

Noise Quality Analysis and Metrics Development under Transient Shifting Condition

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ABSTRACT

The shifting process always activates some changes of noise quality for its transient characteristics, especially for non-powered-shift transmissions, with which the power from engine is intermitted during the shifting period, such as Manual Transmission (MT) and Automated Manual Transmission (AMT). This type of noise change should have a very close relationship with the status of engine directly. But the essential reasons and how to estimate the noise have not been explored before. Therefore there is no clear understanding upon it and no formal methods yet described in the literature. The present study focuses on the phenomenon and makes effort to build reasonable research methods based on vehicles equipped with AMT. Furthermore, the metrics for assessing the noise has been developed with several different experiments and Support Vector Machines (SVMs) technique.

INTRODUCTION

One of the important performances that both manufacture and customers concerned is the possibility to drive in a pleasure driving environment, for noise, which is determined by not only the noise level but also the noise quality. Transmission shift is a typical transient action which inspires the transient response of engine and the variation in noise.

Noise quality has been an important research topic for a long time and a great advantage has been shown in automotive engineering field [1]. However, the effect of the shift on the noise is ignored in most situations. Some clues can be found in literature [2-6], in which the transient variation in noise responding to the shift motion was provided as a part of their research. In order to evaluate the shift quality completely, transient noise was researched deeply and new concept, namely "shift noise", was defined [7-8].

In this paper, the shift characteristic of one AMT vehicle was presented as the research baseline. In the meanwhile, the relationship between engine's responses, including the engine speed and torque, and the noise quality provided by subjective assessment was built for developing the metrics which described the shift noise correctly. The main problems solved by this paper are presented as below:

- Analyze the relationship between the engine variables (speed, torque, etc.) and the noise quality during the shifting process;
- Design a series of special experiments for analyzing and identifying the theory. The experiment was carried on in a semi-anechoic room and the noise level was measured in different positions including the engine side, the interior and the environment;
- Develop some metrics for estimating the noise level and describing the effect on people;
- Apply SVMs method to map the subjective assessment to the objective metrics. So the validation of the objective metrics can be confirmed;
- Use two special acoustic data processing techniques, i.e., time-frequency analysis and statistical analysis, for analyzing the essential reasons of the noise variation caused by the shift action.

The experimental results showed that the phenomenon was clearly understood by the above process. And the relevant engine running field, in which the sound quality was worsened, was easily identified. The metrics developed will be used for assessing the shift quality. As an important branch of shift quality research, the metrics can provide the precise prediction of the transient conduct of shifting. So the relationship between the physical noise and the subjective feeling can be built for further research.



Documents

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DETECTION OF NOISE VARIATION DURING SHIFTING

The experiments presented below aim at exploring the characteristics of shifting and the relationship between the variation in noise and the parameters of engine performance, such as the engine speed, torque and the throttle opening.

EXPERIMENT DESIGN

Same as manual transmission, the power interruption is a distinct blemish of vehicles with AMT. The transient shift action results in the fluctuation of the status of the engine. Figure 1 shows a typical AMT upshift process, in which the engine performance changes during shifting. This will affect the shift quality of vehicles directly.

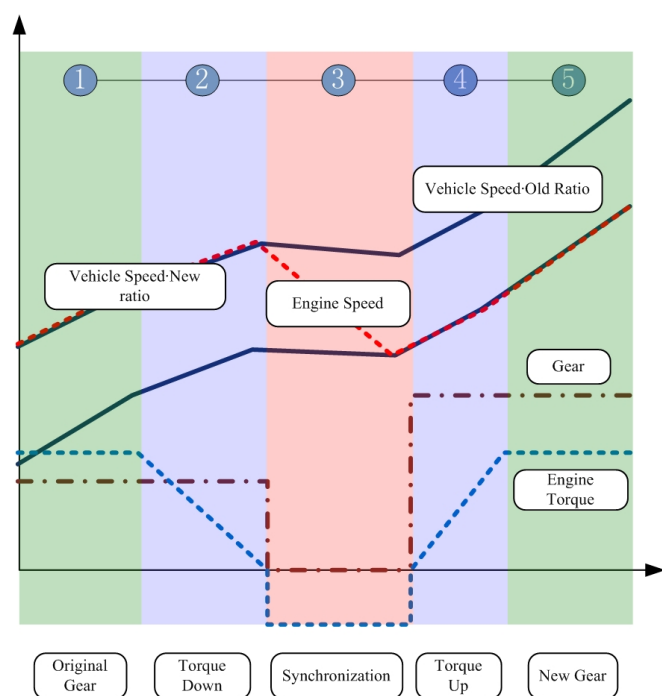


Figure 1. Typical upshift process for AMT vehicles

Because of the power interruption, the negative engine torque and engine speed falling can be seen clearly. It is similar for the downshift process, but in that the engine is increased during the 3rd stage (the synchronization).

Therefore, considering the features of AMT shift process, the experiments were developed to detect the noise change during shifting. The detailed test methods are described as follows:

- **Noise test under constant speeds:** The noise level was tested under different constant speeds, so the noise under the stable status can be acquired.
- **Noise test under the acceleration:** Startup the vehicle from still and accelerates with the given throttle opening of 10%, 20%, ... ,100% respectively,

to the highest gear, then release the pedal back to still.

- **Shift noise detecting test:** Accelerate the engine to a stable speed, and then upshift to the higher gear in manual mode and under a given gear position,. When the status of the engine achieves stable, downshifts by hand and returns to the original gear position. The operation procedure and the initial operation condition are shown in Figure. 2.

The measuring positions on shift noise are shown in Figure 3. Three pairs of different positions concentrate on three measured areas: the engine noise resource (C, D) and two noise received positions: the interior (A, B) and the remote (E, F). The final test results will be the average of the pair of positions in the same area.

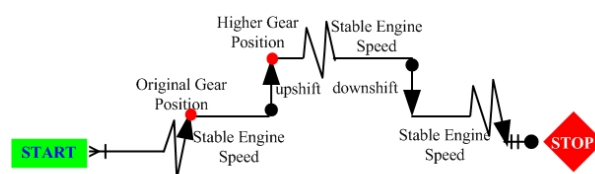


Figure 2. Shift noise test procedure and the initial speeds

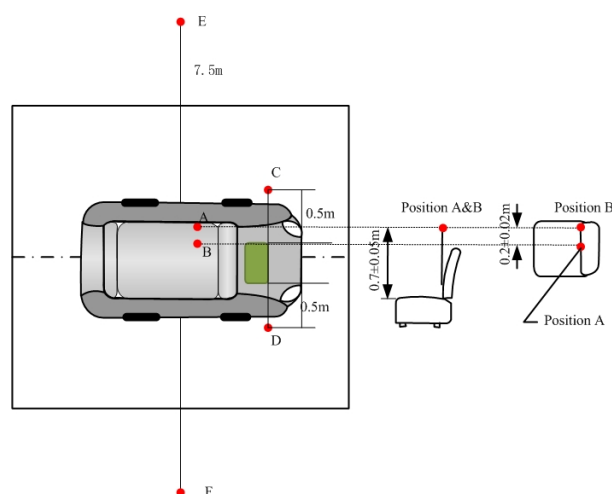


Figure 3. Noise measure positions

TEST FACILITY

In order to avoid the effects from the environment noise, the experiments were implemented in the semi-anechoic room. The parameters of the test vehicle are shown in Table 1. The noise data was also taken with other test

items, such as the engine speed, the engine torque and so on, so that the further analysis work could be carried on based on them.

Table 1. Parameters of tested car

Size	3839•1646•1440	Weight	1053 (kg)
Engine Type	SI (4 cylinders)	Displacement	1.389 (L)
Max. Torque	25/4000 (Nm/rpm)	Transmission	AMT (5 Speed)
Max. Power	66/6000 (Kw/rpm)	Tyre	175/65R14 T

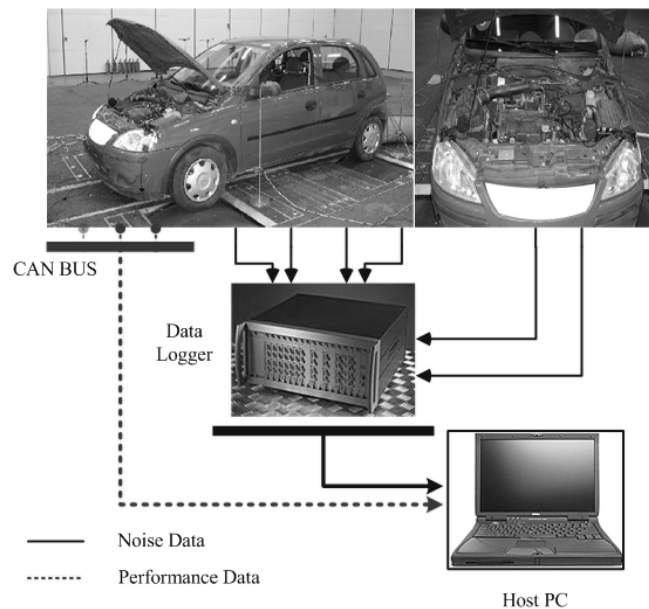


Figure 4. Noise test (sensor fixed positions & test instruments)

SUBJECTIVE RATING PROCEDURE

An important approach to reveal the relationship between the subjective feeling and the essential of the physical phenomenon is subjective rating which is a direct way widely used in NVH research. In this study, nine listeners took part in feeling the noise and providing their suggestion on the noise. Among them, one listener's age is less than 20 years old and one over 60; the others' age distributes from 20 to 55. In addition, two female volunteers are included. All participants were divided to three independent groups and provided the rating results with a resistor device. The subjective rating is divided to four grades with 16 scales in total, as shown in Figure 5.

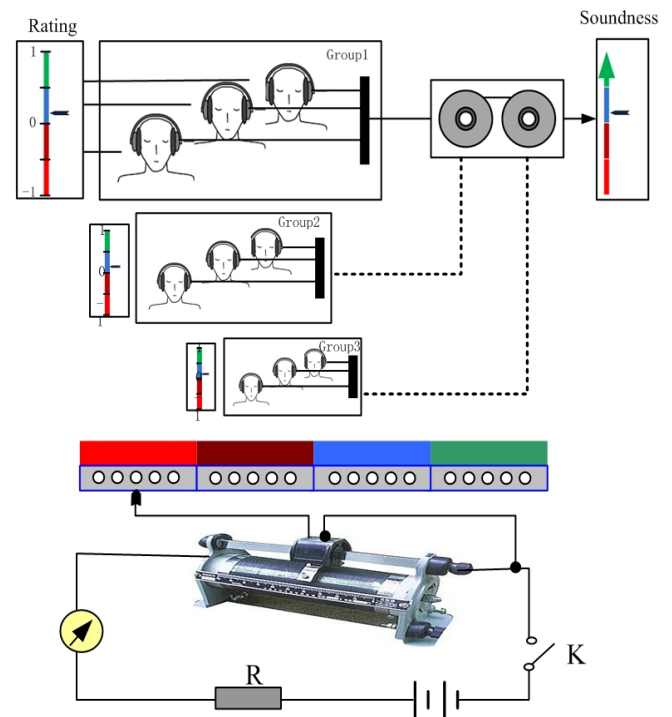


Figure 5. Subjective rating procedure and devices

EXPERIMENT RESULTS ANALYSIS AND METRIC DEVELOPMENT

In this section, the results of the above experiments are presented for analyzing the characteristics of the transient noise existing during shifting process. Based on these results, the effort to find rational metrics has been carried on and some achievements are presented in the following.

EXPERIMENTAL RESULTS

The vehicle constant speed test indicates the basic noise level under the conditions of different vehicle speeds, shown in Table 2. The data summarizes the noise level from six different positions which covers the three areas focused by the research.

Table 2. Noise level under the constant speed (dB)

Vehicle Speed	Position A	Position B	Position C	Position D	Position E	Position F
60km/h	65.5	63.6	67.8	66.2	86.0	84.5
70km/h	67.5	63.9	70.0	68.0	88.1	87.2
80km/h	67.0	63.7	71.9	70.5	89.2	89.4
90km/h	68.8	65.5	73.8	73.1	90.9	89.6
100km/h	71.2	67.3	75.5	75.4	92.6	91.7