International Symposium COMODIA 90: 337-340(1990)

Investigation on Compression Temperature Field in a Diesel Combustion Chamber

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ABSTRACT

In a real diesel engine, the measurements, and studies have been done about compression temperature field at various crankangles in the combustion chamber. The feasibility about measurementy of compression temperature field in real engine by double exposure holographic interferometry method is theoretically confirmed. Compression temperature field and its variation have been analysed and studied. Hence, a new optical method about measuring temperature in the chamber have been provided.

REVIEW

Classical methods of measuring unburned gas temperature in cylinder include followings:

1. Intrusive probes, e.g. thermocouple (I) and resistance wire (2);
2. Optical method (3,4,5), such as infrared or ultraviolet spectroscopy;
3. Sonic velocity technique (6).

Intrusive probes techniques only measure one point at one time. other methods only measure average temperature of a line which the light or sound go through.

In this paper, the authors put forward a new method and its theory about measuring the compression temperature field of the combustion chamber in a real diesel engine by double exposure holographic interferometry method and get the temperature distribution in the chamber during compression.

THEORY

Based on double exposure holographic interferometry, the compression temperature field is quantitatively measured. A set-up of off-set axial holography for experiment is shown as Fig 1.

Firstly, the holographic plate is exposed at an arbitrary crankangle of compression when the engine is running. Hence, the change of temperature field causing the change of index of refraction is recorded on holographic plate.

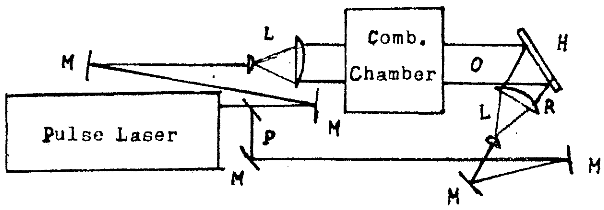

Fig.1 Off-set axial holography for temperature measurement
M-Mirror; L-Collimaling lens;
P-Beam splitter; H-Holographic plate;
O-Object beam; R-Reference beam

After reconstruction of the holograph, the intensity of light

$$\phi \propto \cos(KL(n(x,y)-I)) \qquad (1)$$

where $K=2\pi/\lambda_0$

λ_0 --- wave length of pulse laser
L --- width of combustion chamber
n --- refraction index

when

$$\frac{2\pi}{\lambda_0}L[m(x,y)-1]=\begin{cases} 2i\pi(i=1,2,\ldots) & \text{----britght fringe} \\ (2i+1)\pi(i=1,2,\ldots) & \text{----dark fringe} \end{cases} \qquad (2)$$

If there are two contiguous fringes i and i+1 which is the nearer to the combustion chamber surface and the corresponding index of refraction is n_i and n_{i+1} , then there exists

$$n_{i+1} - n_i = \frac{\lambda_0}{L} \qquad (3)$$

Because there is a relation (7) between P,T and n, i, e.

$$d=(n-1)TP_0/T_0P \qquad (4)$$

where d is a constant, thus, from the distribution of n(x,y). we can get the distribution of temperature field.

$$\frac{1}{T_{i+1}} - \frac{1}{T_i} = \frac{1}{d}\,\frac{P_0}{PT_0}\,\frac{\lambda_0}{L} \qquad (5)$$

Obviously, formula (5) indicate that the unburned gas temperature is higher than combustion chamber surface, otherwise

$$\frac{1}{T_i} - \frac{1}{T_{i+1}} = \frac{1}{d}\,\frac{P_0}{PT_0}\,\frac{\lambda_0}{L} \qquad (6)$$

Because the temperature gradient near combustion chamber surface is so steep, the fringes crowd together tightly and can not be indentified. Hence, from the surface temperature we can not calculate fringes temperature. However, at the center of combustion chamber there is a no-fringe zone which can be considered as an adiabatic compression zone. In this center zone the adiabatic compression temperature is

$$T=T_1(P_1/P)^{(1-k)/k} \qquad (7)$$

where T_1--- Temperature at the beginning of compression
P_1--- Pressure at the beginning of compression
K --- Index of adiabatic compression, for air take 1.4

From interference photograph, we can get the temperature distribution field in the chamber at arbitrary crankangle by formula (5)-(7).

APPARATUS

The scheme of experimental installation is shown in Fif.2.

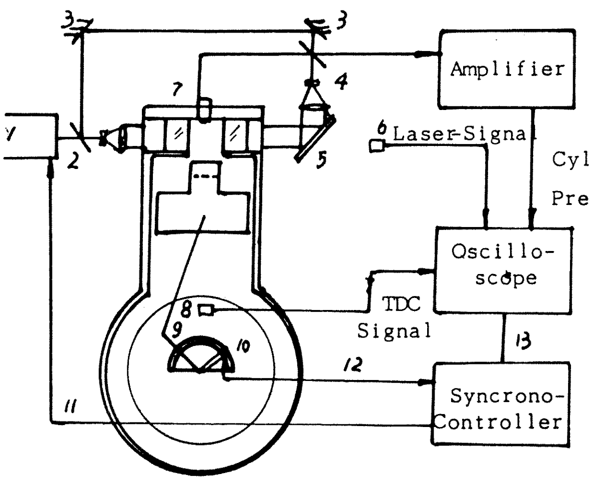

Fig.2 Scheme of experimental installation
1. Laser 2. Beam splitter 3. Reflection merror 4. Beam collimeter 5. Holographic film 6. Photo-electronic tranducer 7. Cylinder pressure sensor 8. TDC tranducer 9. Phase ajustment plate 10. Crankangle pick-up 11. Laser signal trigger 12. Crankangle signal 13.Syncrono-Controller

The engine is motored by a 45kw dynamometer. The specification of engine and laser are listed in table 1.

Table 1. Specification of engine and laser

Engine	Type	E150
	Stroke	2
	Revolution	750 rpm
	Cylinder bore	150 mm
	Chamber type	ω
Laser	Type	ruby pulse laser XJ-1
	Pulse energy	250 mJ
	Pulse width	5 ns
	Wave length	694.3 nm
	Coherence length	1 m
	Q switch	dyestuff box

During experiment of measuring temperature, laser signal, cylinder pressure and TDC signal are recorded by oscilloscope, as shown in Fig3.

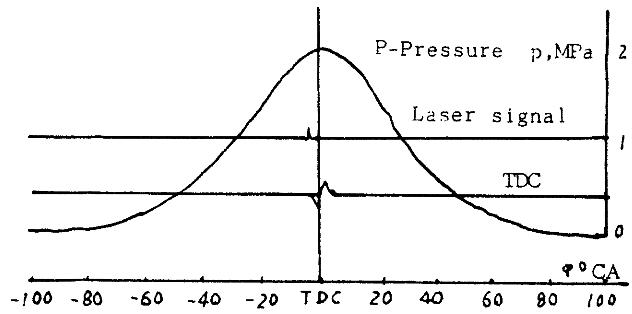

Fig.3 The record of measuring temperature experiment

RESULTS

Fig.4-Fig.7 are photographs of interference fringes which express istherms in the combustion chamber at rating speed. The piston crown surface temperature is about 63C, cylinder head 80C and maximum cylinder pressure 2 Mpa.

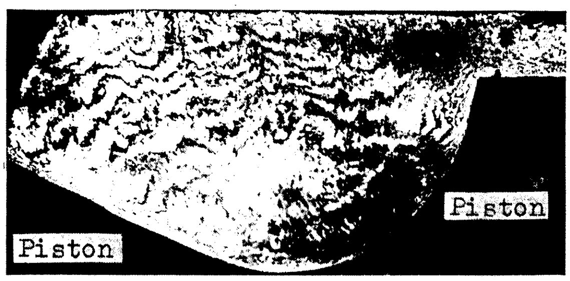

Fig.4 BTDC 10 CA interference fringe photograph

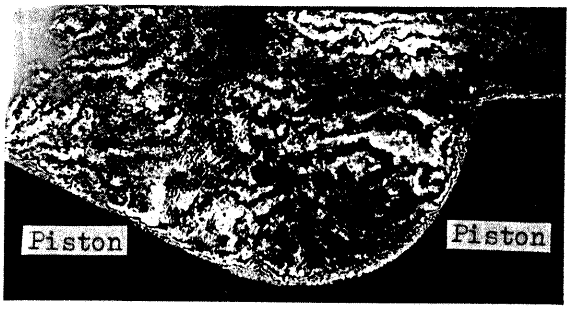

Fig.5 BTDC 15 CA interference fringe photograph

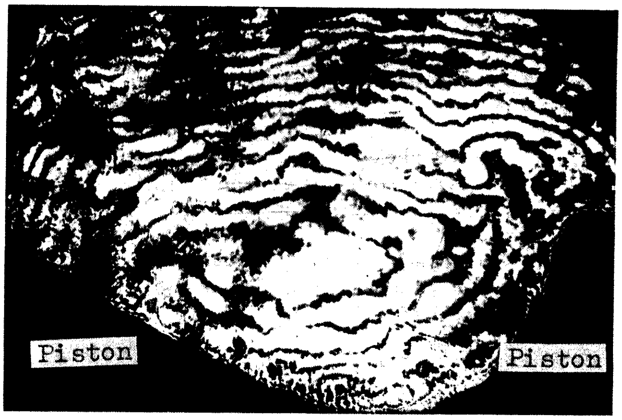

Fig.6 BTDC 25 CA interference fringe photograph

Fig.7 BTDC 30 CA interference fringe photograph

Fig.8-Fig.12 is the isotherm after the numerical graphic treatment by computer from the photographs.

From the results identified above, we can find that there is a no-fringe zone in the center

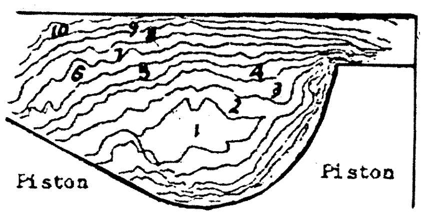

Fig.8 BTDC 10 CA isotherm in the chamber after treatment

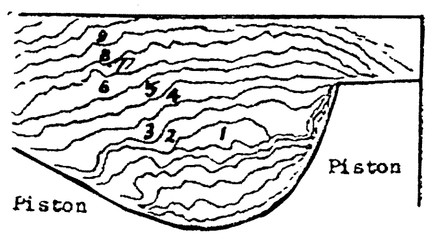

Fig.9 BTDC 15 CA isotherm in the chamber after treatment

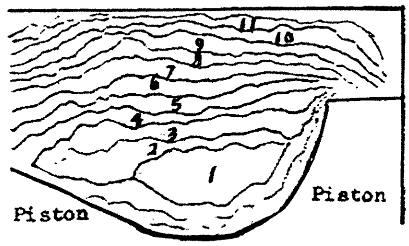

Fig.10 BTDC 20 CA isotherm in the chamber after treatment

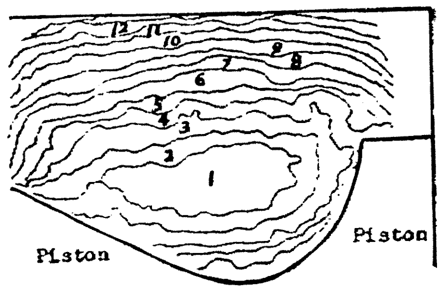

Fig.11 BTDC 25 CA isotherm in the chamber after treatment

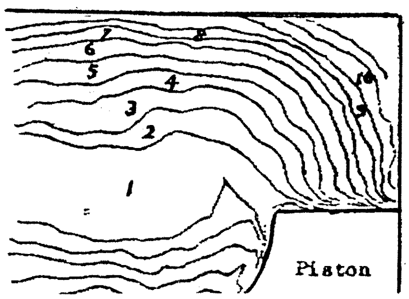

Fig.12 BTDC 30 CA isotherm in the chamber after treatment

of the combustion chamber which can be treated approximately as an adiabatic compression zone. The nearer the surface of the combustion chamber, the dinser the fringes. So the maximum temperature gradient is at the boundary surface of the combustion chamber where the heat transfer is controlled by the connvection of air. Near top dead center TDC, the isotherms appear in more irregular curves.

So it can be concluded that near the TDC the turbulence is mor intense.

Table.2 shows the temperature between two fringes for Fig.8-Fig.12 which are calculated by formuula (5)-(7). Fig.14 is T (temperature)

Table.2 Temperature between two fringes for Fig.8-Fig.12

°CA \ P, MPa \ T, K No.		1	2	3	4	5	6	7	8
BTDC10°	1.705	639.9	635.7	631.6	627.6	623.6	619.7	615.8	611.9
BTDC15°	1.470	612.9	608.5	604.1	599.8	595.6	591.4	587.3	583.2
BTDC20°	1.112	565.0	560.1	555.2	550.5	545.8	541.7	536.6	532.1
BTDC25°	0.909	532.7	527.3	522.1	516.9	511.9	506.9	502.0	497.3
BTDC30°	0.711	495.5	489.5	483.7	478.1	472.6	467.2	461.9	456.7
BTDC35°	0.549	459.1	452.5	446.1	439.9	433.9	428.0	422.3	416.7

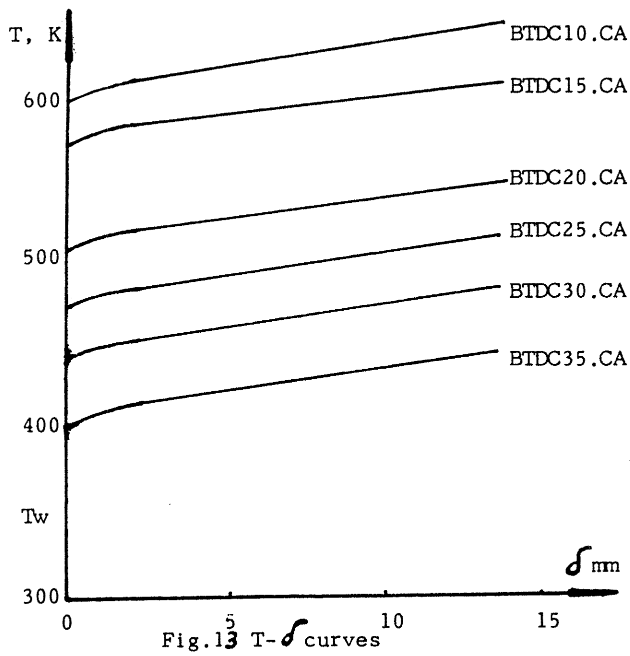

Fig.13 T-δ curves

- (distance from cylinder head) curves at different crankangles. We can find that maximum temperature gradient is at the boundary about 0.5mm near the surface of the combustion chamber. In the center of the chamber, the variation os temperature is mild.

CONCLUSION

1. The authors have clearly measured the temperature distribution at different crankangles by laser double exposure holographic interferometry technique in a motored diesel engine, and provide a new optical method for temperature field measurement during compression.

2. Experiment results show that the maximum temperature gradient is at the boundary surface of combustion chamber, and in the chamber the maximum temperature difference of the compressed air is about 40-60K at different crankangles.

3. In the center of combustion chamber, there is a temperature homogeneous zone which can be treated approximatelly as an adiabatic compression area.

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