# Analysis of High-frequency Combustion Noise Generation Mechanism in Pre-chamber Jet Combustion Gasoline Engine (First Report)

## - Analysis of Combustion Chamber Resonance Modes -

**Kenji Torii [1)] Noritaka Kimura [2)] Hiroki Kobayashi [2)] Hiroyuki Kobayashi [2)] Keizo Konishi [2)]**

*1) Energy System Design Development Supervisory Unit, Business Development Operations, Honda Motor Co.Ltd.*
*4630 Shimotanezawa, Haga-machi, Haga-gun, Tochigi, 321-3393 Japan (E-mail:kenji_torii@jp.honda)*
*2) Power-Unit & Energy Laboratory, Innovative Research Exellence, Honda R&D Co.Ltd.*

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A pre-chamber jet combustion engine, shown in Fig. 1, is being developed. In this engine, a pre-chamber with small nozzles is installed at the position where the spark plug is attached in the conventional spark-ignited combustion engine. A direct fuel injector that controls the air-fuel ratio is installed in the combustion main-chamber, and a spark plug is installed inside the pre-chamber to ignite air-fuel mixture with a stoichiometric air-fuel ratio. As a result, a strong torch-shaped flames (hereinafter referred to as jet flames) are radially ejected into the main chamber from the nozzles set in the lower part of the pre-chamber, realizing faster combustion than conventional. This makes it possible to minitigate knocking under a high compression ratio, so as to enhance engine thermal efficiency. However, rapid combustion by jet flames increases the high-frequency component of the in-cylinder pressure, which raises the issue of increased combustion noise.

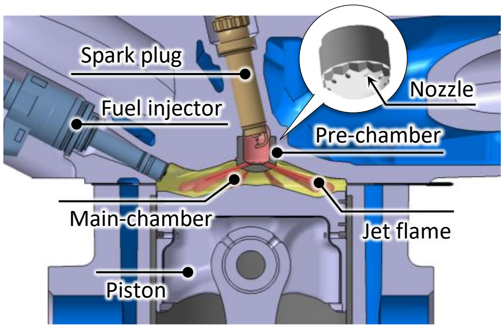


Fig. 1 Configuration of the pre-chamber jet combustion engine

Figure 2 shows the continuous wavelet transform scalogram of the in-cylinder pressure of the main chamber of the prototype engine. Looking at this graph, it can be seen that the pressure vibration level in the high frequency band of 6-9 kHz is high. Moreover, subsequent tests were conducted and it was found that this pressure vibration was the cause of the increased combustion noise in the same band. This type of combustion noise is often an issue in the development of diesel engines, and it is known that it is caused by combustion chamber resonances(4-6). However, in the case of gasoline engines, it has not been a serious issue so far, and its effective countermeasures have not been established.

Therefore, the resonance modes of the combustion chamber of this engine were analyzed through calculations using finite element models and experimental modal analyses. As a result, it was clarified that changes in the resonance frequencies of the combustion chamber occurring in conjunction with changes in its volume affect the characteristics of the in-cylinder pressure. As shown in Fig. 3, there are two combustion chamber resonance modes in the 6-9 kHz band with different node orientations. Near the top dead center of the piston, there is a difference of 1 kHz or more between the resonance frequencies of the two modes. This is because the shape of the combustion chamber is not a right circular cylinder. The upper part of it is pent roof shaped. As the piston descends, the two resonance frequencies decrease and approach each other, eventually asymptotically approaching the resonance frequency of the right circular cylinder. As a result, the bandwidth of the in-cylinder pressure vibration in the 6-9 kHz band during actual operation shown in Fig. 2 is wide near the top dead center of the piston and narrows as the crank angle advances.

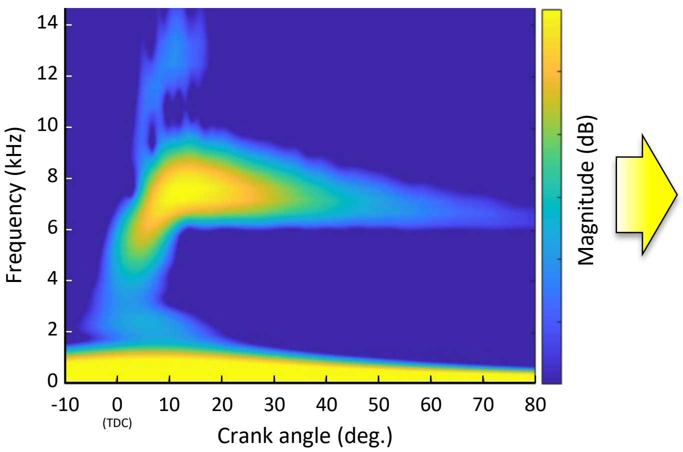


Fig. 2 Continuous wavelet transform scalogram of in-cylinder pressure of the pre-chamber combustion engine

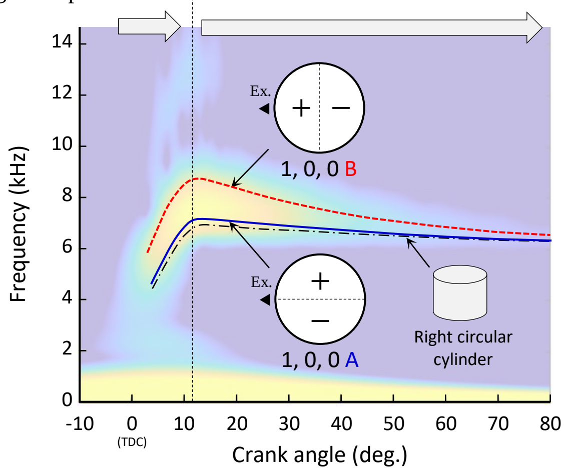


Fig. 3 Changes in in-cylinder pressure vibration and changes in main combustion chamber resonance frequencies