EXPERIMENTAL STUDY AND EVALUATION OF VIBRATION IN A 5-SEAT SEDAN

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ABSTRACT

This research conducts experiments to investigate, evaluate, and simulate the effects of the suspension system on vibration and ride comfort in a 5-seat sedan. The objective is to compare theoretical simulations with real-world measurements to assess the vehicle's vibration quality while driving on roads with varying roughness levels. The study utilizes a mathematical modeling approach to simulate the vehicle's vibrations and designs an experimental methodology to measure relevant parameters using specialized instruments. The suspension system's performance is analyzed in both simulated and real-world scenarios, focusing on how road irregularities affect the vehicle's dynamic behavior and ride comfort. The research aims to provide a comprehensive understanding of the suspension system's impact on vehicle stability and comfort. The findings are intended to support the optimization of suspension designs, leading to improved vehicle performance, enhanced stability, and a smoother, more comfortable driving experience, especially when navigating roads with diverse surface conditions.

Keywords: *Vibration experiment, automobile vibration, vehicle vibration, vehicle dynamics.*

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1. INTRODUCTION

The study of vehicle suspension systems and their impact on ride comfort and vibration has been a subject of increasing interest due to its significant effect on vehicle performance and passenger comfort. Over the years, various studies have been conducted to understand the relationship between suspension dynamics and road conditions. However, despite the advancements, there remain limitations in the methods and outcomes of many of these studies.

In a study by Zhang et al. [1], the authors used a simplified mathematical model to simulate the vibration response of a vehicle's suspension system. While their approach provided valuable insights into the system's behavior, it failed to consider the complex road irregularities that vehicles often encounter. Additionally, the study relied solely on theoretical analysis, limiting the real-world applicability of the results.

Another research by Liu et al. [2] focused on experimental testing of suspension systems under various road conditions. Although the study provided valuable empirical data, it lacked a comprehensive mathematical model for simulating the vehicle's response, thus limiting the ability to predict the system's performance under different conditions.

Similarly, a study by Patel and Kumar [3] combined simulation and experimental methods to analyze the suspension system's impact on vehicle dynamics. However, their work did not consider a wide range of road surfaces and failed to include detailed instrumentation for precise measurement, which led to possible inaccuracies in the results.

Finally, an investigation by Chen et al. [4] explored suspension system optimization using simulation techniques. While the study presented interesting results, the model did not adequately account for variations in road roughness, limiting its ability to provide comprehensive findings.

This paper addresses these gaps by using both simulation and experimental methodologies. A detailed mathematical model is developed, and a robust experimental setup is used to measure the vehicle's performance across different road surfaces. The results not only improve the accuracy of suspension system analysis but also offer a more practical solution for optimizing ride comfort and vehicle stability. This integrated approach provides a clearer, more comprehensive understanding of how suspension systems respond to road irregularities, marking an advancement over previous research.

2. EXPERIMENTAL SETUP FOR VIBRATION OF THE 5-SEAT SEDAN

2.1. Equipment and vehicle setup

The objective of this experiment is to evaluate the impact of suspension system vibrations on ride comfort and vehicle dynamic behavior by utilizing a combination of sensors and data acquisition tools. The sensors used in this study include the AKF390 triaxial accelerometer, the Vibra-Metrics model 1000 accelerometer, and the GF302 frequency calibrator. The collected data will be processed using CarLab Test DAQ software, which is connected to the data acquisition (DAQ) system for signal monitoring and analysis.

AKF390 Accelerometer: The AKF390 sensor, developed and manufactured by RION Technology, is a low-power consumption device with factory calibration, a robust structure, and a stable voltage output signal. This sensor will be placed directly on the vehicle floor to measure vibrations during the experiment. It provides accurate data on the vibration levels of the vehicle floor as the car moves over road segments with varying roughness.

Fig. 1. AKF390 Rion Accelerometer

Fig. 2. Vibra-Metrics Model 1000 Accelerometer

Vibra-Metrics Model 1000 Accelerometer: The Vibra-Metrics Model 1000 is a high-frequency accelerometer designed for vibration measurement. This sensor will be mounted directly on the seat frame, near the headrest area, to measure vertical vibrations. It helps assess the ride comfort experienced by passengers while seated.

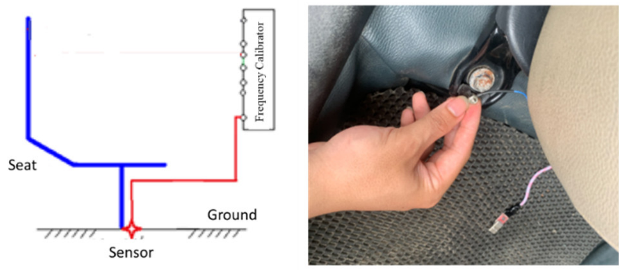

Fig. 3. Sensors installation on vehicle seat and floor

GF302 Frequency Calibrator: The GF302 frequency calibrator is used to ensure the accuracy of sensor signals by standardizing the voltage output of the sensors. This calibrator helps guarantee precise sensor calibration, providing stable and reliable measurement results.

Fig. 4. GF302 frequency calibrator

CarLab Test DAQ Software: The CarLab Test DAQ software is used to interface sensor signals with the data acquisition (DAQ) system. This software collects voltage signals as the vehicle moves over rough road segments, enabling the processing and analysis of seat and floor vibrations.

Fig. 5. CarLab Test DAQ interface

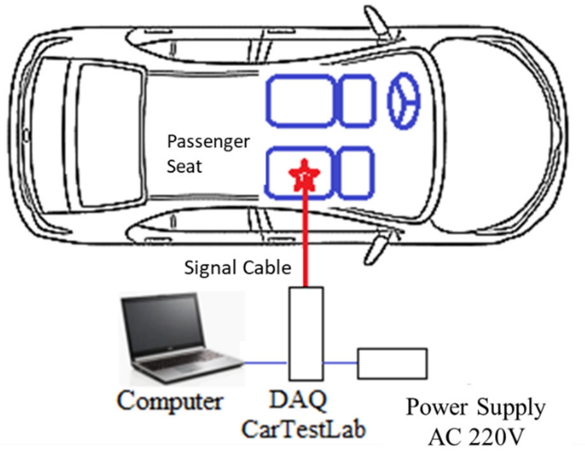

Fig. 6. Experiment setup diagram

A sinusoidal-shaped bump road surface was designed and manufactured according to the standards of the Vietnam Directorate for Roads [5].

After completing the preparation steps, the research team conducted the experiment on the vehicle at a speed of 20km/h.

Fig. 7. Sine-shaped speed bump

2.2. Experiment process

The AKF390 sensor will be securely mounted on the vehicle floor to measure vibrations caused by road surface irregularities. The Vibra-Metrics Model 1000 sensor will be placed on the seat frame, near the headrest area, to measure vertical vibrations perceived by passengers. The GF302 frequency calibrator will be used to calibrate both sensors, ensuring the accuracy and stability of the recorded signals. The CarLab Test DAQ software will continuously record voltage signals from both sensors as the vehicle moves over different road conditions (smooth, moderately rough, and highly uneven surfaces). The collected data will be analyzed to assess the vibration characteristics of both the vehicle floor and the seat. The results will provide insights into how the suspension system influences ride quality and passenger comfort.

3. DATA PROCESSING, ANALYSIS AND EVALUATION

3.1. Data processing

The signals from the sensors will be recorded and processed in real time through the CarLab Test DAQ software. The collected data will be analyzed to determine the amplitude, frequency, and vibration patterns as the vehicle moves through different road conditions. The correlation between vibrations measured on the vehicle floor and the seat will be evaluated to assess ride quality and passenger comfort.

The combination of high-precision sensors, reliable calibration, and advanced data analysis ensures that the results obtained are accurate and applicable to real-world driving scenarios.

3.2. Data analysis and result evaluation

The floor vibration acceleration is presented in Fig. 8.

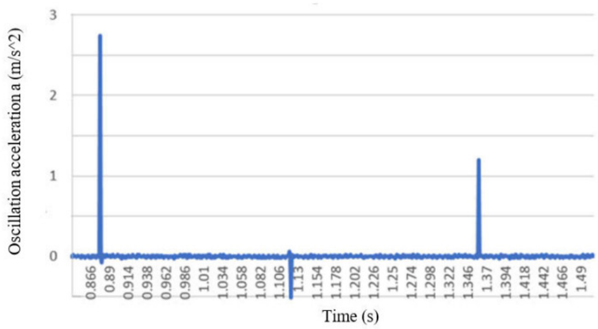

Fig. 8. Graph of vehicle floor vibration

From the results obtained, it can be observed that when the vehicle passes over bumps, the floor experiences stronger vibrations, causing a sudden increase in acceleration. Immediately after passing the bumps, the vehicle returns to a stable state with smaller vibration amplitudes.

3.3. Compare results between simulation and experiment

Simulated vibration acceleration of the vehicle floor in Fig. 9.

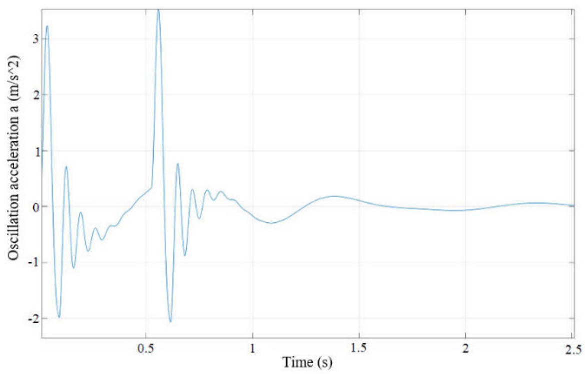

Fig. 9. Graph of vehicle body acceleration in simulation

From Fig. 8 and Fig. 9, the similarity in vibration acceleration amplitudes is evident, demonstrating that the vibration model is highly accurate and effectively reflects the vehicle's actual vibrations. However, it can be observed that most experimentally measured acceleration values are lower than the simulated ones. This discrepancy may be attributed to measurement instrument errors, mounting variations, and uncertainties during the experimental process.

4. CONCLUSION

This study investigates the impact of suspension system dynamics on ride comfort and vehicle vibrations in a 5-seat sedan. Using experimental measurements with simulations, we analyzed vibrations at the vehicle floor and passenger seat using the AKF390 and Vibra-Metrics Model 1000 sensors.

The results indicate that road surface irregularities significantly affect vehicle vibrations, particularly contributing to passenger discomfort. This study highlights the importance of an effective suspension system in minimizing vibrations caused by uneven road conditions. Furthermore, the comparison between the theoretical model and experimental data provides valuable insights for improving suspension system design.

The findings contribute to optimizing suspension systems, enhancing vehicle performance, stability, and passenger comfort, especially on rough roads.

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