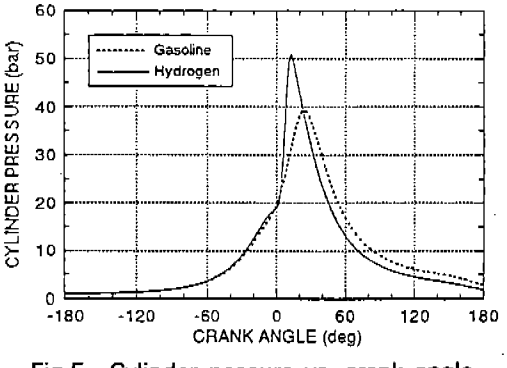

Fig.5 Cylinder pessure vs. crank angle

Fig.5 is the pressure vs. crank angle diagram. Fig.6 is the mass fraction burned diagram and the combustion duration of hydrogen is shorter. Fig.7 is the heat release diagram and Fig.8 is the

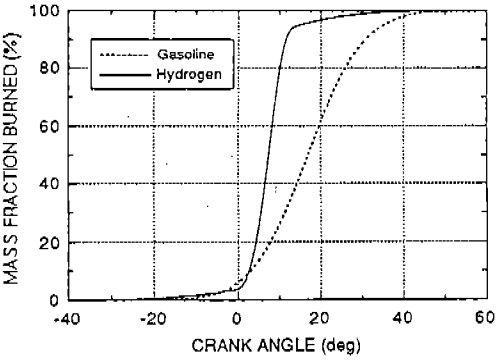

Fig.6 Mass fraction burned curves determined from measured cylinder pressure data

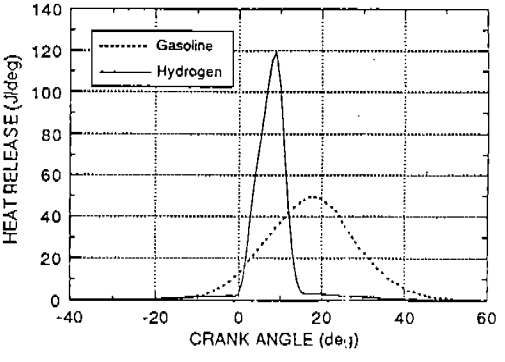

Fig.7 Heat release rate curves determined from measured cylinder pressure data

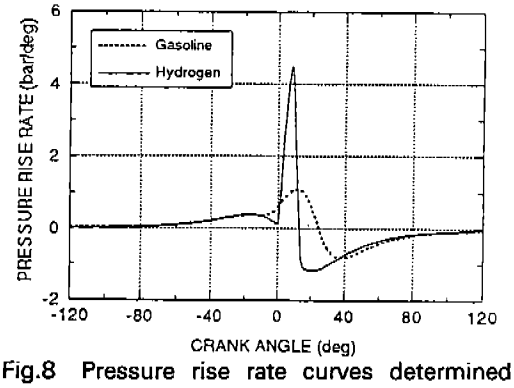

Fig.8 Pressure rise rate curves determined from measured cylinder pressure data

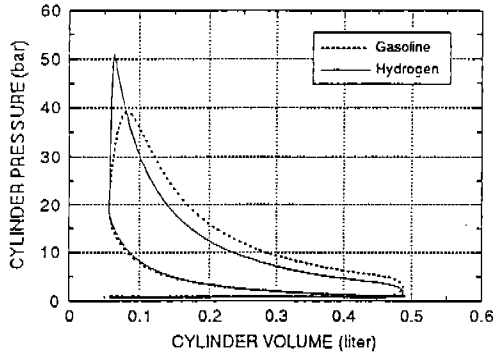

Fig.9 Pressure vs. volume curves determined from measured cylinder pressure data

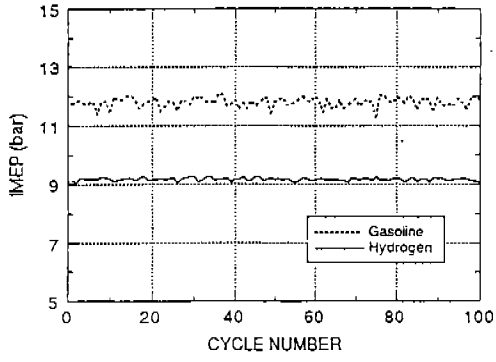

Fig.10 IMEP vs. cycle curves determined from measured cylinder pressure data

pressure rise rate diagram. Fig.9 is the pressure vs. volume diagram and the cyclic variation of hydrogen is smaller than that of gasoline in the Fig.10.

5. Conclusions

(1) It is convenient to operate this system compared with conventional combustion analyzer, for there is no need to handle the hardware and every function is supported in the icon of the monitor by clicking the mouse.

(2) The software was composed of three modules and it is easy to alter the program if user wants.

(3) This system is operated in DOS environment so it can be installed easily in the PC.

(4) The memory size of this system is more flexible than the commercial one. In this system the memory size is just dependent on the size of hard disk when the speed of data processing is below 100kHz and dependent on the size of ram above 100 kHz.

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