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95 An Experimental Study on the Surface Temperature Measurement of a Marine Engine's Combustion Chamber

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In the recent development of internal combustion engine, considerable increase in speed and power has been accomplished. This achievement, however, brought up various problems due to the excessive temperature of engine parts, which becomes a crucial factor in engine durability. In the present paper, temperature measurement of a marine engine was investigated experimentally. The adapter is made to pull out a thermocouple through the safety valve hole of the engine. The thermocouple is welded on the surface of the cylinder cover to measure the average temperatures of the engine cylinder cover. Ceramic adhesive was used for preventing the affect of high temperature combustion gas. The cylinder cover temperatures of the engine were measured by means of surface welding method. As a result, average temperatures of the engine cylinder cover were successfully in the range of 85~335℃. In the present study, the surface welding method was confirmed from the temperature measurement of cylinder cover in an experimental engine, and can be applied to large-sized marine engine without damage.

Keywords: Measurement, Instruments / Surface Welding method, Average Surface Temperature, Marine Engine

1. Introduction

A diesel engine is one of the most efficacious thermal engines. For this reason, the engine is used widely as a power source for many kinds of vehicles, vessels, and motors, including industrial and private machines. Recently, development of the internal combustion engine, has brought about considerable increases in speed and power. These increases have led to various problems due to the extreme temperature increase of the engine which plays a crucial role in engine durability. This problem of thermal deformation greatly influences an engine's performance and increases engine vibration.

In order to get the highest efficiency from an engine, engines are run at as high a temperature as possible. This acts to increases the pressure and temperature of the combustion chamber. To solve the thermal problem to the engine parts, new materials or improved of cooling systems have been developed by engineers. The temperature measurement of an engine cylinder wall is a very important factor in the test of engine performance. However, the wall temperature of a combustion chamber is crucially important when we design an engine [1, 2]. Also, measuring temperature is the most important process in engine development [3].

A combustion chamber is an essential part of a diesel engine. The movement of mixed gas, flame diffusion and temperature distribution are important aspects of a combustion chamber. However, there have been many difficulties with temperature measurement. As a result, theoretical temperature measurement has been tried [4]. Measuring methods for engine surface temperature are the link method, contact-point method, telemeter method, electromagnetic induction method and wire take-out method [5, 6, 7].

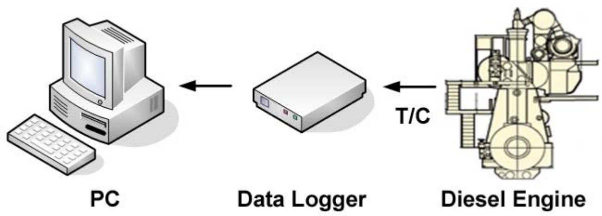

Fig. 1 Schematic Diagram of the Experimental Apparatus

In this study, the followings processes were measured. First, the temperature of the cylinder cover, cylinder liner and piston crown of a small experimental engine were measured. Second, the efficacy was assessed of the contact-point method used for the temperature measurement of cylinder cover. Third, the same experimental procedure was applied to the low-speed engine(K90MC) using the contact-point method, which can measure the temperature of the cylinder cover without damaging the engine. Fourth, develop the moment contact-point method was developed; it gives a signal from the piston crown to the data logger. As making the piston slide intermittently when the piston approaches the BDC(bottom dead center). Last, the piston crown's temperature was measured.

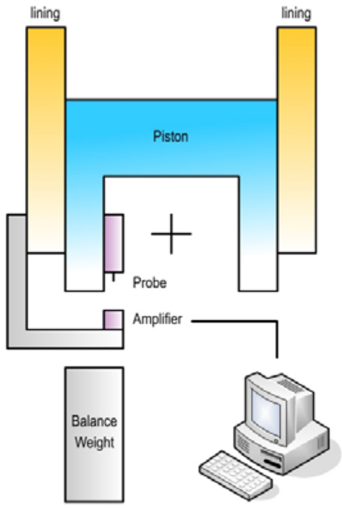

Fig. 2 Schematic Diagram of Temperature Measurement on Piston Crown

2. Experiment Device

Fig. 1 shows an outline of the experiment apparatus used to measure the engine temperature and Table 1 shows the engine specifications. The external material of the thermocouple used in this study is 304-E-MO-062 which is K-type(outer diameter: 3 ㎜, wire diameter: 0.559 ㎜) sheathed metal(Inconel 600). And the extension thermocouple is EXTT-K-24 which can with stand temperatures up to 200℃ and its exclusive wire is K-type. It was connected to an OM-5000 series using a low-noise connector(HGST-K-MF) and we used a 40 channel OM-5000 series data logger(the measure range: -2 ~ +2 volts) to receive data. The temperature was measured by inserting the K-type thermocouple into the combustion chamber using the safety valve hole(diameter 12㎜) of the low-speed engine(K90MC). Points of measurement were three distinct points in each cylinder, which can be seen in Table 2 The end of the thermocouple was fixed to the safety valve hole through spot welding. To measure the temperature of the cylinder cover, we set the contact points of the thermocouple on each measuring point and the K-type wires were connected to the data-logger through the safety valve.

While the engine was operated, we prevented the high temperature and pressure gas in the combustion chamber from leaking. To do so, we designed the integrated thermocouple and the adapter, then inserted three thermocouples into the adapter center hole and, lastly, we welded it with the adapter. The material of the adapter is SUS316, its shape is not changed by high temperatures and its permission pressure is 150bar. To measure the temperature of the piston, we used a DEWETRON device(300㎐ amplifier) and a momentary temperature measurement method. This method measured the temperature by making the piston slide intermittently when the piston approached the bottom dead center(BDC). Also, to prevent the exhaust gas from affecting the contact-point of the thermocouple directly, we used a sheet-plate(0.3㎜, SUS304) to shield the contact-point. The sheet-plate from affecting the temperature measurement value through a simulation experiment and, after that, the temperature was corrected. The thermocouple fixed to the cylinder cover by spot welding it to the sheet-plate. Spotted Welding, traces were minimized by sand papering the welded area. In the case of the cylinder linear, two temperature points were measured on the camshaft and the exhaust side by using the measurement-hole of the cylinder linear

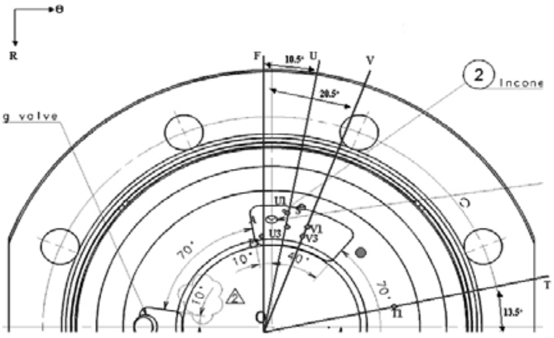

Fig. 3 Measuring Points of K90MC Engine Cylinder Cover

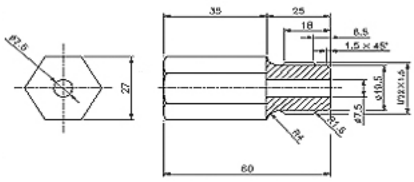

Fig. 4 Detail Configuration of K90MC Engine Adapter

3. Experiment Method

In the low speed engine, when the engine load reached levels of 25%, 50%, 75% and 100%, the temperature of the cylinder cover and the cylinder liner were measured twice at each level. The position of the thermocouple was defined by the R-axis and θ-axis. Dimension should be described in Table 2 The thermocouple contact position of the cylinder liner is 9㎜ inward from the surface of the cylinder liner.

The measurement-hole is 255㎜ above the top of the linear. The measurement was carried out while the engine was running. In addition to, the temperature was measured for 3~5 hours at each engine load. In the case of the piston crown, when the piston approached the BDC(bottom dead center), the temperature was measured and the temperature data passed through the amplifier and the A/D board while the contact-plate was in contact with the probe. A measurement-hole 3㎜ in diameter was bored through the top of the piston crown and connected the thermocouple by the silver-lead brazing method. The thermocouple was drawn out into the piston and then was fixed by a stopper and a high temperature adhesive. After that, the thermocouple was connected to the probe is end. The measurement position was P1: 27㎜ and P2: 57㎜. Carrying out this experiment, the probe was fixed to the under side of the piston and caused the probe to move at intervals of 8㎜. The probe was specially designed and assembled to prevent drive shaft interference. And the probe was assembled to accurately make contact with the BDC.

4. Experiment Results

Table 4 and Table 5 show the average surface temperatures according to each load of the low speed engine(K90MC). Temperature measurement was carried out twice at each engine load. Each measurement point was F1, U1, V1, U3, V3 and T1. F1, U1 and V1 were installed on cylinder cover 7 and U3, V3 and T1 was installed on the cylinder cover 8. P7 and P8 were installed at the measurement-hole of the camshaft and exhaust side in cylinder 6. P9 and P10 were installed at the measurement-hole of the camshaft and exhaust side in cylinder 7. To protect the contact point from

Table 1 Specification of Test Engine

Items	Specification
Engine Type	4 Cycle, Direct Injection Diesel Engine
Cylinder No.	6
Bore×Stroke(㎜)	200 × 240
Output at MCR(bhp)	210
rpm	900

Table 2 Measuring Location of the Cylinder Cover and Cylinder Liner(K90MC)

Point	R-axis	θ-axis	Cylinder No.
F1	+54	0	7 Cylinder
U1	-46.4	+35.7	
V1	-18	+66.2	
U3	+10.2	+32.1	8 Cylinder
V3	+24.3	+60.8	
T1	-53.4	+527.4	

the effects of the high temperature exhaust gas inside the combustion chamber, a sheet-plate was used. The temperature increased as the load of the engine increased and the temperature data showed stability because the contact-point was protected by the sheet-plate. Table 6 shows a comparison of the temperature measured by the company and the temperature measured by our experiment.

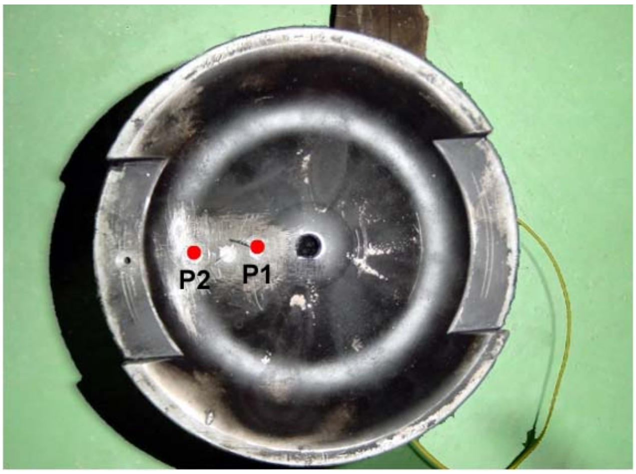

Fig. 5 Measuring Points of the Piston Crown

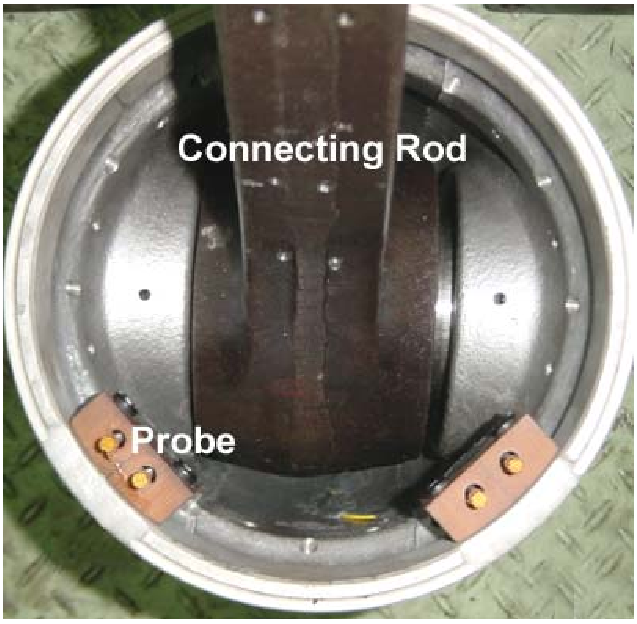

Fig. 6 Location of Thermocouple Probe on the Piston

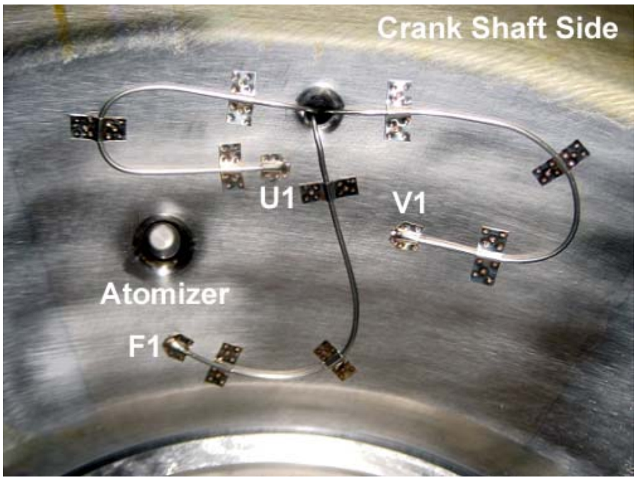

Fig. 7 Measuring Points of K90MC Engine Cylinder

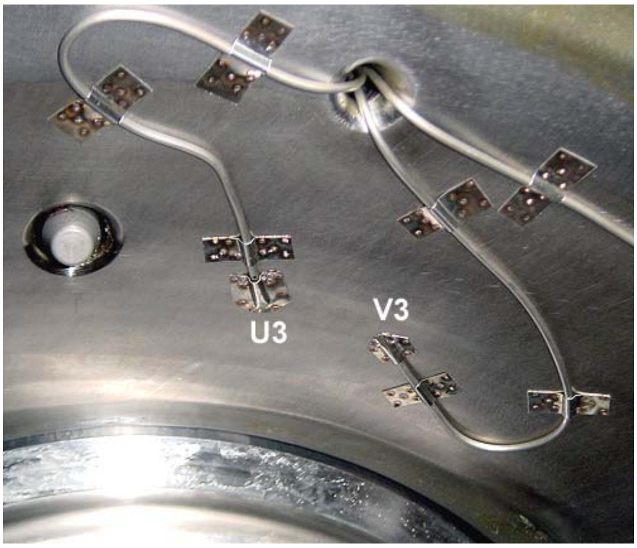

Fig. 8 Measuring Points of K90MC Engine Cylinder

Table 3 The Average Surface Temperature of Piston Crown

Load	0%	75%	100%
Average Temperature, P2	38℃	190℃	201℃

Table 4 The Average Surface Temperature of K90MC Engine (Running)

Load (%)	Cover (No.7)			Cover (No.8)			Liner (No.7)			
	U1	V1	F3	U3	V3	T1	P7	P8	P9	P10
50	263	254	281	258	246	294	111	109	111	110
75	292	273	294	278	268	349	127	126	130	127
90	318	303	309	288	285	380	134	137	135	136
100	333	315	318	291	297	378	152	164	138	137

Table 5 The Average Surface Temperature of K90MC Engine (Confirm)

Load (%)	Cover (No.7)			Cover (No.8)			Liner (No.7)			
	U1	V1	F3	U3	V3	T1	P7	P8	P9	P10
50	264	259	280	247	253	298	110	108	111	110
75	287	275	298	261	278	329	126	122	120	125
90	310	296	307	279	288	349	134	136	129	137
100	330	314	319	307	297	366	139	146	138	136

Table 6 A Comparative Table of the Average Surface Temperature (℃)

	U1	V1	F1	U3	V3	T1	A7-7	E7-7	A7-8	E7-8
Company	350	321	324	314	302	358	148	146	148	146
Experiment Value	330	314	319	307	297	366	146	153	145	143
Difference Value	20	7	5	7	5	-8	2	-7	3	3
Difference Value(%)	5.7	2.2	1.5	2.2	1.7	-2.2	1.4	-4.8	2.0	2.1

Compared with the temperature values measured by the company, the temperature values of our experiment were a little bit lower overall and the error range was stable within 10℃. The Fig. 11 shows that the temperature data graph of the cylinder cover was similar to the temperature measurement value recorded by the company. Table 3 shows the temperature of the piston crown. The temperature of the piston crown was measured by the momentary contact temperature measurement method. There was much noise during the experiment because the contact time (4~5ms) was very short and the generator was connected directly with the experiment engine. As such, the temperature measurement experiment had to be finished through trial and error.

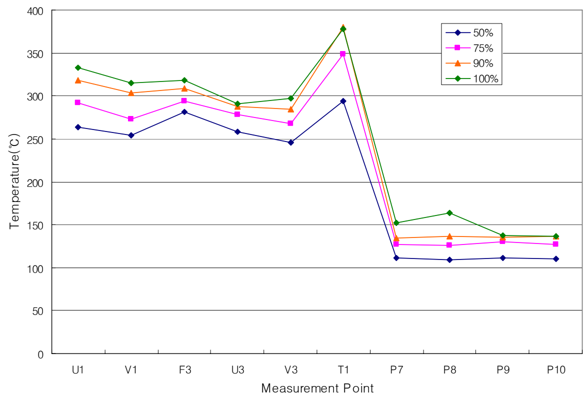

Fig 9 History of the Average Surface Temperature K90MC Engine Load (Running)

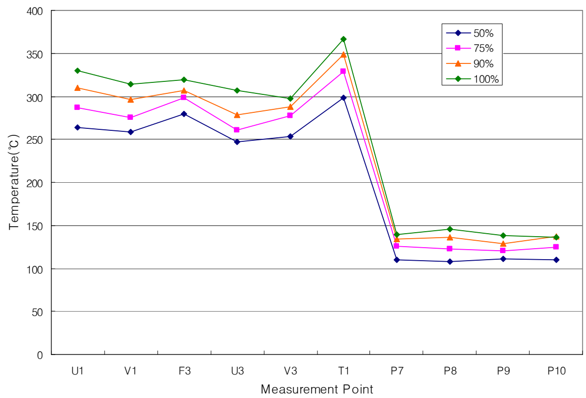

Fig. 10 History of the Average Surface Temperature K90MC Engine Load (Confirm)

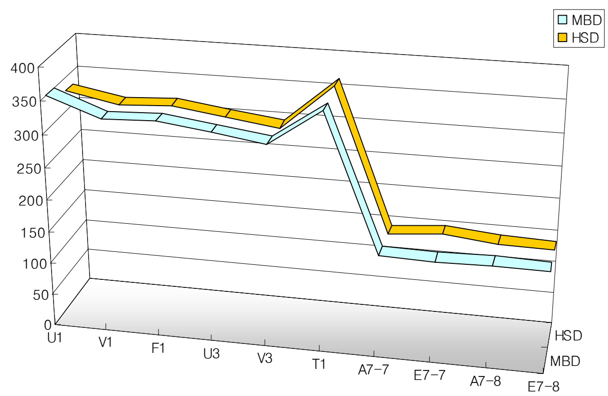

Fig. 11 Comparative Diagram of the Average Surface Temperature

5. Conclusion

This study confirmed it is possible to measure the surface temperature of the combustion chamber without causing engine damage through experimentation with a marine diesel engine.

5.1 An adapter was made so that the surface temperature of the cylinder cover could be measured at each engine load without causing engine damage. High temperature and pressure exhaust gas was prevented from leaking by integrating the thermocouple and the adapter. Spot-welding was used to fix the thermocouple that was connected through the combustion chamber to the cylinder cover. Through this spot welding, the at fixed thermocouple's stability could be confirmed. Also, to protect the contact point of the thermocouple fixed to the surface of the cylinder cover, a sheet-plate was used. By doing so, high temperature exhaust gas was prevented from affecting it directly.

5.2 When measuring the temperature of the piston crown, we used the moment contact temperature measurement method was used. As the contact time (4~5ms) was very short and the generator was connected with the experimental engine, much noise was produced during the experiment. Therefore, many trials and errors were endured. Through this process, a surface temperature measurement method was developed for a piston that runs at high speeds.

5.3 The temperature was measured at the point with the highest relative temperature centering around the Inconel welding. Compared with the temperature that was measured by the company, the temperature was a little lower. An error range was stable within 2%. The temperature data trend of the cylinder was almost same as the company measurement value.

5.4 There was little temperature difference evinced by the application of a sheet-plate. The slight difference between the experiment measurement value and the company measurement value is thought to have been due to the cooling condition, PJT, the drive condition, etc. As a result of this experiment, we could develop the momentary contact temperature measurement method using a safety valve.

6. Acknowledgement

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