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Modeling of the load transmissibility up to 300Hz of an vehicle air suspension

Jang, Joonghwan[1*] **Lee, Jongwha**[1] **Park, Sangwon**[1]
Jung, Jinnyon[2] **Lee, Sangil**[2] **Sohn, Byunggil**[2]
[1] Hyundai Mobis, South Korea
[2] JINN, South Korea

ABSTRACT

In this study, an analysis model was developed to predict the performance of the air suspension NVH in the road noise region. For road noise analysis, testing was conducted in the 30-300 Hz range, and test equipment was also developed for performance testing. Unlike conventional air suspension test equipment, equipment was developed for pre-loading without using an air damper, to model the boundary conditions of the analysis model. Since the road noise region is a frequency range with no displacement, load transmissibility was measured using load sensors on both the input and output parts[1]. The load conditions applied to the suspension were set to match the actual vehicle conditions, and load transmissibility was tested for various input load conditions, considering different road and vehicle boarding conditions[2]. Modal and ODS tests were conducted to correlate with the analysis model, and ODS correlation corresponding to the main peak frequencies was established[3]. As a result of the tests, the prediction of load transmissibility by the analysis model was verified, and an analysis model with behavior and levels observed in the tests.

Keywords: *Air Suspension, Chassis module, NVH, FE, Road Noise.*

*Corresponding author: jangjoonghwan@mobis.com
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1. INTRODUCTION

Air suspension is a system that adjusts suspension of a vehicle by using air pressure instead of coil spring or plate spring. It is possible to adjust and height of a vehicle according to the speed and environment of the vehicle, so it is mainly used in high-end passenger cars and off-loader vehicles due to improved ride comfort and improved driving performance. Due to the advantages of air suspension, many manufacturers are developing vehicles equipped with air suspension. Air suspension is an important part of chassis module. It is necessary to know the characteristics for NVH performance analysis and improvement, and it is a necessary part for chassis module NVH analysis. In the case of existing studies on the FE analysis of air suspension, the vehicle air suspension analysis model has been modeled with a frequency band of less than 50 Hz as a target, and many studies have been conducted mainly to analyze the behavior of low frequency bands[4-6]. However, since road noise generated during driving is generated from 30 to 500 Hz, it is necessary to analyze the NVH of the chassis module over 30 Hz in order to identify the cause of the noise problem occurring in the frequency band and to suggest an improvement plan. In order to carry out this, an analysis model of an air suspension capable of predicting NVH performance over 30 Hz was required, so the research was conducted. Ideally, the goal was to implement and verify an analysis model up to 500 Hz, but an air suspension NVH analysis model capable of predicting load transmissibility up to 300 Hz was developed due to various situations such as test equipment.

2. FREE-FREE MODAL CORRELATION

In order to secure the properties of the air suspension, the modal test of single-component free-free conditions was conducted first[7-8]. In order to conduct a modal test with air pressure in the air suspension, air must be injected, so it is a fixed condition, and through the air suspension modal test without constraints, physical properties are secured and a basic analysis model is constructed. The frequency domain of interest is 300 Hz, and as a result of the FRF SUM graph in Fig.1, a total of 5 modes up to the frequency band were found[9]. For the test and analysis correlation, the physical properties and contact modeling of the analysis model were modified, and as shown in Fig.2, a basic analysis model was constructed that follows the same frequency as the mode shape derived from the test[10].

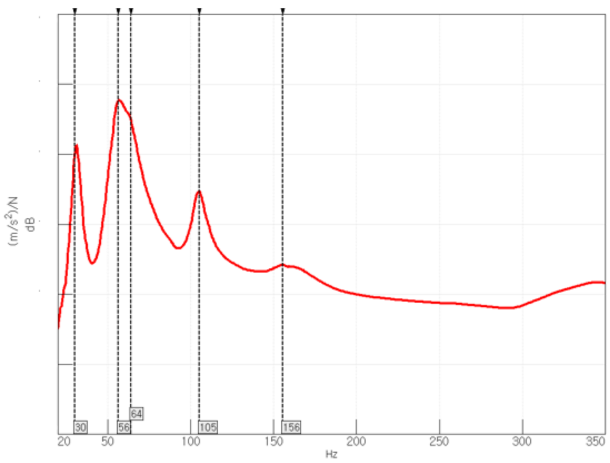

Figure 1. Free-Free condition Modal FRF Sum

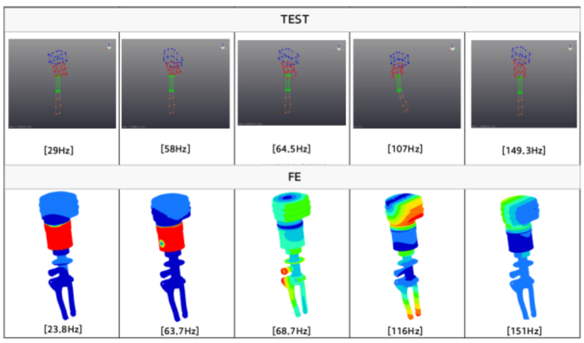

Figure 2. FE Modal Correlation results

3. ODS TEST & LOAD TRANSMISSIBILITY TEST

3.1 Establishment of test equipment

In the case of an air suspension single component performance tester, if a load of 500 to 900kgf, which is a vehicle load condition, is applied, the air suspension shall be excited. Although there are many test equipment commonly used to evaluate a single component of an air suspension up to 300 Hz, All of the equipment is in the form of an air bellows applying a virgin load and exciter. However, it is also very important to implement boundary conditions to create an analytical model. Since the air bellows are also as difficult to model as the air suspension, which also requires correlation, additional experiments must be conducted to develop equipment that does not use the parts. In order to eliminate the air bellows, the exciter itself must be excited while loading the vehicle, so the hydraulic exciter cannot be excited to a high frequency band, so equipment construction was carried out through the electro- magnetic-actuator. The test equipment can be subjected to vehicle load conditions up to 1000 kgf and can be excited by inputting additional load at the same time. Evaluation equipment plays a role in applying the load while the exciter is excited, and controls the applied load with the static load sensor below. A dynamic load sensor is installed to measure the input load, and a dynamic load sensor is installed at the upper end of the air suspension to measure the dynamic load of the output unit. The measured dynamic load is calculated as Eqn. (1)

$$F_{OUT}/F_{In} \tag{1}$$

and the load transmissibility is measured.

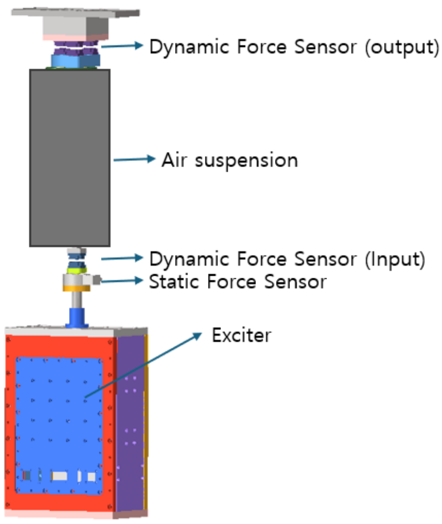

Figure 3. Test equipment

3.2 Test

In general, a fixed-condition modal evaluation is performed, but the main behavior of the air suspension is in the axial direction. In the case of fixed-condition, it is determined that the proper modal evaluation cannot proceed because it restricts the axial direction, so the dynamic behavior in the frequency domain of interest was confirmed through ODS test. During the ODS test, the load transmissibility was also evaluated by measuring the input and output loads at the same time. The vehicle load condition was evaluated based on the load applied to the suspension when two people under the 2up condition boarded the vehicle. There are three ODS test conditions, and a total of 6 (25N, 35N, 50N, 60N, 75N, 80N) tests were conducted for the load transmissibility evaluation. Although many studies have been conducted on the input load entering the wheel center when the vehicle runs on the road, since the size of the input load entering the air suspension through the wheel center, bush, and arm current is not currently known, the output load when the input load under various conditions is applied is measured.

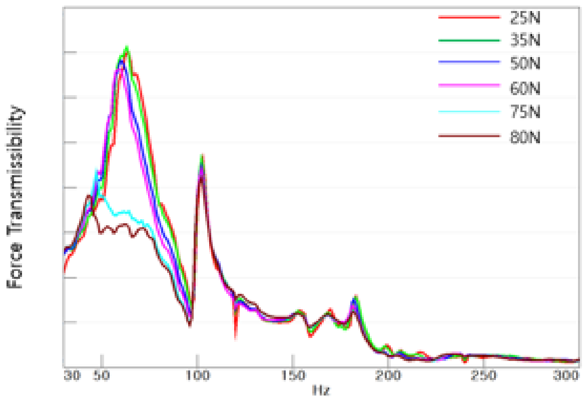

Figure 4. Load transmissibility

As a result of the measurement, it was confirmed that the load transmissibility varied according to the input load condition, and it was determined that the difference was due to the nonlinearity of the air suspension. In particular, at 60 Hz and 100 Hz, the load transfer rate is amplified in common. The ODS results show that the axial behavior of the 60 Hz air suspension acts as the main cause. The characteristics of the bellows indicate that the direction of excitation is axial and the main behavior is axial, so amplification is possible in the corresponding frequency band. The 100 Hz band moves in the opposite phase of the air suspension head and the fork, and thus has the overall behavior of the head. It is understood as the resonance phenomenon of the boundary condition. It can be seen that the axial mode of the boundary condition and the excitation direction overlap and amplify.

4. FE ANALYSIS

For FE modeling, Hypermesh was used, and solving was analyzed using OPTISTRUCT. As a result of the Load transmissibility test, it was confirmed that the Load transmissibility varies depending on the input load. However, since the solving of the NVH analysis model to be developed is performed by linear analysis, which is OPTISTRUCT, nonlinearity in which the Load transmissibility changes according to the input load cannot be implemented. Therefore, in this study, we developed a model that can predict the load transfer rate by changing the factors for each input load. Prior to the development of the Load transmissibility analysis model, ODS correlation was conducted based on the ODS evaluation results. In the air suspension analysis model, the parts with high difficulty are bellows and air pressure. Among them, bellows are composite materials in which rubber and cord are combined, and the characteristics of rubber change in rigidity as shape changes. When air pressure is injected into the air suspension, the bellows expand, and as the bellows expand, the bellows stiffness changes. Because this must be done in a nonlinear analysis, the bellows and air pressure were replaced with stiffness values in six directions using the spring element (CBUSH) in this study. In addition, in the Load transmissibility test result, 100 Hz was identified as a resonance due to boundary conditions, and the same boundary conditions as the test environment were implemented in the analysis model. As shown in Figure 5, ODS correlation was performed on the main frequency band that appears to be the peak in the Load transmissibility. As a result of the Load transmissibility analysis based on the model, it was confirmed that the test and the tendency were the same and the level were well predicted. As shown in Figure 6, a model for predicting the Load transmissibility for various input load conditions was developed based on the model. The factor that has the greatest influence is bellows rigidity. And the factor that determines the magnitude of the load transfer rate is the damping of the bellows. Therefore, we have completed the development of a model that predicts the Load transmissibility by identifying bellows rigidity and damping by input load.

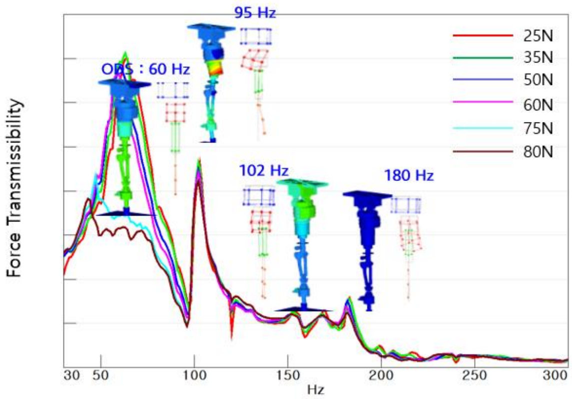

Figure 5. ODS Correlation

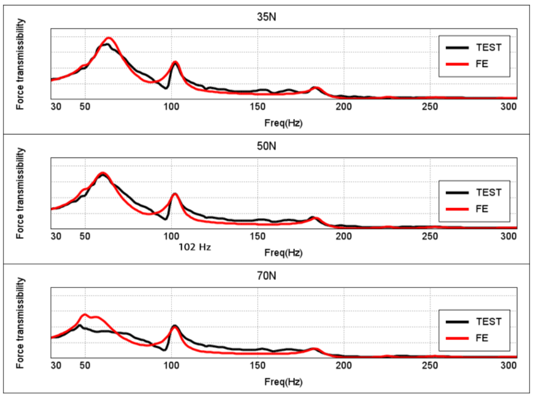

Figure 6. FE analysis result (Test vs. FE)

5. CONCLUSION

In this study, the NVH analysis model of the air suspension, which can predict the load transfer rate up to 300 Hz, was developed for the NVH analysis of the chassis module. Dynamic behavior correlation was completed through ODS test, which is the actual operating condition of a single component, and an analysis model was developed to predict the Load transmissibility. The stiffness and damping values for each input load were secured. If the input load condition can be identified in the air suspension, it is possible to predict the performance of the chassis module NVH and derive an improvement plan. Therefore, further research will be conducted to develop a load measurement input to the air suspension and a model to predict the Load transmissibility.

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