©2016 Published in 4th International Symposium on Innovative Technologies in Engineering and Science 3-5 November 2016 (ISITES2016 Alanya/Antalya - Turkey)

A Case Study for a Bus Body Design Improvement Using Virtual Analysis Methods

*Muslum Yaman, Volkan Yildiz, Emre Sert, Sertac Dileroglu, Ahmet Salih Yilmaz
Anadolu Isuzu Automotive Co.

Abstract

CAE (Computer Aided Engineering) has been an important tool in the process of automotive product development. CAE significance has gained ground in the recent years through the introduction of the "No Prototype" vehicle concept. In this essay, an innovative LED destination board implemented to a bus and possible failure on the bus body is investigated using virtual analysis method. Modal analysis has been performed for bus body structure. A resonance of the flexible vibration of bus body has been detected and resonance cancellation has been performed via modal separation in earliest stage of development.

Key words: Virtual analysis, vibration analysis, modal seperation

1. Introduction

Over the last few years, manufacturers have focused on surviving the down economy and preparing to prosper as markets recover. CAE allows companies to meet the demands for reduce cost and faster time to market, but without compromising product quality. One strategy that is providing value in this environment is digital design validation using simulation technologies.

Generally, classical LED destination board is used for urban buses. In this study, innovative LED destination board implemented to a urban bus and possible failure on the bus body is investigated in terms of vehicle noise and vibration design principles using CAE tools.

In literature survey, Huailong Shi and Pingbo Wu can find feasible solution to avoid resonance in their study.The resonance of the flexible vibration of car body, which has not been detected before on a passenger coach, occurred recently on a high-speed Electric multi units (EMU) when the train was running at 300 km/h on Beijing-Shanghai line. In this investigation, the force transmission from track to car body via suspensions is elaborated first with possibly induced factors briefly discussed. Both the measurements and experiments in field and in laboratory were conducted to evaluate the resonances and the excitation as well as transmission. Moreover, a three-dimensional railroad vehicle model was built in a computational non-linear Multibody system (MBS) framework, inwhich the car body flexibility was modeled using Finite element (FE) method[1].

Shoabo Young define that decouple frequency of excitation forces from frequencies of vehicle structures or acoustic cavities. This is done by designing the vehicle so that the resonances of the vehicle, systems and subsystems are separated in frequencies[2].
Xu Li perform modal analysis for bus body frame using Finite Element Method and explain the advantage of the virtual analysis methods. Because the bus body frame is very complex structure,

*Corresponding author: Address: Anadolu Isuzu Otomotiv Sanayi A.Ş., Şekerpınar Mah. Otomotiv Cad. No:2, 41435, Çayırova / Kocaeli TURKEY. E-mail address: muslum.yaman@isuzu.com.tr, Phone: +908502001558

experimental modal analysis has some difficulty, and the method cycles are long with heavy workload and high costs, it is not favorable for control and evaluation for ride comfort during the period of early product design and development, which limits the modal analysis applications on the passenger car body[3].

Zhewen Tian et al. establish a school bus body frame finite element model for modal analysis. Analyzing the free modal of the body frame get the inherent frequency and vibration mode, and evaluate the body frame vibration characteristics, and put forward improvement proposal on the problem of body frame[4].

2. Innovative LED Destination Board Design Application

Classical LED Destination Board

Continuous Curved LED Destination Board

Figure 1. Classical Design and Innovative Design

Continuous curved LED destination board implementation was planned for a urban bus project at the early-phase of bus body development. The idea behind this; passenger standing on the bus station can see the destination board not only on front side of the bus but also on the right-hand side of the bus. Despite the innovative idea, the implementation can cause vibration and noise problem on the front upper corner of the bus body frame. Wide door mounting place and continuous curved LED destination board mounting place can cause front door side structure stiffness degradation. So, possible vibration and noise problem can occur on physical prototype. Possible problem will be fixed in this study before physical prototype phase of development process. In order to examine possible vibration problem three-dimensional vehicle model was built in a computational non-linear multibody dynamic system (MBDS) framework, in which the bus body flexibility was modelled using finite element (FE) method.

3. CAE Model and Analysis

According the modal theory, excitation frequency should be decouple from natural frequency of bus body structure. The most important vibration excitation source is suspension for frame front upper corner area. Because of that, the force transmission from road to bus body through suspensions will be investigated.

In order to determine suspension excitation frequency originated from tire-road interaction MBDS model is used and also Msc. Adams software is used for multibody dynamic model analysis.

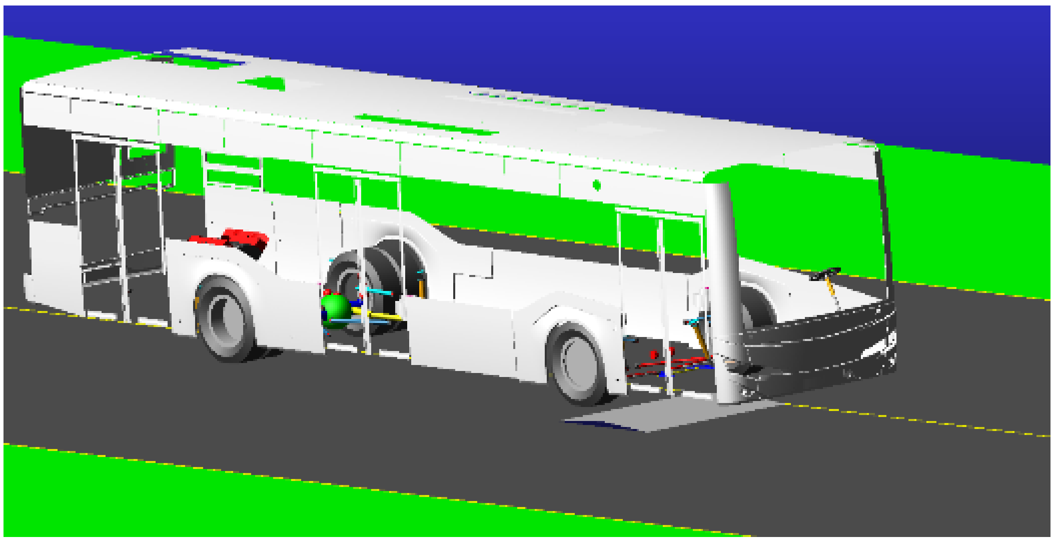


Figure 2. Msc. Adams Multibody Dynamic Model Analysis

MBDS model's right tire is passed over the bump with a vehicle speed of 15km/h. Moreover, the bus body front side excite to roll motion. Acceleration data acquired under air suspension front axle attachment point (Figure 3). Air suspension excitation frequency is determined using FFT analysis method (Figure 4).

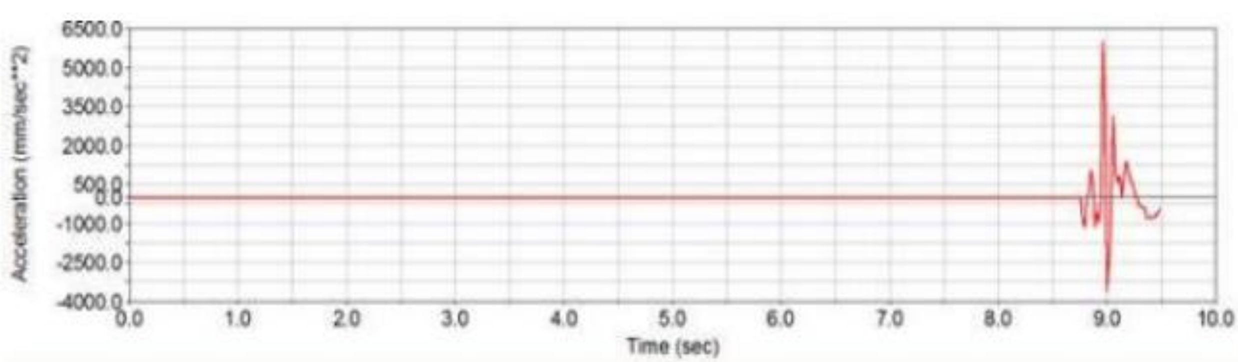


Figure 3. Air Suspension Time Domain Acceralation in Lateral(y) Direction

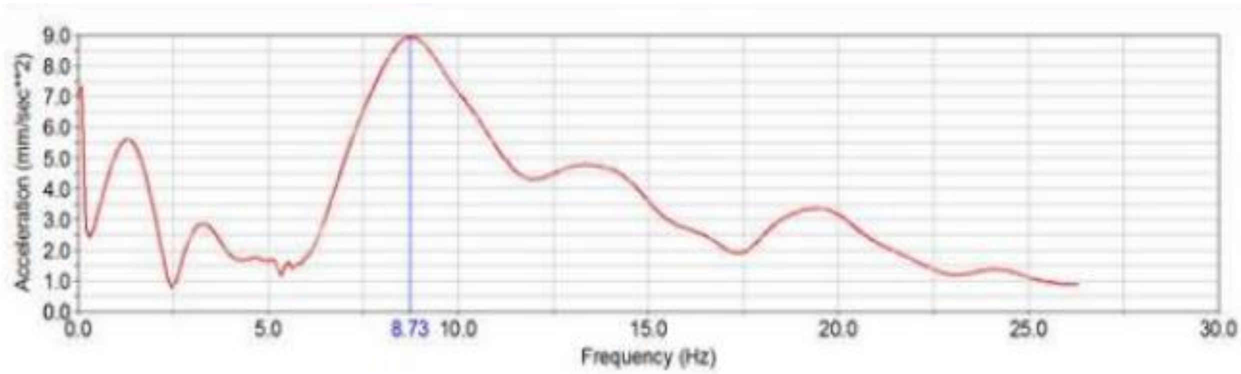


Figure 4. Acceralation Data's FFT Spectrum

Bus front body frame excite to roll motion, while vehicle pass the bump. Frequency peak on the FFT spectrum shows that air suspension has excitation frequency at 8,73 Hz.

Additonally, Modal analysis has been performed, in order to determine natural frequency of the flexible body structure. Altair hyperworks softwares are used for FE model. The natural frequency and mode shape of the bus body structure have been obtained around the frequency range of interest at free-free boundary condition.

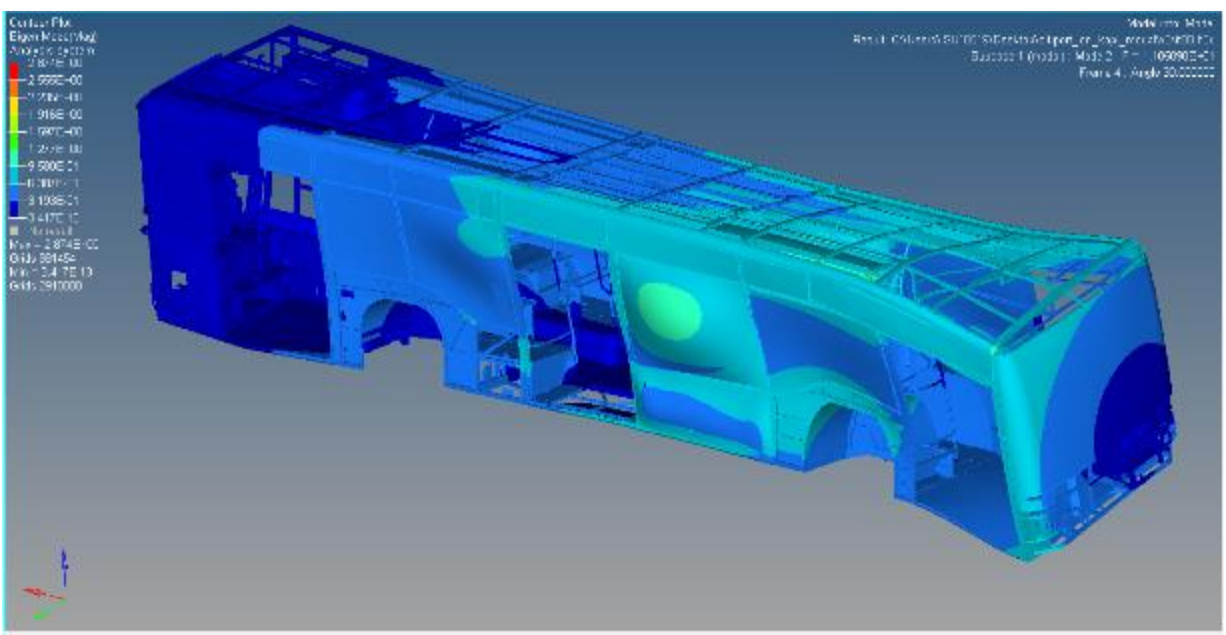


Figure 5. Bus Front Structure Natural Frequency @11,05 Hz and Its Mode Shape

Modal analysis was performed between the range of 6-12 Hz frequency and one flexible natural frequency was found between frequency of interest. Bus body frame has a local natural frequency at 11,05 Hz.

4. Modal Seperation

According the modal theory, excitation frequency should be decouple from natural frequency of bus body structure. There must be at least 2,5 Hz between excitation frequency and body natural frequency. Because of that, bus body local natural frequency will be increased through given design change proposals below;

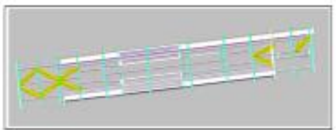
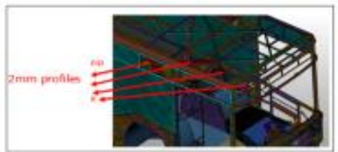
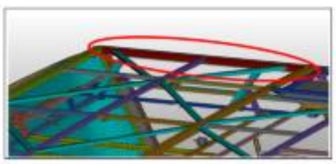
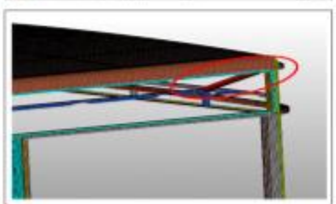
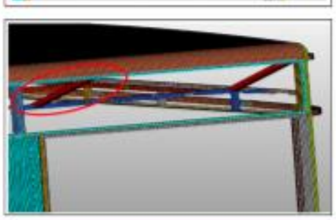
İterations	Design Change Explanations	Design Change Proposals	Natural Frequency (Hz)		Mass Increase	
it 00	Base Design		11,05	Hz		
it 01	Add 1,5 mm profiles to the ceiling		11,07	Hz	11	kg
it 02	Add 2mm 4 profile right-hand side of the body structure		11,16	Hz	4,9	kg
it 03	Add 3mm U shape profile to upper side of the door area		11,28	Hz	3,7	kg
it04	Increase thicness of the red profiles from 1,5mm to 2mm		11,29	Hz	3,5	kg
it05	Add 2mm first cross profile to the right-hand side of the bus frame		11,29	Hz	1	kg
it06	Add 2mm second cross profile to the right-hand side of the bus frame		11,3	Hz	1	kg
TOTAL WEIGHT INCREASE					25,1	kg

Figure 6. Design Change Proposals to Increase Interested Natural Frequency of Body

FRF (frequency response function) evaluation was performed with unit force and also resonance peaks were investigated. Acceleration level decrease can be seen from the Figure 7 for frequency range of interest.

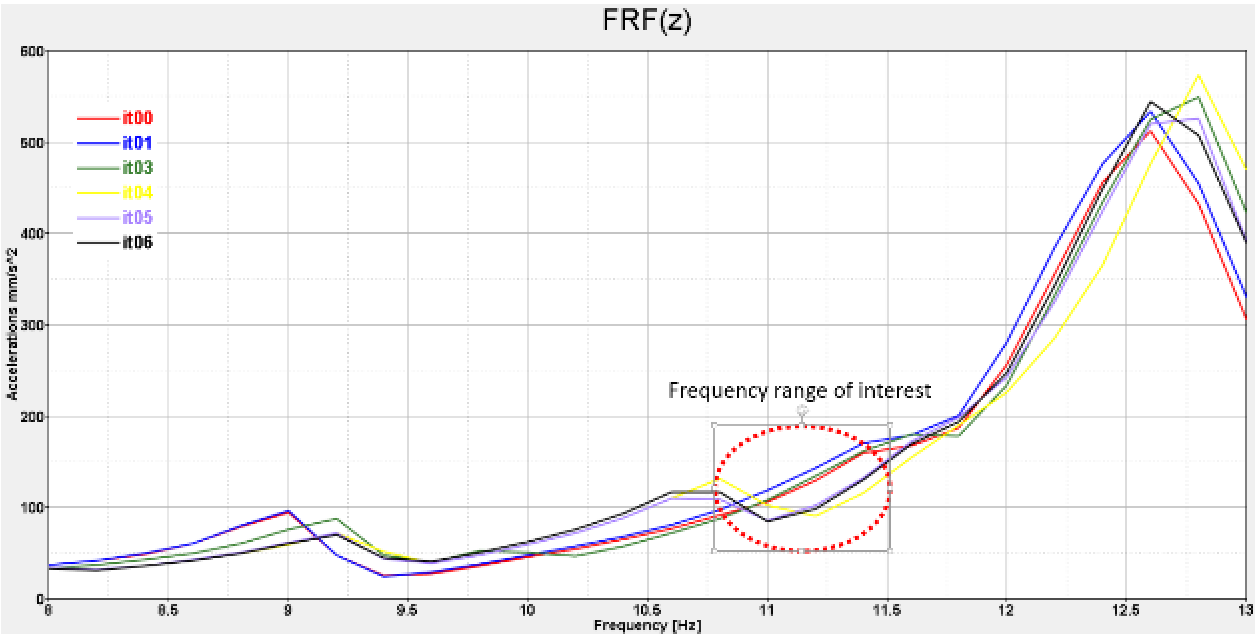


Figure 7. Unit Force FRF Evaluation

Excitation frequency (8,73 Hz) and body structure flexible natural frequency (11,3 Hz) was separated by 2,57 Hz. Under this condition any structural resonance is not supposed to arise on structure.

5. Validation Test

Two different bus body (Base design and improved bus body design) were produced and drove rough road with vehicle speed of 15km/h. The base design vehicle have annoying noise upper side of the front door. After design change implementation, improved design eliminate the annoying noise.

In order to present vibration level change, acceleration data acquired from buses have different front frame design.

Accelerometer locations can be seen from Figure 8.

Figure 8. Accelerometer Location

FFT spectrum of accerelation data can be seen from Figure 9.

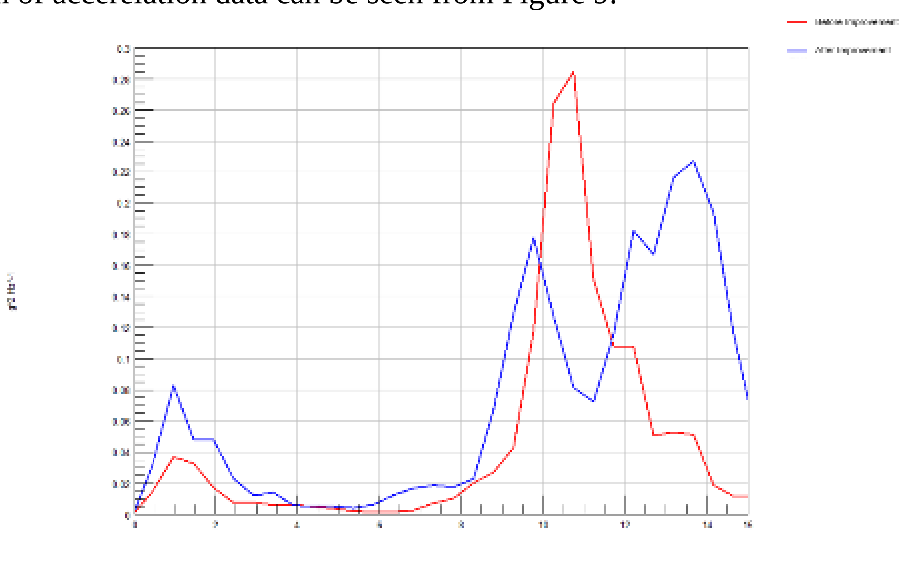


Figure 9. FFT Spectrum of Acceleration Datas for Two Different Design

Red line on the figure shows FFT spectrum of the base design. Blue line on the figure shows FFT spectrum of the improved design. Acceleration magnitude of FFT spectrums show that vibration level of upper door is decreased with proposed design.

6.Conclusions

Innovative continuous curved LED destination board implemented to new product. Using virtual analysis methods, possible problem was determined before physical prototype phase. Modal separation study was performed. This study shows that 2,5 Hz frequency difference between excitation frequency and natural frequency of the body prevent the structural resonance problem and also noise problem of vehicle.

7.References

Reference to a journal publication:
[1] Shi H, and Wu P. Flexible vibration analysis for car body of high-speed EMU. Journal of Mechanical Science and Technology; 2016, 30(1):55–56.
[2] Young S. Vehicle NVH development process and technologies. The 21st International Congress on Sound and Vibration; 2014, 13-17 July.
[3] Xu L. Ansys Application in Modal Analysis of Bus Body Frame. Advanced Materials Research; 2012, Vols. 605-607: pp. 656-659.
[4] Tian ZW, Wei YG, Si HJ, Mei XM, Kuang Y. Ansys Modal Analysis of School Bus Body Frame. Advanced Materials Research; 2014, Vols. 445-449: pp. 61-65.