講演番号 019

Determining Stabilization Parameters in the Inverse Matrix TPA

-Part 1: Validation with Road Noise-

Hiroshi Kashiwazaki [1)] Makoto Takeshita [1)] Zhiqiang Weng [1)] Michio Murase [1)]

1) Ono Sokki Co., Ltd

1-16-1 Hakusan, Midori-ku, Yokohama 226-8507, Japan (E-mail: kashiwaz@onosokki.co.jp)

KEY WORDS: **Vibration, noise, and comfort, Road noise, Transfer path analysis,** matrix inversion method [B3]

Transfer Path Analysis (TPA) is an essential tool in automotive development for quantifying vibration transmission from sources to receivers. It facilitates target setting and diagnostic analysis during both the design and prototyping phases. With the progress of vehicle electrification, road noise has emerged as a dominant factor in cabin quietness. Accurate input identification is critical in TPA process, but direct measurement of operational inputs like road noise is often impossible. Consequently, the matrix inversion method or in-situ method is widely used to estimate forces from measured responses. However, transfer function matrices for automotive structures are often ill-conditioned, leading to unrealistic force estimates due to significant noise amplification. To suppress this, stabilization techniques like TSVD and L_2 regularization are employed, but selecting their hyperparameters remains time-consuming and labor-intensive. Although GCV and L-curve method are established techniques for hyperparameter selection in general inverse problems, their application to automotive TPA reveals practical limitations. GCV is sensitive to the statistical properties of noise, while the L-curve often suffers from indistinct shapes in complex automotive structures, causing the selected parameters to fluctuate significantly across frequencies.

In this report, as an approach to solve these challenges, we propose the Anchor Matching Method, which uses consistency with "independent measurement points" not used for input estimation as an evaluation index (Fig.1). Minimizing the evaluation function defined below establishes a basis for parameter selection rooted in consistency with measured data, which is expected to provide highly physically reliable input estimation.

$$E(\alpha) = \frac{\| |\mathbf{q}| - |\hat{\mathbf{q}}(\alpha)| \|_2^2}{\|\mathbf{q}\|_2^2}$$

The proposed method was validated through in-situ TPA experiments targeting road noise across two actual vehicles, it was confirmed that target point sound pressure can be accurately reproduced across all frequency bands for both TSVD and L_2 regularization (Fig.2). Even in frequency bands where conventional GCV and L-curve methods tend to exhibit unstable behavior, the use of physical consistency as an "anchor" enables the stable selection of appropriate parameters without extreme fluctuations.

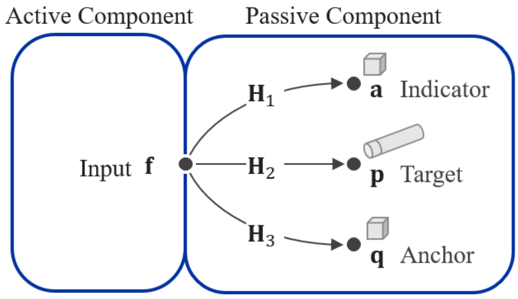

Fig.1 Schematic of the Anchor Matching Method

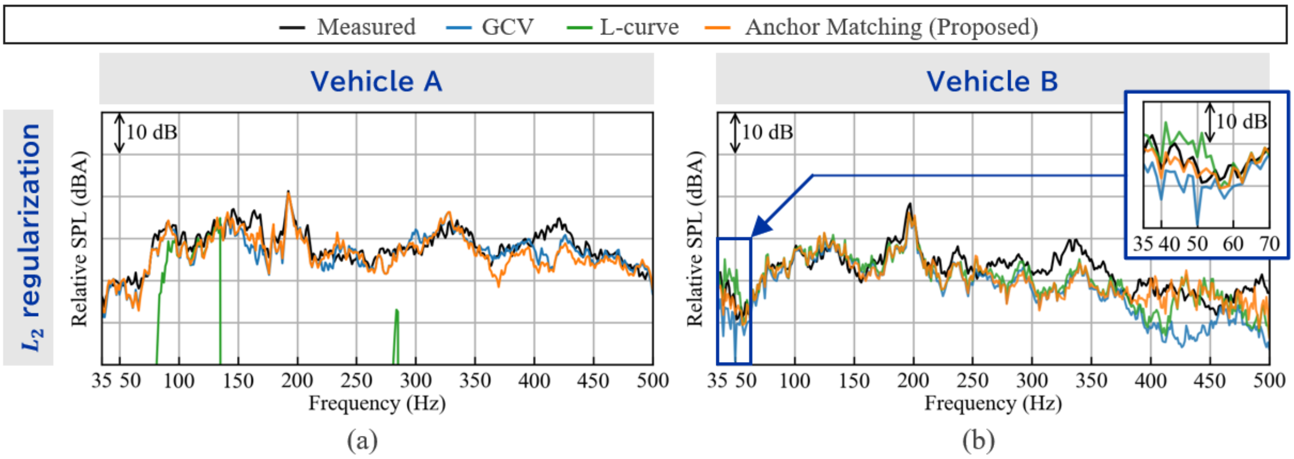

Fig.2 Comparison of estimated and measured SPL for Vehicle A and Vehicle B using various parameter selection