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The Application of Simulink for Vibration Simulation of Suspension Dual-mass System

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Abstract: The car's suspension play a decisive role in car's driving smoothness and handling exercised stability. Therefore, the research of suspension is vital important. This paper presents a simulation of Suspension Dual-mass System based on mathematical formula of the car wheel and body double quality system, and the suspension dual-mass system model which established by using the Simulink. And taken the suspension spring stiffness, shock absorber damping coefficient, the given incentives for the road as the basic parameters for suspension vibration system simulation model, the results prove the feasibility and effectiveness of the model, and the vibration characteristics of the suspension during the analysis process, we are convenient and quick to adjust the corresponding parameter independently by using this simulation model, can get an intuitive vibration characteristics of the image data, get a better analysis of the simulation results meet the design requirements. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Suspension Dual-mass, Simulink, Simulation, Driving smoothness.

1. Introduction

Typically, the suspension is the general term that ensures the wheels or axles and cars' loading systems to have elastic connection and transfers loads, eases shock, decays vibration and adjusts the cars' body position and attitude of running. The suspension system plays the effects that transfers the force and moment between the wheels and the frame, guidance and control of the car wheels and the relative motion of the body, to ease the impact of the rode to the frame, and decays the systems vibration. Currently, the world's research institutions and major car companies have invested a large number of human and material resources, to develop the cost-effective vehicle suspension dual-mass system so that it can be fully widely used [1].

Suspension performance dual-mass system is affecting the comfort, safety and handling stability, which should have different performances in different driving conditions. For example: The car should have a good ride when the vehicles run straightly and the speed is stability; the vehicles should have a high steering stability when cars is steering or braking. Therefore, vibration characteristics of the suspension system are to study the car ride comfort [2].

With the suspension system becoming more complex and the suspension system simulation's requirements continue to increase, making use of differential equations to establish the dynamic simulation traditionally require many programming, It is heavy workload, low efficiency, and not nice to meet simulation requirements. Matlab language

sets the functions of scientific computing, automatic control, signal processing and so on in oneself with a high programming efficiency. Meanwhile Matlab also provides the Simulink, being used of the software can easily study the suspension dual-mass system by simulation, design the parameters and validate the vehicle riding comfort, improve the speed and quality of designing suspension can effectively. We can complete the main analysis of the riding comfort, can greatly simplify the steps when studying the vibration characteristics of the suspension through the established simulation model of suspension dual-mass system, and the simulation model parameters can be adjusted independently of the vehicle interior and driving external parameters, the operation simple and quick, intuitive and reliable results. Dynamic simulation of automotive suspension dual-mass system is of great significance for improving vehicle riding comfort and safety [3].

2. Overview of Automotive Suspension

Modern Motor is currently working to improve the safety and comfort in addition to ensuring their basic properties, namely driving performance, steering and braking, etc. Comfort of the car is one of the most important performances, but in this regard, in order to improve the cars' handling stability and ride comfort, the suspension must make the appropriate improvements.

Automotive suspension including three parts, they are elastic components, shock absorber sand power transmission devices, this three-part separately play the effect of buffer, shock absorber and force transmission. Elastic element transfer vertical force, and mitigate shock and vibration caused by the road roughness; vibration damper is to accelerate the decay of the body, the shock absorber in suspension mechanism is the most sophisticated and complex mechanical parts; vehicle power transmission device is the upper and lower arms, steering knuckles and other components, is used to transfer longitudinal force, lateral force and moment, to ensure that the wheels relative to the frame (or body) has determined the relative motion law [4].

The main role of suspension is to pass the suspension acting on the wheel and the body all the forces and moments, for example the driving force, braking force and support force, etc. And uneven road passed by the body to ease the impact load, vibration attenuation resulting ensure occupant comfort, reduced cargo and vehicle dynamic load itself. Suspension and preperformance variety of car, in order to fulfill these capability, the suspension system must be able to meet the se performance requirements: First, to guarantee that the auto has a high ride comfort; secondly, to ensure that the body and wheel suspension resonant region small amplitude vibration distringas; once again, to be able to ensure the car has good handling stability, on the one hand, suspension must ensure when the wheels runout, wheel alignment parameters do not change a lot, on the other hand to reduce the dynamic load wheel sand wheel runout, there is to ensure that the body in the braking, cornering, stability during acceleration, pitch and roll body decreases; finally, to pledge the reliability of the suspension system, and enough intensity, stiffness and lifespan. Simultaneously, the vehicle suspension is both a mechanical power transmission that link frame and axle, also is the important part to ensure the safety of cars. Therefore, the vehicle suspensions are often incorporated into the car's technical specifications sheet as important components, be considered as a significant indicator to measure car's quality.

3. Suspension Vibration Simulation Dual-mass System

3.1. Dual-mass System Model

Spring is said of the relationship of force and displacement components, the mechanics model, it is abstract become no quality and has a linear elastic element; damper is a relationship between force and velocity components in the mechanical model, which is abstracted into mass less and with linear damping element; quality is the relationship between force and acceleration components in the mechanical model, which is abstracted into an absolute constant rigid body. Thus, we can simplify the suspension system of two degrees of freedom dual-mass vibration system is shown in Fig. 1, the dynamic characteristics of the system not only has a body portion, but also reflects the high-frequency resonance wheel part of the dynamic characteristics, it ride and grounding of the wheels have a greater impact, closer to the actual situation of automotive suspension systems [5].

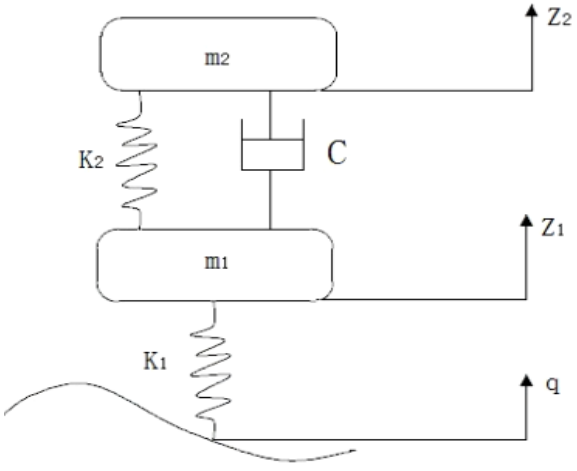

Fig. 1. Vibration systems of two degrees of freedom about body and wheels.

Z_1, Z_2 is the Vertical displacement coordinates of the wheel and the body, the original taps of coordinates are in their equilibrium positions, therefore, the suspension motion equation of two degrees of freedom is

$$\left.\begin{array}{l} m_2 \ddot{z}_2 + C(\dot{z}_2 - \dot{z}_1) + K(z_2 - z_1) = 0 \\ m_1 \ddot{z}_1 + C(\dot{z}_1 - \dot{z}_2) + K(z_1 - z_2) + K_t(z_1 - q) = 0 \end{array}\right\}, \quad (1)$$

where m_2 is the sprung mass (body mass); m_1 is the non-suspended mass (wheel mass); K represents spring stiffness; C refers the shock absorber damping; K_t is the tire stiffness; $\ddot{Z}_2$ indicates body vibration acceleration; $\ddot{Z}_1$ is the vibration acceleration of the wheel; $\dot{Z}_2$ is the known as body vibration velocity; $\dot{Z}_1$ is the wheel vibration velocity; Z_2 is the body vibration displacement; Z_1 is the vibration displacement of the wheel; q refers to incentives for the uneven pavement[6].

3.2. Dual-mass System Simulation Model

In the Matlab command window, type Simulink simulation than one can be integrated into the environment. Simulink includes a lot of modules, for example Sinks (output) module, Source (input source) module, Linear (linear part) module, Nonlinear (non linear part) module, Connections (connection) module, Simulink Extras (secondary link) module, each module which also contains many sub-modules. One can be directly set up simulation model in Simulink of Matlab, shown in Fig. 2 by using these modules according to the movement of suspended driving double quality system differential equation (1).

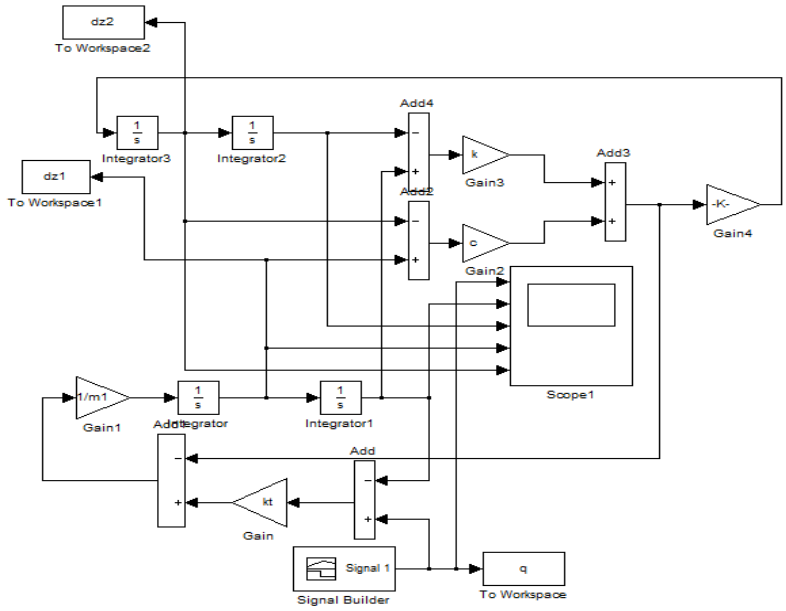

Fig. 2. Simulation model of suspension dual-mass system.

In order to simulate the road suspension system impulse response experiments, the road displacement input q can be set to pulse input, use Simulink source library "Signal Builder" to establish a single pulse input. And the pulse width is set to 1.0 s, pulse amplitude is set to 0.8, as signified in Fig. 3.

In the model, there are changes of the number of car's bearing, so sprung mass should also be a number of changes with the bearer of a variable, but considering the complexity of the research, we take a fixed sprung mass value research. Value of the input variables in the command window of simulation model is shown in Table 1 below.

Table 1. The value of variables in the command window.

Name	Value
Wheels Quality (m_1)	45.4
Body Quality (m_2)	317.5
Spring Stiffness (K)	22000
Tire Stiffness (K_t)	192e3
Shock Absorber Damping (C)	1.52e3

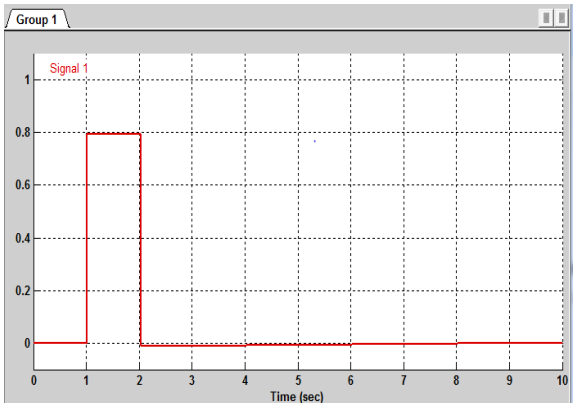

Fig. 3. Setting interface of inputting single.

3.3. Suspension Dual-mass System Simulation Analysis

Starting dynamic simulation for suspension system after building simulation models in the Simulink simulation software interface to set

parameters such as time, for example, the time taken is 5.0 seconds, and then selecting simulation items. After the simulation we can double-click the oscilloscope to observe the waveforms.

As can be seen from Fig. 4, wheel vibration displacement signal is similar with the road input signals waveform, rapidly decay occurred after 2 s; while body vibration displacement signal is more obvious oscillation signal waveform amplitude than the input signal q amplitude, it can be reached to 1.25, but after four times of the damped oscillation, it tends to be flat in 4.0 s. The reason is vibration energy is quickly absorbed by suspension damping elements.

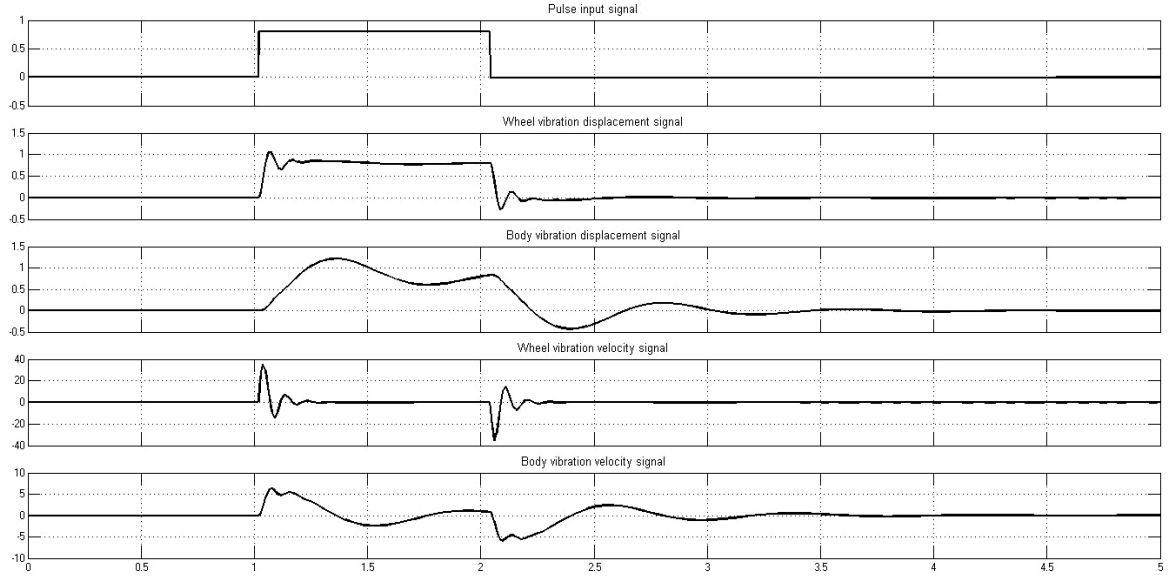

Fig. 4. Comparison of pulse input signals and displacement and velocity signals of wheel and body vibration.

Similarly, we can observe from the oscilloscope wheel and body vibration speed signal waveform, thus it can be seen that the vibration of the wheel speed should be greater than the vibration velocity of the body, and the vibration of the wheel speed fluctuation is larger.

4. Conclusions

Automotive suspension is an important component, its performance is directly related to the vehicle's jostle longitudinal stability and ride comfort is good or bad. Study the vibration of the suspension is effective control of vehicle vibration, important measures to improve comprehensive performance of modern vehicles. Therefore, the suspension vibration simulation study is particularly important, through analyzing the simulation in this paper. The following conclusions can be drawn.

1) Suspension Vibration has two kinds of low frequency vibration and high-frequency vibration, low frequency vibration of the wheel vibration, the vibration frequency vibration to the body. Change the suspension of the relevant parameters can be observed on the carried without improvement.

2) From the suspension system dynamic simulation results can be seen, Simulink is the suspension system of a dynamic simulation effective way, and has a convenient, intuitive and accurate. The use of Simulink dynamic simulation steps are: firstly establishing suspension system simulation model, secondly initializing the system parameters, finally starting the dynamic simulation.

3) The use of vehicle dynamics theory, and dynamic characteristics of the vehicle suspension system analysis carried out to establish two degrees of freedom based on this active suspension system dynamics model. Taking into account the input of the rode disturbance impacts suspension conformity considerable, establishing a dual-mass vibration model of suspension, and its implementation in the time domain simulation.

4) Suspension vibration simulation using the established model, the sprung mass (body mass), the unsprung mass (wheel mass), spring stiffness, shock absorber damping, tire stiffness parameters to the suspension dual-mass system vibration analysis. The results show that the models feasible and effective, and fairly practical, simple and quick, intuitive and reliable results, which further improve the suspension system for the design and analysis of the vibration characteristics of the foundation.

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