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A Study of Light Truck Cab Elasticity Impact on Ride Comfort

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Abstract: Taking a light truck for study, using finite element method and virtual prototyping technology to establish a vehicle's rigid model and rigid-flexible coupling model considered cab elasticity. On a random road with cab suspension of rubber and semi-floating we made a simulation analysis on vehicle ride comfort, taking into account acceleration power spectral density and weighted acceleration rms of cab elastic effect on driver's seat pan, and in accordance with relevant standards, both models were analyzed for comparison. The results showing that cab elastic has a certain influence on vehicle ride comfort, this will provide references for further study as well as vehicle cab design. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Rigid model, Rigid-flexible coupling, Ride comfort, Weighted rms.

1. Introduction

Car Ride is the ability to absorb shocks and vibrations when driving cars, keeping the impact of vibration and shock generated by car motion on occupant comfort within certain boundaries, which is an important indicator to evaluate car performance. The performance will directly affect other vehicle ability and life of car, while vehicle ride comfort is also related to car's competitiveness in the market [1].

In the course of previous studies on truck ride, found that the frame elasticity has a great influence on vehicle's ride comfort [2-4], and regarded cab as a rigid body ignoring its elastic deformation during motion analysis. In fact when driving a car, road roughness will have some impact on cab deformation. If considering the cab elastic deformation, it can be a more realistic evaluation of vehicle's ride comfort. So we need to study the impact of rigid cab and elastic cab on vehicle's ride simulation analysis. In addition, taking into account cab suspension as vehicle's second suspension, these two models of cab in rubber suspension and semi-floating suspension were both analyzed for comparison.

This paper taking a truck for the study, makes a finite element model of cab with analysis software Hypermesh, and derives a modal neutral file (MNF) of cab in Hypermesh, and then established vehicle rigid-flexible coupling model and rigid model with software ADAMS, and using ADAMS ride analysis module to complete comparative simulation of the two models in different cab suspension.

2. Basic Characteristic Parameters of a Vehicle

A major factor affecting the analysis accuracy of vehicle ride comfort is the parameters precision of car model, so it is very important in modeling process to make parameters as much as possible close to the actual value. Vehicle characteristic parameters include kinematic parameters, quality parameters, and mechanical parameters. Method to get the model parameters are: experimental test, calculation, CAD modeling approach, drawings inspection method etc. [5-6]. According to CATIA models of some company, as well as CAD drawings and related data files, we get the basic characteristic parameters of vehicle: Cab weight 425 kg, vehicle curb weight 3280 kg, wheelbase 3815 mm.

Fig. 1 – Fig. 3 shows some characteristic curve of rubber and semi-floating suspension elements.

All three directions rubber suspension damping are 0.5 N•s/mm. Semi-floating suspension damping coefficient is 4000 N•s/mm.

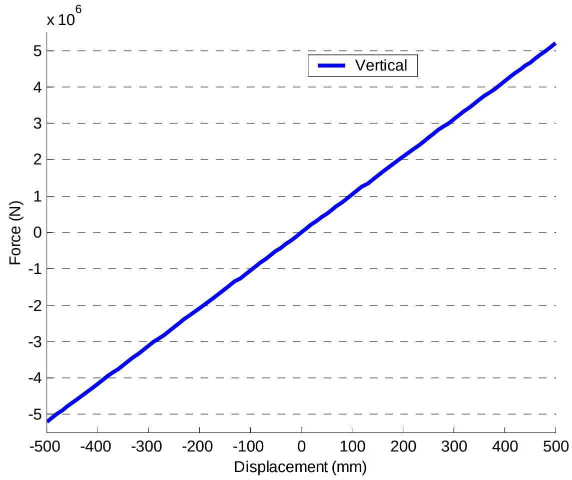

Fig. 2. Spring stiffness characteristics of semi-floating suspension.

3. Models of Vehicle

3.1. Establish Cab Elastomeric Model

When finite element model connected to multi-rigid model, due to the large number of freedom degree of finite element model, it must be reduced to fewer freedom of finite element dynamic model, which process is called power reduction. Using component mode synthesis method in MSC/ADAMS software, inter-components modal integrated through super-cell implemented in finite element analysis, and in MSC/ADAMS super-cell model is transformed to elastomeric element of multi-rigid kinetic model.

Before creating cab elastic model in ADAMS, need to build finite element model of cab in Hypermesh according cab CAD models provided by manufacturer, and setting relevant card in Hypermesh, then converted the cab finite element model into ADAMS modal neutral file, that is MNF format. Finally, imported cab modal neutral file into ADAMS, we establish cab elastomeric models.

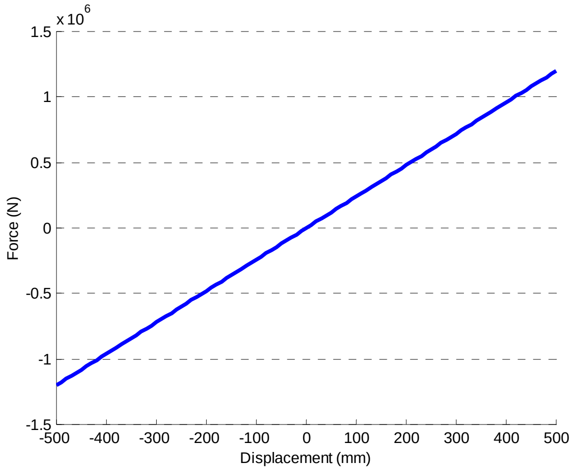

Fig. 3. Bush stiffness characteristics of semi-floating suspension.

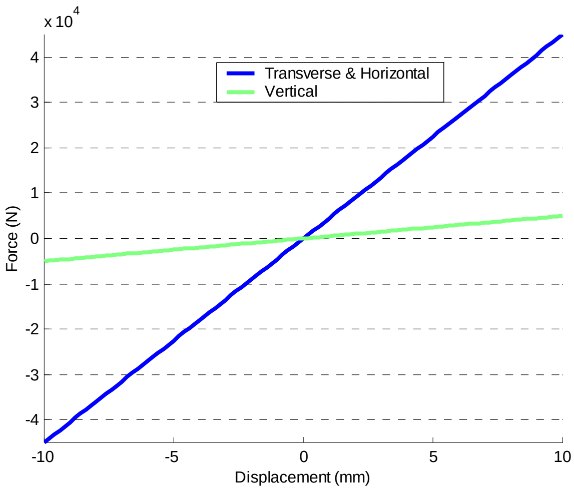

Fig. 1. Stiffness characteristics of rubber suspension.

3.2. Building Cab Rigid Model

Rigid body model is relatively simple, we can directly make use of ADAMS/Car's rigid model, the mass of rigid body focused on position of centroid, and the specific location is determined by vehicle parameters. Due to geometry making no impact on the simulation, so we just use simple geometry schematic of cab outline.

3.3. Establishment of Vehicle Models

The car is a very complex system, to establish an actual identical prototype model is neither realistic nor necessary, therefore, only parts which have major impact on analysis results need to establish the corresponding prototype, so as to achieve efficient and effective modeling analysis without compromising accuracy. Therefore, in modeling we build relevant models of suspension system, chassis, axles and tires, which caused several major influence on vehicle ride. According to the obtained data, model parameters modified in the software, we obtain a desired accurate simulation model. Fig. 4 and Fig. 5 show vehicle assembly model diagram.

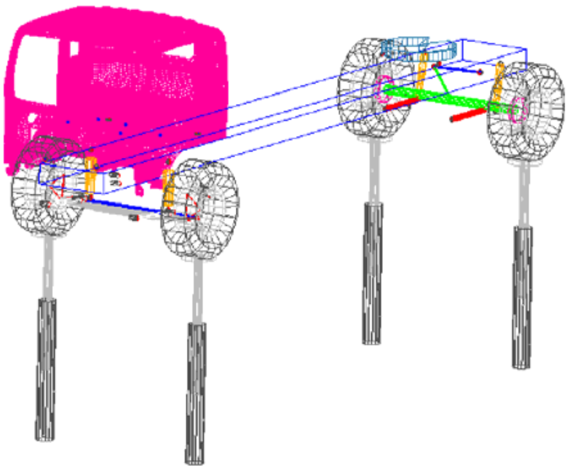

Fig. 4. Vehicle rigid-flexible coupling model.

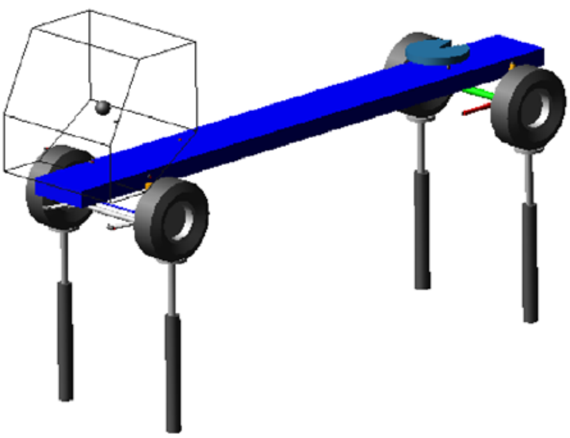

Fig. 5. Vehicle rigid body model.

3.4. Establishment of Random Road Profile

Ride-Profile Generation is a road generation tool of digital model provided by ADAMS/Car Ride; the model is based on Sayers empirical model, a combination of many different types of road measurement parameters, and can be used to describe actual road random roughness. Simultaneously given left and right tread surface profile parameters, the model input length unit is m, and output random height of left and right tread is mm [7, 8].

In the road generator, generate random road parameters: spatial power spectral density G_e=0, speed power spectral density G_s=12, acceleration power spectral density G_a=0.17. Class B road surface profile generated by the profile generator is shown in Fig. 6.

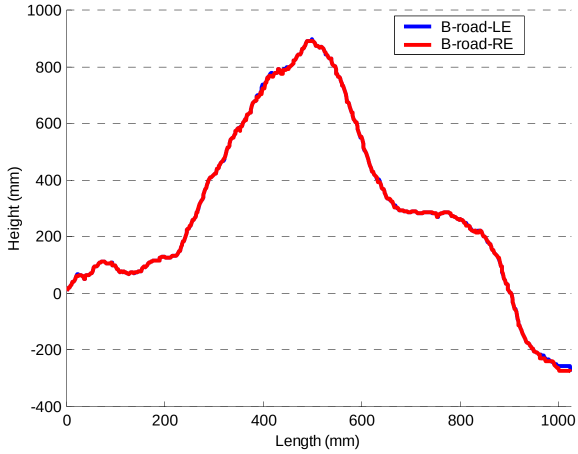

Fig. 6. Road profile curve.

4. Simulation Results of Vehicle

4.1. Evaluation of Ride Comfort

According to ISO2631: 1997 (E) standard, when vibration waveform peak factor<9 (peak coefficient is the ratio of peak value of weighted acceleration time process a_w (t) to mean square acceleration a_w), with basic evaluation method of weighted rms acceleration to evaluate the effects of vibration on human comfort and health. According to measurements, various car in normal driving conditions are applicable to this method [9, 10], the specific calculation process can refer to relevant literature.

4.2. Vehicle Simulation on Ride Comfort

Selected 3 axial weighted rms acceleration on the floor beneath driver's seat as vehicle ride comfort evaluation index, we made comparative analysis on ride comfort of two models with reference to evaluation method described above. When conducted simulation analysis using ADAMS/Car Ride, the test trucks with rigid model and rigid-flexible coupling model ride at constant speed of 60 km/h on B-class road, measuring 3 axial vibration acceleration time course on the floor beneath driver's seat [11, 12]. Fig. 7 – Fig. 9 and Fig. 10 – Fig. 12 show 3 axial acceleration response time-domain curves of rigid model and rigid-flexible coupling model using rubber suspension measured on the floor beneath driver's seat.

Fig. 7 – Fig. 12 clearly show that vertical acceleration responses were greater than horizontal, transverse acceleration. Thus, the vertical acceleration response has great impact on Ride Comfort, which is more prominent in rigid model. Moreover, in rigid model, the vertical acceleration response appears two distinct peaks.

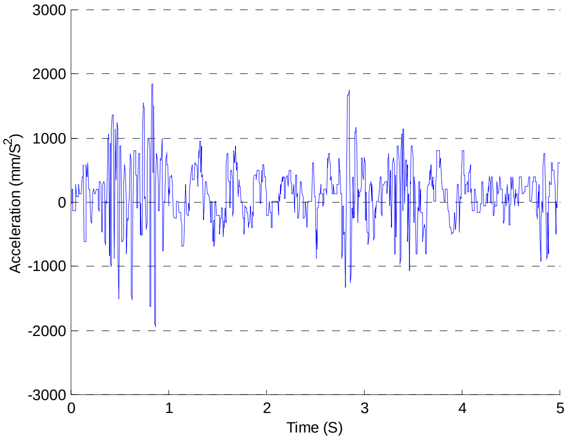

Fig. 7. X_Acceleration of rigid model.

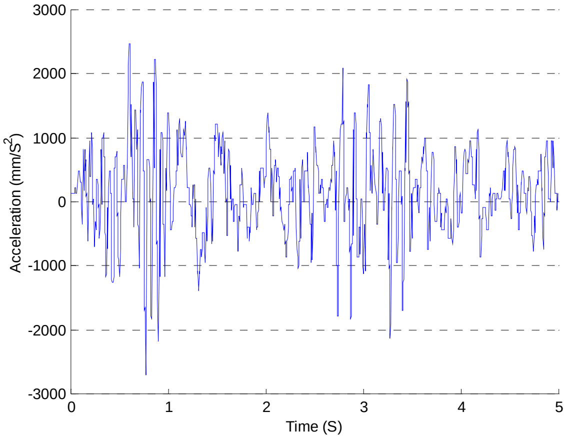

Fig. 8. Y_Acceleration of rigid model.

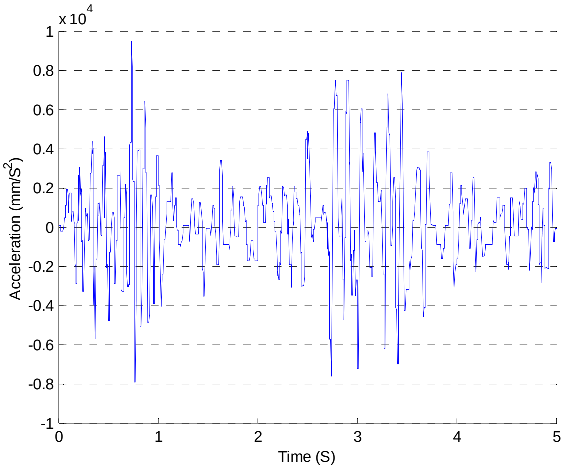

Fig. 9. Z_Acceleration of rigid model.

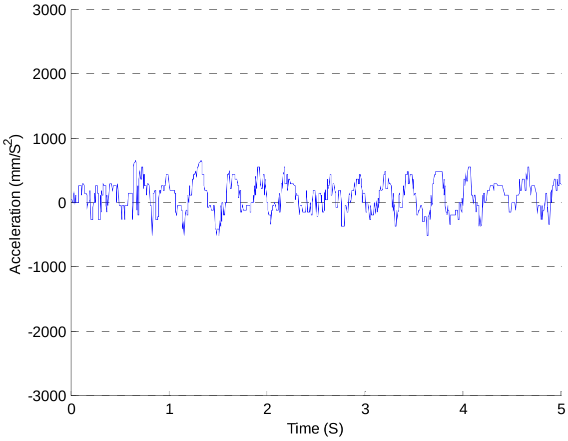

Fig. 10. X_Acceleration of rigid-flexible model.

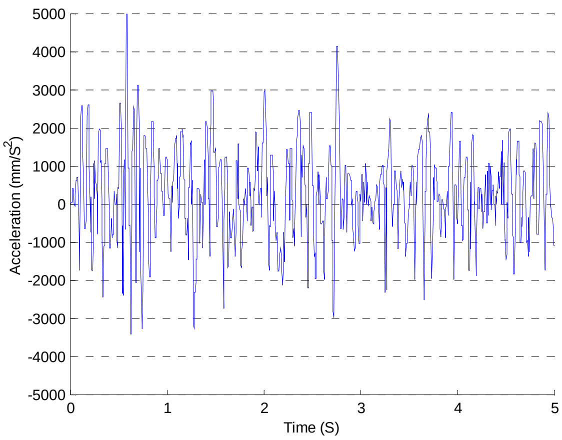

Fig. 11. Y_Acceleration of rigid-flexible model.

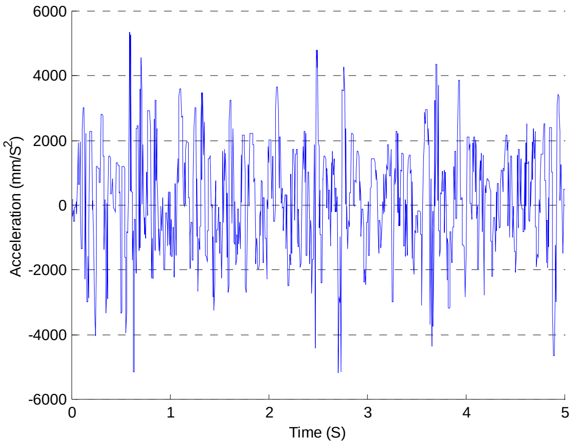

Fig. 12. Z_Acceleration of rigid-flexible model.

In order to analyze the acceleration response difference between the two models, and taking into account vertical acceleration response impact on ride, Fig. 13 shows a comparison of the two models in vertical acceleration time-domain curves.

The blue line in Fig. 13 represents a vertical acceleration time-domain response of rigid-flexible coupling model, while red line represents the vertical acceleration time-domain response of rigid model.

Through comparative analysis, acceleration value of rigid model is significantly greater than rigid-flexible coupling model in two major locations, but has little difference in other locations, nevertheless these two curves are very close in other locations. Overall, the vertical acceleration response of rigid model is greater than coupled model.

According to the evaluation formula on ride comfort, in ADAMS/PostProcessor doing FFT computation of acceleration response time-domain curves, we get acceleration power spectral density (Acceleration PSD) curve. Here Fig. 14 and Fig. 15 shows vertical acceleration power spectral density curves of the two models.

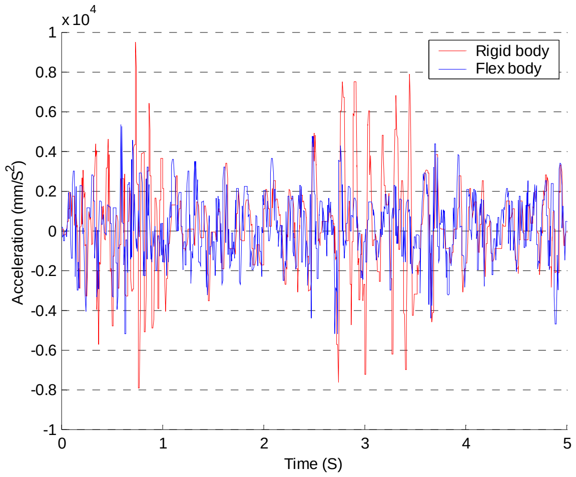

Fig. 13. Rigid model vs. rigid-flexible model.

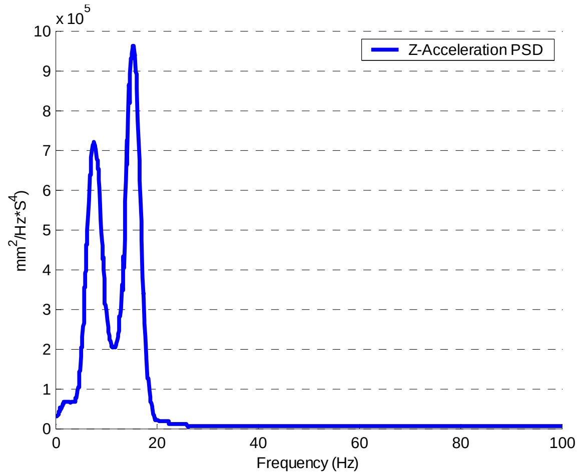

Fig. 14. Z_Acceleration power spectral density of rigid model.

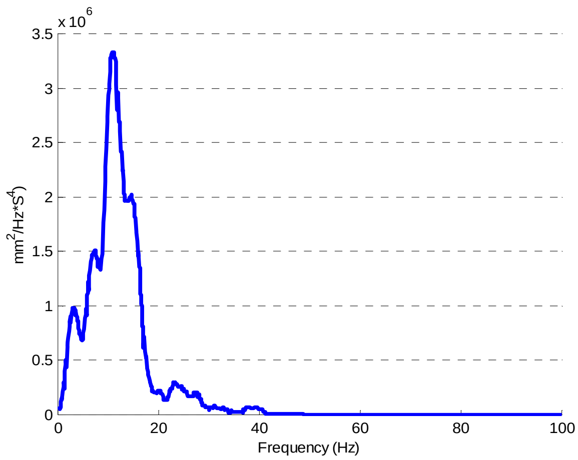

Fig. 15. Z_Acceleration power spectral density of rigid-flexible coupling model.

As can be seen from Fig. 14, curve of rigid body model occurs two vibration peaks, corresponding to two vibration frequency, which are respectively 7.75 Hz and 15.25 Hz. While in Fig. 15 of rigid-flexible coupling model, there has been a major peak, which corresponds to a frequency of 10.89 Hz.

Based on the above analysis, 3 axial weighted acceleration rms and total weighted acceleration rms value of the two models on the floor beneath driver's seat can be calculated according to the formula, as shown in Table 1.

Table 1. Comparison of 3 axial weighted acceleration rms and total weighted acceleration rms value of two models.

	Rigid Model	**Rigid-Flexible Coupling Model**	**Results Comparison**
X-axis $a_{xw}/(m/s^2)$	0.143	0.128	+0.015
Y-axis $a_{yw}/(m/s^2)$	0.297	0.086	0.383
Z-axis $a_{zw}/(m/s^2)$	2.299	1.495	+0.804
$a_v/(m/s^2)$	2.345	1.598	+0.747

Last column of Table 1 is a numerical result of rigid model subtracting coupled model, "+ " indicates rigid model result is greater than rigid coupling; " - " indicates that rigid body model result is less than coupled model.

After analyzing the data in Table 1, it can be concluded that horizontal, vertical, and total weighted acceleration rms of rigid body model are all greater than coupled model, only transverse weighted acceleration rms is less than rigid-flexible coupling model.

That is easy to see with suspension systems, axles and tires unchanged, the greater cab rigidity, worse vehicle ride comfort, actual elastomer is better predicted cab ride than the average rigid model.

In order to do further analysis and comparison of the two models, we make the same simulation in case of semi-floating suspension, through calculation obtained Table 2.

Last column of Table 2 has a same meaning as in Table 1.

Table 2. Comparison of 3 axial weighted acceleration rms and total weighted acceleration rms value of two models under semi-floating suspension.

	Rigid Model	**Rigid-Flexible Coupling Model**	**Results Comparison**
X-axis $a_{xw}/(m/s^2)$	0.556	0.104	+0.452
Y-axis $a_{yw}/(m/s^2)$	0.283	0. 313	-0. 030
Z-axis $a_{zw}/(m/s^2)$	1. 389	1. 310	+0. 079
$a_v/(m/s^2)$	1. 641	1. 389	+0. 252

Analyzing data in Table 2, it is found that in semi-floating suspension, except for transverse weighted acceleration rms of coupled model is greater than rigid model, the value of the other directions are less than rigid model; ride comfort of rigid model in this case has been significantly improved, rigid-flexible coupling model ride has also been further improved, and ride comfort of coupled model is better than rigid model, by comparing obtained the previous similar results.

Special note that the above data are weighted acceleration rms at the bottom of the driver's seat, rather than weighted acceleration rms on the seat surface, considering human body- seat system further attenuating acceleration, the actual vehicle ride is even better.

5. Conclusions

Using multi-body dynamics software ADAMS, created two different models of the vehicle, through simulation analysis and comparison of the model in the case of two different cab suspensions, obtained the ride difference in the two models, found that coupled model has a better ride comport. However, in the actual design and development of automotive, the cab should have a certain rigidity to meet performance requirements, which require more in-depth study of the cab, the cab in order to select the appropriate stiffness to achieve better vehicle performance. The above simulation results play a guiding role on the vehicle ride further analysis, but also provide a reference for cab design and development, has laid a good foundation for the next step analysis.

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