講演番号	086

Study of Achievement Both Noise and Vibration and Thermal Efficiency by Using the Excitation Force of a Piston System

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KEY WORDS: heat engine, spark ignition engine, vibration/noise, performance/fuel economy/efficiency [A1]

Rapid combustion is being attempted as a means of improving thermal efficiency of internal combustion engines, but rapid combustion deteriorates the vehicle interior noise level, which may become a problem in terms of product competitiveness. Therefore, technology that achieves both improved thermal efficiency and suppressed noise and vibration is required. This study focused on the piston system as a phenomenon of noise and vibration caused by combustion. As shown in Figure 1, noise and vibration in the piston system is generated when the piston moves due to forces such as combustion, and this movement causes the piston to excite the cylinder liner. The force that moves the piston through combustion is defined as the combustion excitation force, while the force that excites the cylinder liner through the piston movement is defined as the structural excitation force. This study investigates the relationship between thermal efficiency and engine vibration by varying the combustion excitation force that affect piston movement, and reports the results of a study of combustion conditions that achieve both these two factors.

As combustion excitation force indicators, combustion speed: the maximum second derivative of heat release $(d^2Q/d\theta^2)_{max}$ and the combustion phase: CA50 were extracted. As shown in Figure 2, combustion data ABC which represents different combustion speed at the same combustion phase and combustion data CDE which represents the same combustion speed but at different combustion phases were obtained, and the relationship between thermal efficiency and vibration was investigated for each engine speed. Figure 3 shows the indicated thermal efficiency and peak-to-peak cylinder liner vibration values for combustion cycles A through E. Under all engine speed conditions, the indicated thermal efficiency is similar for combustion ABC, where the combustion phase is advanced, but decreases when the combustion phase is retarded. With regard to liner vibration, at high engine speed of 4000 and 3200 rpm, it decreases when the combustion speed decrease in the ABC combustion. On the other hand, at low engine speed of 2,400 and 1,600 rpm, even when the combustion speed decreases in the ABC combustion, the change in vibration is small. Figure 4 shows the liner vibration for the combustion speed in the ABC combustion at each engine speed. Thus, as the engine speed decreases, the sensitivity of the vibrations to the combustion speed decreases. Based on the above, at high engine speed of 4,000 and 3,200 rpm, it is possible to suppress vibration while improving thermal efficiency by advancing the combustion phase CA50 and decreasing the combustion speed $(d^2Q/d\theta^2)_{max}$. At low engine speeds of 2,400 and 1,600 rpm, since the sensitivity of vibrations to the combustion speed $(d^2Q/d\theta^2)_{max}$ is low, advancing the combustion phase CA50 makes it possible to suppress vibrations while improving thermal efficiency.

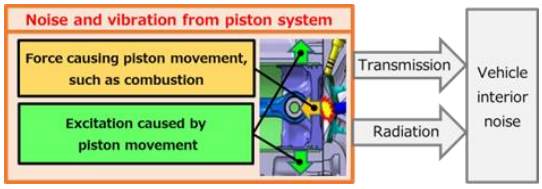

Fig.1 Schematic of Noise and Vibration from Piston System

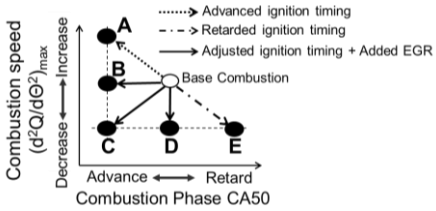

Fig.2 Image of combustion conditions for Investigating Vibration and Thermal Efficiency

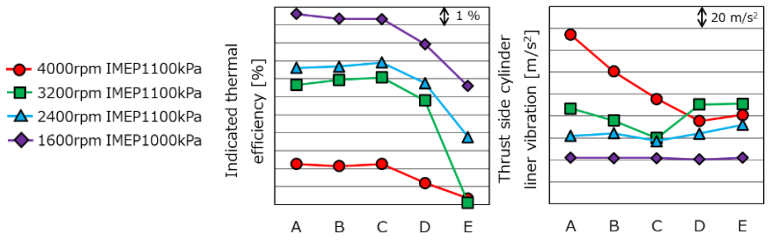

Fig.3 Indicated Thermal Efficiency and Liner Vibration for Combustion A–E at Each Engine Speed

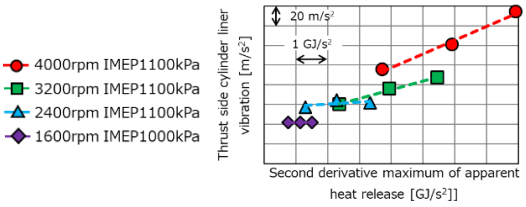

Fig.4 Relationship between Liner Vibration and Combustion Speed at Each Engine Speed