

Development of Pass-by Noise Analysis Technology with Utilization of Engine Control Data

Jun KITAHARA*

Jason RAY**

Mark PAFUMI**

ABSTRACT

The purpose of this paper is to introduce the new pass-by noise analysis technology with utilization of engine control data. This newly constructed measurement system obtains comprehensive engine control data while measuring vehicle pass-by noise levels with real-time data analysis capability. The measurement system combines two different data acquisition systems into one. The first system converts digital values obtained from an engine control unit into an analog signal output, while the second system obtains multiple channel analog signals. By performing pass-by noise testing with this system, the relationship between environment induced fluctuating engine control parameters, such as charging efficiency and ignition timing, and the effect on noise levels is determined. Furthermore, by normalizing obtained data to standard environmental conditions, vehicle noise levels and the amount of change in noise levels resulting from specification changes are accurately evaluated.

1. Introduction

Pass-by noise regulations place legal limits on the exterior noises, which may be emitted by an automobile. These are composed of the 'Regulation on exhaust proximity noise', which limit noise when the automobile is stationary, the 'Regulation on constant-speed pass-by noise', applying when the automobile is moving at a steady speed, the 'Regulation on acceleration pass-by noise', applying when the automobile is accelerating, and others. The testing methods for all these standards are specified. Of these, quite strict conditions are posed on permissible noise during acceleration, when the automobile is emitting a large amount of acoustic energy.

An example is given in Fig. 1, which shows the testing method specified in Japan for determining acceleration noise. The test vehicle enters the noise measurement area at a steady speed of 50 kph, accelerates at full throttle from Begin Acceleration Line A-A' to the End Acceleration Line B-B', and coasts thereafter. The sound pressure level during acceleration is measured by a microphone placed 7.5 m from the centerline of the car's path. The car is assessed by the maximum level recorded.

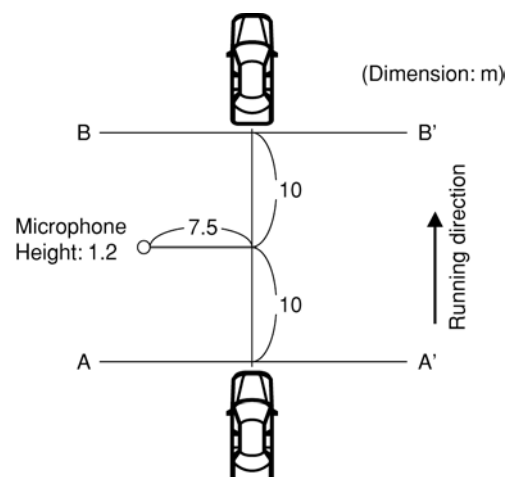


Fig. 1 Japan pass-by noise regulation method

* Tochigi R&D Center

** Honda R&D Americas, Inc.

Since the pass-by noise testing must be conducted outside throughout the year, it is greatly influenced by varying environmental conditions. Sound pressure levels recorded from the same vehicle will fluctuate with different environmental conditions. For example, changes in acceleration will result from an increase or decrease in intake charging efficiency, which has direct impact to ignition timing as commanded by the ECU (Electronic Control Unit). Therefore, in order to correctly assess the sound pressure level emitted by the test vehicle, it is essential to specify the parameters affecting these fluctuations and to obtain a quantitative assessment of their influences on the sound pressure level.

In the present study, a new pass-by measurement system was constructed to simultaneously measure and analyze all fluctuating parameters: sound pressure level, environmental conditions and ECU data. This system was successful in identifying relations between these variables, and is presented below.

2. New System for Measuring Pass-by Noise

The ECU continuously performs fine optimization of the engine in response to the vehicle driving conditions. Therefore, monitoring of the engine control data is critical for accurate assessment of pass-by sound pressure level. Fundamental engine performance data is obtained from the ECU using the ECU Monitor Card System (EMCS). This information is processed using a D/A convertor and streamed to a second computer, which combines all measured noise, weather and ECU information; MBBM PAK system. The overall configuration of the system is shown in Fig. 2. The signals output by the ECU including ignition timing and intake air temperature are digitized into hexadecimal format. It was necessary to convert the signals from the ECU to analog in order to synchronize them with the sound pressure level measurements, so a digital/analog convertor was incorporated into the EMCS.

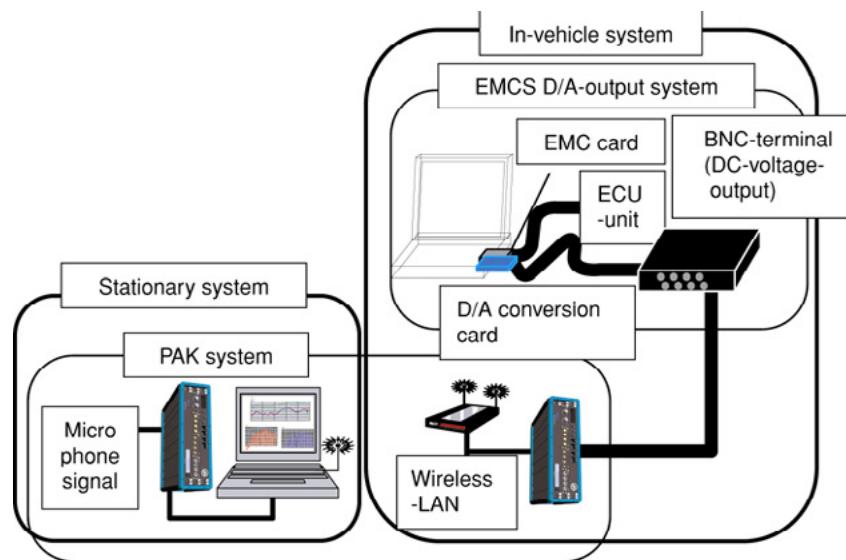


Fig. 2 System configuration

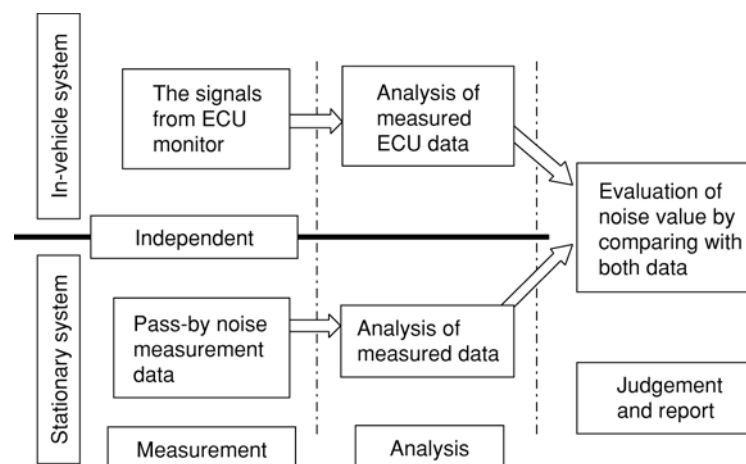


Fig. 3 Old system for analysis: Flow chart of ECU data and pass-by noise data

The conventional system was as shown in Fig. 3; the onboard engine control data monitoring system and stationary noise monitoring system were completely independent, making it very difficult to synchronize the information for analysis. The new system, shown in Fig. 2, contains the onboard and stationary modules in the ‘front end’; the onboard system transmits the data to the noise measurement system over a radio telemetry link. Thus, the engine control data in the vehicle are input directly into the stationary system, allowing analysis of those data with sound pressure level data in real time (see Fig. 4).

The new system is therefore able to make comprehensive observations of the engine control data and sound data for comprehensive, real-time processing and analysis.

The PAK system provides for processing of observation results for user-specified visual output of data. The format for displayed data can be set in advance, which allows increased efficiency in data analysis and processing.

3. Analytical Results

The sources of pass-by acceleration noise are the engine and power train, air intake, exhaust, exhaust radiation noise, tires, and others. These all combine to generate the pass-by acceleration sound pressure level. Engine noise accounts for most of this, as shown in the chart of noise contributors in Fig. 5. Accordingly, the authors investigated the relationship of pass-by sound pressure level with charging efficiency and ignition timing, the chief engine parameters strongly influenced by the environment and therefore key parameters in noise.

3.1. Influence of Charging Efficiency

Since the charging efficiency fluctuates with temperature, humidity and atmospheric pressure, and causes fluctuations in engine output, acceleration characteristics change and have significant impact to overall SPL in the noise measurement area. To correct for this phenomenon, an ‘engine power correction coefficient’ is provided in the Japan Industrial Standards to estimate engine output in varying atmospheric conditions. The following equation shows how to calculate the correction coefficient (K):

$$K = \left(\frac{P_o}{P} \right)^{1.2} \left(\frac{\theta_o + 273}{\theta_o + 273} \right)^{0.6}$$

P_o :Standard dry atmospheric pressure (= 99 kPa)

θ_o :Standard atmospheric temperature (=25 °C)

P :Observed dry atmospheric pressure (kPa)

$P = P_a - P_w$

P_a :Observed atmospheric pressure (kPa)

P_w :Observed partial pressure of water vapor (kPa)

θ :Observed intake air temperature (°C)

To confirm the accuracy of the engine power correction coefficient, it was compared to acceleration performance within the measurement area. Results can be seen in Fig. 6 with the corresponding acceleration values graphed as percentages of the acceleration corresponding to an engine power correction coefficient of 1. Clearly, the relation was linear. In other words, the acceleration can be standardized using the engine power correction coefficient, and a course

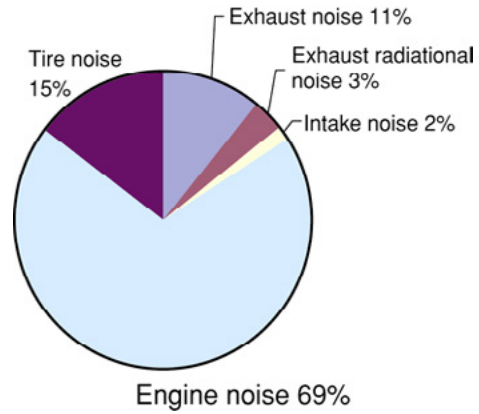


Fig. 5 Example of contribution analysis for pass-by noise

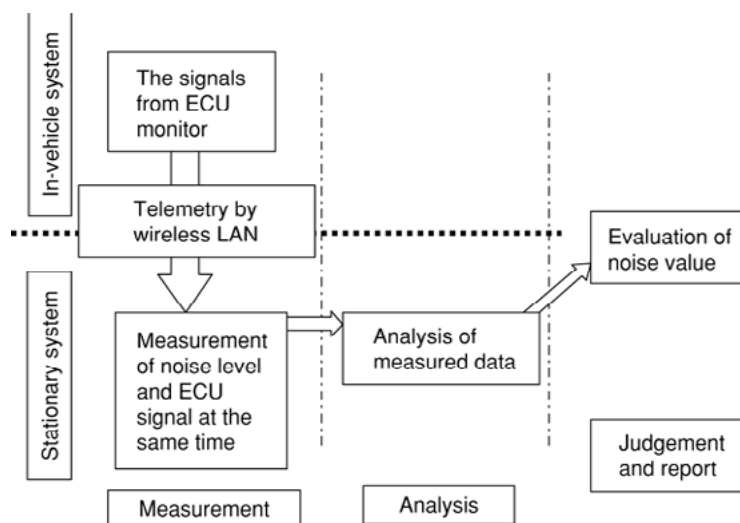


Fig. 4 New system for analysis: Flow chart of ECU data and pass-by noise data

exit speed can be calculated by adding the averaged acceleration rate to the initial course entry speed. When the ignition timing and other conditions are identical, the sound pressure level has an approximately linear regression relationship with the final speed, as shown in Fig. 7. Using the engine power correction coefficient, a standardized final speed can be calculated which allows calculation of a standardized pass-by sound pressure level based on the charging efficiency.

3.2. Influence of Fluctuations in Ignition Timing

The value set for engine ignition timing is modified according to intake air temperature, coolant temperature and the detection of knocking. The inlet air temperature varies in proportion with exterior air temperature (Fig. 8), so ignition is retarded in order to prevent abnormal combustion, or “knocking”, when the inlet air temperature is high (Fig. 9). Also, in the case where a vehicle sits at idle between test runs, the under hood temperatures may be raised and cause ignition retard during noise measurement, because the air intake is often located inside the engine compartment. Thus, the ignition timing may fluctuate during pass-by noise measurements even when the atmospheric conditions are

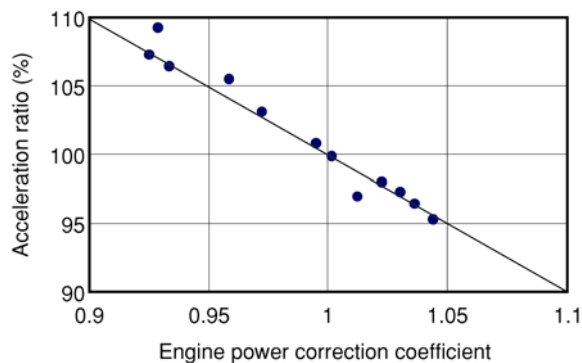


Fig. 6 Relationship between correction coefficient of engine power and acceleration ratio

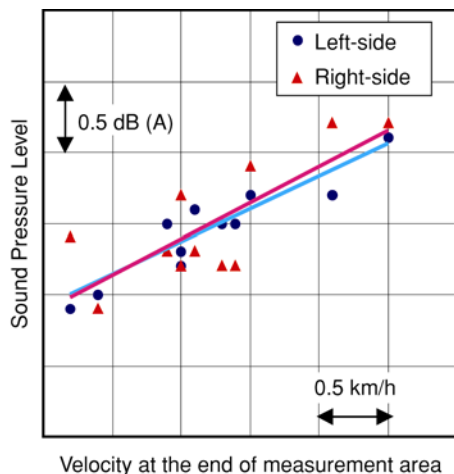


Fig. 7 Relationship between velocity at the end of measurement area and sound pressure level

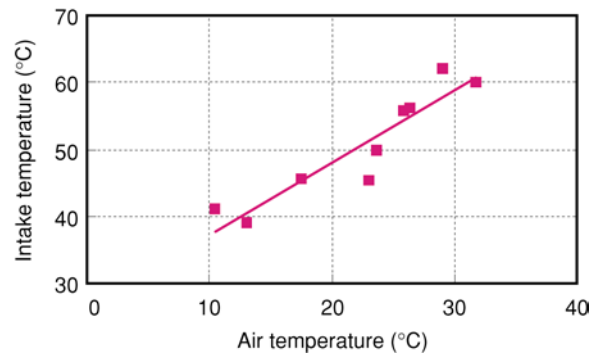


Fig. 8 Relationship between air temperature and intake temperature

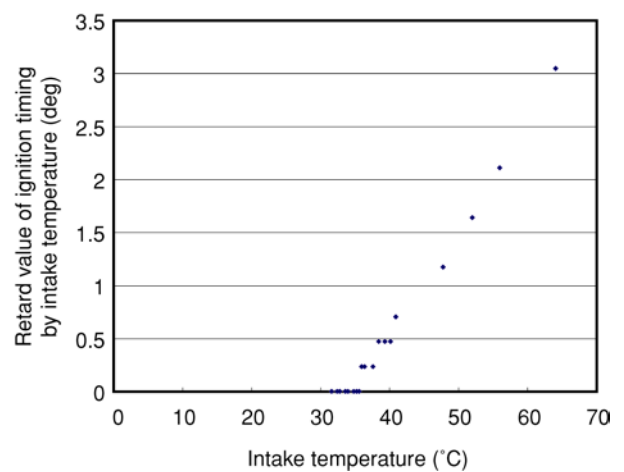


Fig. 9 Relationship between intake temperature and retard value of ignition timing by intake temperature

uniform. Figure 10 presents fluctuations in engine RPM and ignition timing during actual pass-by noise measurements. The engine noise fluctuates with ignition timing even at constant RPM (Fig. 11), which affects pass-by noise. As a

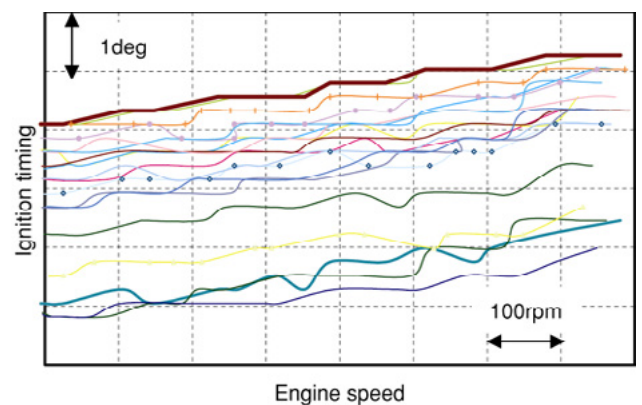


Fig. 10 Change of ignition timing while measuring pass-by noise

result, the sound pressure level may vary even when the final speed, i.e. the engine RPM, is the same, weakening the correlation of sound pressure level with speed, as shown in Fig. 12. This relation cannot be assessed with these data alone.

However, if data at nearly constant ignition timing are selected, the trend of noise with respect to final speed and the changes in sound pressure level with respect to ignition timing can be specified (Fig. 13). On closer examination of changes in sound pressure level due to variations in specifications, it was possible to make precise comparisons of sound pressure level at constant ignition timing under varying environmental conditions.

Furthermore, ignition timing retard will increase with temperature rise, so that the control value is increasingly delayed from the regular timing; as a result, the sound pressure level decreases. This relationship is shown in Fig. 14. Finally, by monitoring the difference between the ignition timing and the control value and comparing the change in sound pressure level corresponding to the ignition timing, it is possible to make more precise predictions of the sound pressure level from the commanded ignition timing.

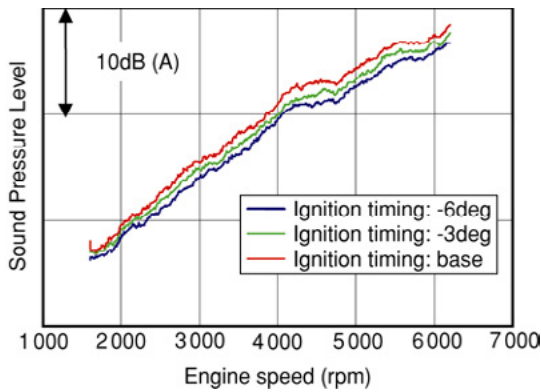


Fig. 11 Influence of ignition timing on engine noise

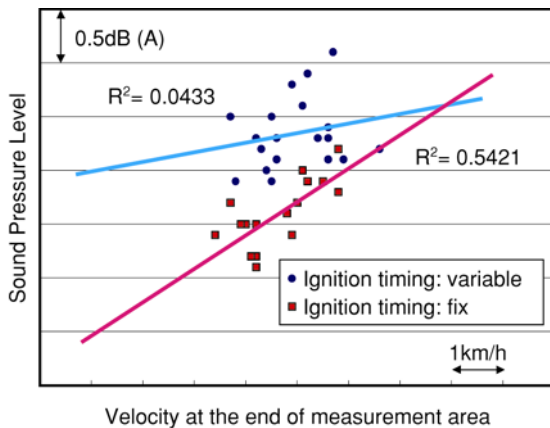


Fig. 12 Influence of ignition timing change on pass-by noise

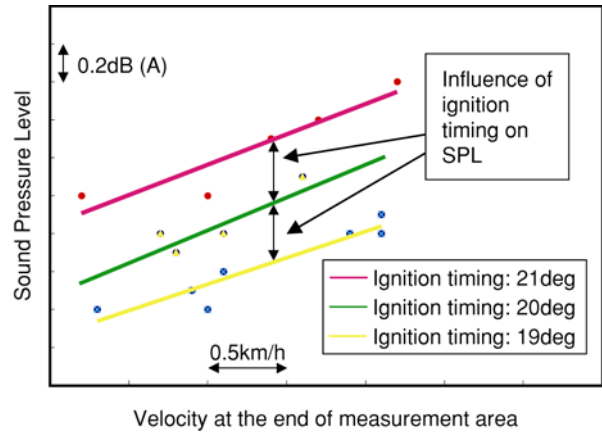


Fig. 13 Sound pressure level due to the difference of ignition timing

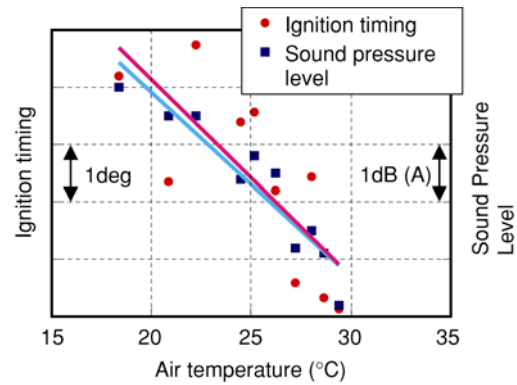


Fig. 14 Relationship of ignition timing and sound pressure level with air temperature

4. Summary

Technology was developed for real-time measurement and analysis of sound pressure levels and engine control data, which are key parameters in assessing pass-by noise from automobiles. Charging efficiency and ignition timing are key engine control parameters, which fluctuate greatly with environmental conditions and influence the overall engine noise. The following results were obtained while investigating the influence of fluctuating atmospheric conditions on sound pressure levels:

- (1) Charging efficiency, influences engine output, and sound pressure level during acceleration through the noise measurement area. It was possible to estimate a standard sound pressure level as a function of charging efficiency, by correlating exit speed and sound pressure level, in combination with the standardized engine power correction coefficient, which is determined by the atmospheric conditions during acceleration.
- (2) A quantitative relation between ignition timing and sound pressure levels was determined, allowing estimation of the change in sound pressure level from ignition timing.

A method for standardizing sound pressure level was established on the basis of the relationship between the

measured sound pressure level and parameters causing fluctuations. The method enabled precise measurements of sound pressure levels and changes in levels with changes in specifications.

This technology was developed as a joint effort of the Tochigi R&D Center and the Ohio R&D Center. Authors believe that the fruit of this combination of approaches and know-how on systems and noise measurements from the two large institutions for research on automobiles holds great promise for future development of automobiles.

References

- (1) Kanemaru, K., Uno, M.: Development of Computer System for Vehicle Exterior Noise Analysis, Journal of Society of Automotive Engineers of Japan, Vol. 44, No. 10, pp. 38-42 (1990)
- (2) Road vehicles-Engine power test code, JIS D 1001
- (3) Nagashima, K., Maeda, Y., Kimura, Y., Takaoka, N., Tadaka, K., Hatakeyama, K.: Development of Engine Performance Data Acquisition System, HONDA R&D Technical Review, Vol. 12, No. 2, pp. 55-60 (2000)

■ Authors ■



Jun KITAHARA



Jason RAY



Mark PAFUMI