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Visualization of abnormal combustion during high speed and high load conditions in a turbocharged SI gasoline engine

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Due to the enhanced emissions control and the introduction of RDE regulations, purification of exhaust gas during enrichment conditions has become an issue for gasoline engines. In order to maintain the output during high-load operation and achieve stoichiometric operation without raising the exhaust temperature, technology to avoid abnormal combustion that does not rely on enrichment is essential.

However, it is known that abnormal combustion accompanied by extremely strong pressure oscillations (called high-speed knock) occurs sporadically during high-speed, high-load conditions, but there are few research reports on this. For this reason, it is currently difficult to develop effective technology to avoid abnormal combustion in the high-speed, high-load operating conditions. Therefore, it is necessary to clarify the mechanism of high-speed knock that occurs at high rotation speed and the difference from knock at low rotation.

The purpose of this study is to clarify the cause of high-speed knocking accompanied by extremely large pressure oscillations that sporadically occur in supercharged gasoline engines under high speed and high load operating conditions. In this study, abnormal combustion during high speed and high load operating conditions in a commercially available turbocharged SI engine was visualized using an endoscopic technique. Also, simultaneously measured in-cylinder pressure at different locations was thermodynamically analyzed. By measuring the combustion pressure at multiple points, the location of abnormal combustion, which causes strong pressure oscillations in the high-speed knock cycle, was determined.

The visualization results acquired synchronously with the in-cylinder combustion pressure measurement of the high-speed knock cycle shows that In the high-speed knock cycle, two abnormal combustions occurred, and it was clarified that the second abnormal combustion induced a strong pressure oscillation. The analysis results of frequency components of cylinder pressure in high-speed knock cycle is shown in Fig. 1. And in Fig. 2, the result of directly photograph and heat release rate analysis of the two abnormal combustions in high-speed knock cycle is shown.

In addition, a method of estimating the position of abnormal combustion, which is the cause of pressure oscillation, was proposed using pressure data measured at multiple points in the combustion chamber. Together with the results of high-speed direct photograph, we identified the location of the second abnormal combustion in the high-speed knock cycle. As the result shown in Fig. 3, it was found that the second abnormal combustion in the high-speed knock cycle was distributed near the clevis and near the exhaust valve in the combustion chamber.

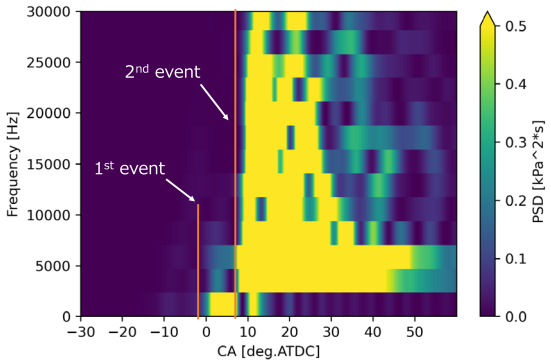

Fig.1 STFT result of high-speed knock cycle

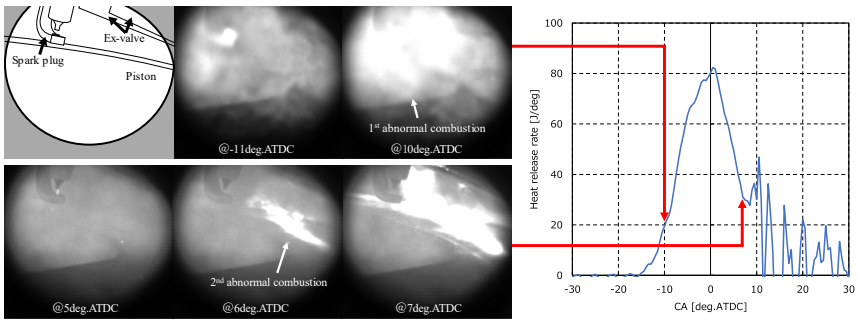

Fig.2 Directly photograph and heat release rate of the 2-times abnormal combustion in high-speed knock cycle

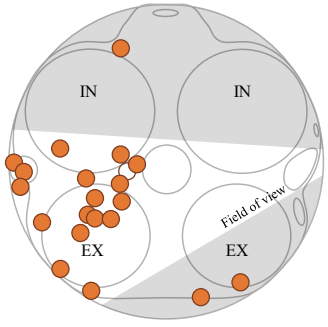

Fig.3 Position of 2nd abnormal combustion