

# Evaluation of Sound Quality and Sound Design Strategy of the Outside Folding Mirror

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## Abstract

According to the increase in the overall quality of the vehicle, the quality of customer actuated sounds also has become increasingly important. The folding mirror sound, which is one of customer actuated sounds, has less masking effect by driving sounds. Therefore, despite the low noise level, drivers may not be satisfied with the sound quality. The aim of this work is to identify sound quality factors which mainly contribute to customer's preference regarding the outside folding mirror. For this purpose, subjective evaluations were carried out and the sound quality index was developed through the statistical analysis. Next, noise source identification was carried out to reveal the contribution of motor excitation regarding sound quality. And then, development guideline in the viewpoint of the sound quality index, loudness and fluctuation term is suggested for improving sound quality.

## Introduction

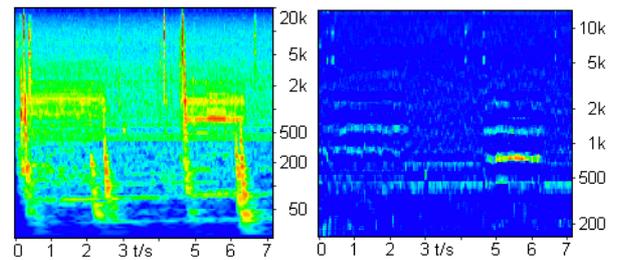
As the overall quality of the vehicle is improved, the importance of sound quality is also increasing. Not only the driving sound but also operational sound quality and electrical feedback sounds are also being considered in the sound quality study in the automotive field. The car body and trim parts such as window lift, central door lock, sun roof, windshield wiper, power seat, and outside mirror are mainly operated by the electric motor. So operational sound quality research is strongly related to the electric motor [1][2].

In this research, we present the sound quality index about the outside folding mirror of a passenger car. First, sound characteristics were analyzed to reveal a weak point based on VOC analysis. Through this result, improvement direction of sound quality was derived. Next, the subjective and objective evaluation was conducted to derive the sound quality index. Using this result, the regression model was derived. And then, simple noise source identification was carried out to reveal the contribution of the electric motor. And we modified the electric motor to improve the noise and vibration characteristics. Finally, we compared the sound quality index about the original and improved parts.

## Folding Mirror Sound Characteristics

Figure 1 shows the sound characteristics of general outside folding mirror. Sounds were measured at the driver seat in the cabin. The left figure indicated the wavelet analysis and right figure indicated the prominence analysis result. The x-axis means the time and y-axis means frequency. The important factors that affect sound quality are as follows.

- Level of impact at start/stop
- Level of motor tonal noise
- Modulation strength when glass is moving



**Figure 1:** Sound characteristics of outside folding mirror. Left figure shows the wavelet analysis and right figure shows the prominence analysis result.

In order to derive weak sound quality factors, subjective evaluation to obtain the VOC was carried out on various folding mirror sounds. As a result, the following weak points were derived.

- The sound is quiet, but motor sound is audible
- The sounds are varied by the movement of mirror
- I don't want any strong tones

Based on this, sound target image was also derived.

- Low tonal components of motor
- Low impact noise when the operation is start/stop
- Uniform sound when glass is moving

## Sound Quality Index Development

In this study, the sound quality index about "high sound quality" was derived. Subjective evaluation was conducted for 30 adults. Rating method was used to evaluate the high sound quality sensation [3]. Figure 2 shows the demographic composition of the evaluators.



**Figure 2:** Demographic composition of the evaluators.

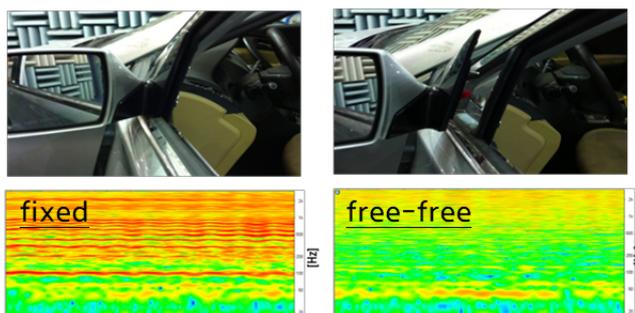
The regression analysis model was constructed by subjective evaluation result and objective evaluation result. R square value of this model is 0.72.

$$SQ\ Index = \text{Beta}0 - \text{Beta}1\ N - \text{Beta}2\ FS$$

Where, N indicate the averaged loudness value and FS means the fluctuation strength value. Overall level and modulation characteristics contribute greatly to the high sound quality sensation. Also, it can be seen that the contribution of fluctuation strength of the sound is greater than the sound level.

### Noise Source Contribution

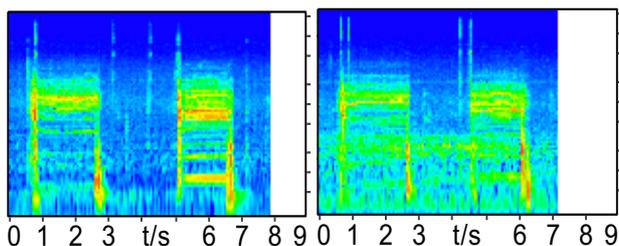
In order to verify the noise source, a simple contribution evaluation was performed. Noise from electric motor can be divide into structure borne noise and air borne noise. The mirror mounting effect was evaluated to evaluate the contribution by motor excitation. Operation sound was measured in the driver seat under the condition that the mirror was completely removed and the normal fastening condition. As shown in Figure 3, it was confirmed that the level of the tonal component is reduced when the mirror is detached from car body. From this result, it can be confirmed that motor exciting force is dominant than noise radiation.



**Figure 3:** Noise characteristics along the boundary condition: left figure shows the normal fixed condition and right figure shows the detached condition.

### Noise Source Improvement

Next, an improvement sample was made to improve the motor excitation force and the improvement effect was examined. Improved samples were made by increasing the number of slots in the motor and improving the clearance. Figure 4 shows a effect of improvement. Left figures indicated the original sound and right figure indicate the improved sample sound. We can easily find that the level of tonal component was reduced when glass is moving. Table 1 shows the improvement effect in view point of sound quality index



**Figure 4:** Noise characteristics of original and improved motor sample: Left figure shows the original sound and right figure shows a improved sample

**Table 1:** Analysis of improvement effect

	Before	After
Loudness	5.94	4.45
Fluctuation Strength.	0.0798	0.0290
SQ Index	3.76	6.71

### Conclusion

In this study, the sound quality index was developed through subjective evaluation and objective evaluation of the outside folding mirror. Through the regression model of sound quality index, overall level and modulation were founded to be major factors. Also, it is confirmed that the fluctuation when the mirror moves is important than sound level. Influence of the motor excitation force was evaluated. Through this result, improved sample was made and tested. Finally, it was confirmed that the sound quality during operation was improved by improving the motor excitation force.

### Reference

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- [3] Cerrato-Jay et al., “Implementation of Sound Quality Measurements in Component Rating Tests”, presented at Sound Quality Symposium at Inter-Noise 2002, Dearborn, MI, USA, August 22, 2002.