Predictive Simulation Approach for Elevator Cabin Noise Reduction: Enhancing Ride Quality and Passenger Comfort

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Abstract Elevator cabin noise is a critical factor in ride quality, directly impacting passenger comfort and satisfaction. Traditional noise reduction techniques are often iterative and applied during the later stages of design, leading to increased costs and extended timelines. This paper presents an approach that leverages advanced simulation techniques, including VTF, NTF, and Acoustic Frequency Response Analysis, to predict and mitigate elevator cabin noise. A strong correlation between simulation and testing results is demonstrated.

By identifying and troubleshooting problematic noise sources through simulation and test data, the cabin design is optimized with various design modifications. This approach achieves the targeted noise reduction and results in a notable weight reduction of 10% in the cabin design.

Aiming to enhance ride quality and passenger comfort, this simulation-driven method allows for early-stage prediction and optimization of noise levels through corrective measures in elevator design. This process eliminates the need for extensive physical testing of numerous prototypes, thus saving both development time and costs.

1 INTRODUCTION

Elevator ride quality gauges the comfort experienced by passengers, closely tied to their personal perception and sensitivity to movement and sound. This metric is influenced by the noise and vibrations from the system in operation. It also serves as an indicator of product quality. Enhancing ride quality is a key goal for elevator manufacturers. Users' impressions are influenced by noise, vibration, and in-cabin performance.

The sources of discomfort inside lift cabins can be produced by noise and vibration sources such as machines (drive), door operators, electrical control cabinets, sliding systems in cabin and counterweights. These source excitations coupled with resonances of cabin components and insufficient isolation between the sources and the receptor can cause high vibrations and associated vibroacoustic noise inside cabin as perceived by passengers inside the cabin[1]. Thus, a good understanding of vibration phenomena occurring in lifts systems is essential to design a system which will satisfy ever demanding ride quality criteria.

The objective of current paper is to build a methodology to fulfil cabin interior noise criteria through simulation and experimental testing. Use of this methodology enables defining the design guidelines for component design to achieve the cabin NVH (Ride Quality - RQ) targets within the design phase (frontloading).

2 IN-CABIN NOISE PREDICTIVE SIMULATION APPROACH

The sequence of steps in the methodology are as follows:

Baseline RQ assessment

- Testing – Baseline assessment of ride quality
- System level, Noise path level test data measurement
- Sound pressure v/s frequency, Acceleration v/s frequency measurement

Test analysis + Inputs to Finite Element Analysis (FEA)

- Source identification, components Frequency response function (FRF), Transfer path analysis (TPA) etc.
- Ranking of structure borne & air borne sources
- Panel contribution analysis
- Input excitation to FEA

FEA: Vibration and Acoustics

- Vibro-acoustics model preparation
- Sound Pressure level (SPL) prediction
- Model correlation
- Panel contribution analysis

Design modifications evaluation in simulation

- Critical variables
- Sensitivity analysis
- Design of experiment
- Modification proposals validation through testing

2.1 Baseline RQ assessment

An existing elevator system is selected for baseline assessments of ride quality as per ISO 18738-1 [2]. For vibration measurements, input is given using an impact hammer at excitation locations: guide shoes and pulley locations. Output accelerations are measured at driving points and cabin structure. Figure 1 shows a generic elevator system nomenclature.

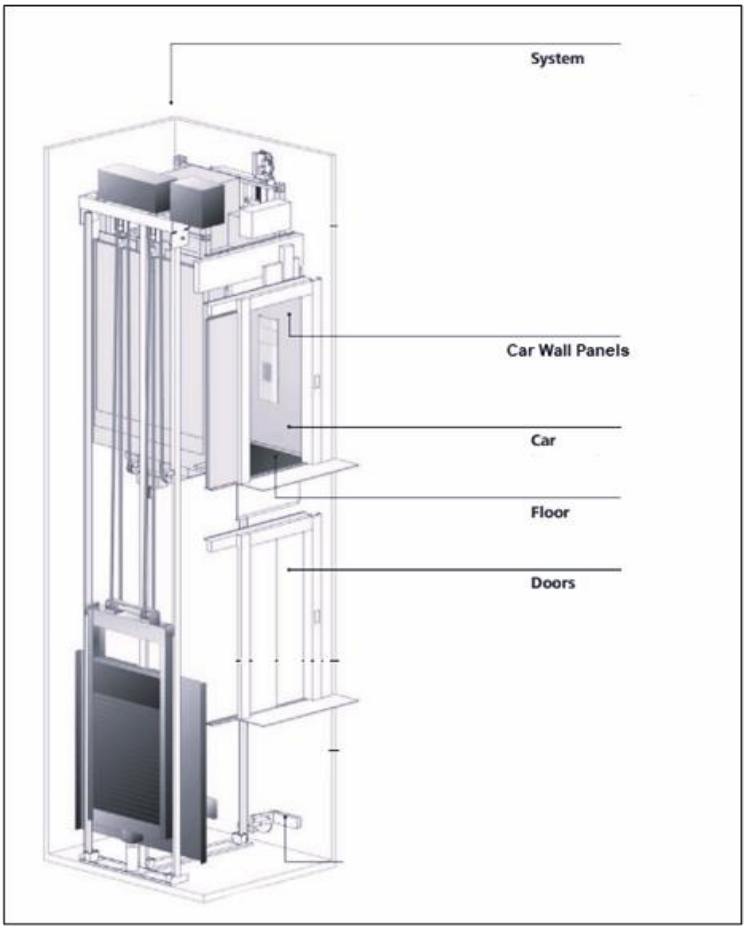

Figure No. 1 – Elevator system generic nomenclature [3]

Vibration Transfer Function (VTF) is calculated at both the excitation locations and the response locations. SPL is measured using microphone placed at 1m from floor at centre of the cabin. Noise Transfer Function (NTF) is calculated for SPL response for all excitations. Refer Figure 2 for TPA process flow.[4]

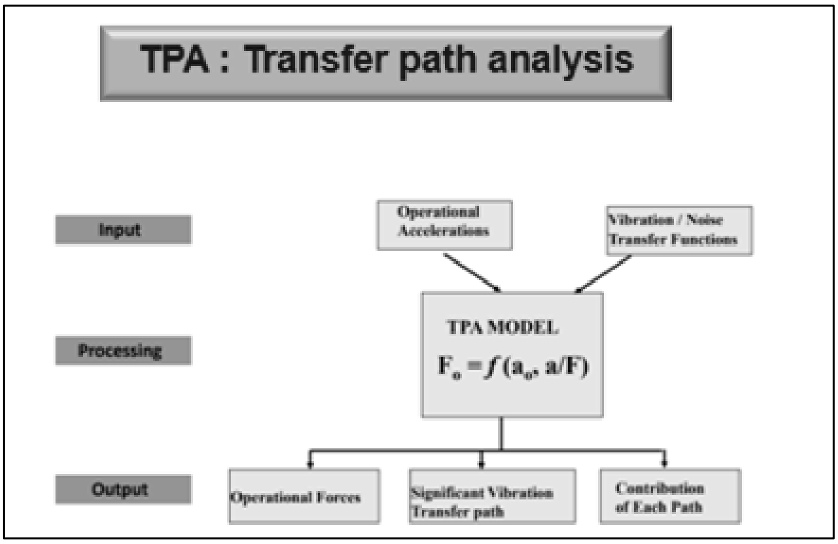

Figure No. 2 – TPA Process flow

The noise levels allow us to estimate whether the noise transmission is mainly airborne or structural through the hoistway to the cabin.

2.2 Test analysis and Inputs to FEA

Source identification, components FRF and Transfer path analysis is used in ranking of structure borne, air borne sources and analysis of panel contribution. Attribution of dominant frequencies with high noise to the respective excitations have been identified. TPA for noise reveals that the dominant path is through bottom part of elevator cabin.

2.3 Vibro-acoustic analysis under operational loads from testing as input to FEA

- The test accelerations at system to cabin interface locations are given as input to FE model.

Validation of the FE model

The FEA model validation was accomplished by performing a modal analysis and comparing it with testing results, which exhibited a very good match (>90% correlation). Air cavity mode is simulated through FEA and validates very well with the analytical calculations.

Prediction of SPL under operation forces

Under operational forces the SPL is predicted at 1.5m from the floor at the centre of cabin as per ISO 18738-1 [2]. The one-third octave comparison of test vs simulation results is presented in Figure 3. The correlation is not quite good at lower frequencies, but the noise contribution of lower frequencies is very low towards overall noise. Good correlation is observed at frequencies where the noise contribution to the overall noise is high.

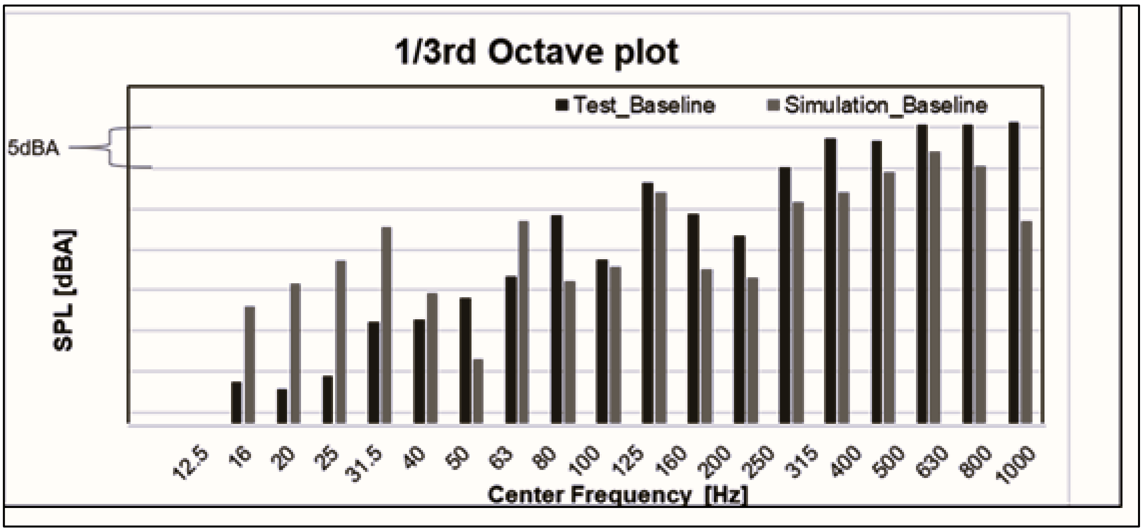

Figure No. 3 – 1/3rd Octave plot of SPL (dBA) – Test vs simulation

2.4 Modifications to reduce the overall SPL

Based on the study of simulation and testing results, components which had resonances were identified. Also, through TPA the components contributing to the noise were identified. Structural modifications and isolations were proposed & evaluated through this FEA methodology to mitigate noise inside cabin as detailed below. With these modifications, a significant SPL improvement of ~6.5 dBA is achieved. The structural modifications in elevator cabin, helped optimize the design leading to weight reduction of ~10% over baseline design.

3. CONCLUSION

The study highlights the effectiveness of leveraging advanced simulation techniques, such as VTF, NTF, and Acoustic Frequency Response Analysis, to address elevator cabin noise issues. By identifying and addressing noise sources early in the design phase, this approach enhances ride quality and passenger comfort while reducing development time and costs.

The research shows a strong correlation between simulation and testing results, validating the models' accuracy. Design modifications, including reinforcement of platform stiffeners and strengthening of the cabin traction module, led to significant noise reduction (~6.5 dBA) and a 10% weight reduction in the cabin design.

This simulation-driven methodology supports the goal of improving ride comfort and establishes a model for future advancements in elevator design and engineering.

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BIOGRAPHICAL DETAILS

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