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Research on The Influence of Continous Damping Control Shock Absorber on Frequency Response Function of Spindle Coupled Road Simulation Test Bench

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Abstract

When the semi-active suspension is tested based on the 6-DOF spindle coupled road simulation test bench, the traditional test method is no longer applicable, because the continous damping control shock absorber of the original vehicle controller cannot be used and the overall nonlinear of the system is stronger. At present, there are few related engineering applications in the industry. This paper introduces the current reproduction technology of semi-active suspension on the 6-DOF spindle coupled road simulation bench and researches the difference of the system frequency response function by excitation of continous damping control shock absorber with different control current.

Keywords

Continous Damping Control Shock Absorber; Road Simulate; FRF.

1. Introduction

The 6-DOF spindle coupled road simulation test of suspension system is the test method with the highest accuracy that can simulate the actual force and motion attitude of the suspension system in the laboratory at present. Because it can quickly discover the damage location and expansion of each component of the suspension, it is currently mostly applied to the early stage of vehicle development and the updating and verification stage of components.

For the traditional passive suspension system, its corresponding test methods and test specifications have been relatively mature.However, the research results of semi-active suspension and active suspension testing in the industry are few and no perfect guiding method has been formed.As semi-active and active suspension are equipped with some electronically controlled elastic elements,the nonlinearity of the system becomes stronger which increases the difficulty of data iteration.It is impossible to start the original vehicle controller to apply excitation current to the electronically controlled elastic elements in the actual test process.So the relevant engineering application and test experience in the industry are less.This paper based on the 6-DOF spindle coupled road simulation test bench introduces the current reproduction technology in the testing process.The difference of the frequency response function(FRF) of the system is researched by excitation of the continous damping control shock absorber with different control currents.

2. Continous Damping Control Shock Absorber

Shock absorber is an important component of the chassis suspension system,which can effectively prevent tire overload,help control the balance of the body,ensure smooth driving,maintain wheel positioning and reduce the risk of abnormal wear of tires and other suspension components.In recent years,with the development of the automobile industry and the progress of consumption concepts,consumers pay more attention to the safety and

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smoothness of driving.The comfort and safety of vehicles equipped with passive suspension are contradictory in the actual driving process[1].Vehicles with high comfort are often equipped with low damping shock absorbers,then the safety of vehicles is poor when the shaking amplitude is too large.On the contrary,the safety performance of vehicles equipped with high damping shock absorbers will be improved but the ride comfort of vehicles will be significantly reduced which affecting the driving experience.

In view of the problem that the damping of passive suspension shock absorber can not be adjusted in real time during driving, the concepts of semi-active suspension and active suspension arosing.With the advent of relevant suspension types,the idea of achieving vertical force control during motion became possible.The continous damping control shock absorber is a new type of shock absorber which can realize the continuous adjustment of damping force for semi-active and active suspension. The whole damping characteristic and vertical damping force of the shock absorber are changed by controlling the solenoid valve.The central control unit of the vehicle can adjust the excitation current in real time according to the actual road conditions to change the damping characteristics of the shock absorber which can ensure the smoothness and safety of the vehicle in different road conditions.

3. Test Bench Construction

In this paper,front double-wishbone suspension and rear multi-link suspension are selected as the test object. Before 6-DOF spindle coupled road simulation test,the road spectrum was first collected in the test field strengthen road surface A (non-braking condition).The road spectrum data included not only the WFT and other sensor data,but also the current data of the four shock absorbers.After the road spectrum collection was completed, the test bench was constructed.

In this paper, the method of fixed BIW is selected to evaluate the front and rear semi-active suspension system.During the test the BIW is stationary.This method more truly retains the connection stiffness between the tested suspension and the BIW which is closer to the actual situation.At the same time,it can also be evaluated in the places prone to crack failure such as the shock absorber tower bag of the BIW by using remote control parameter (RPC) software and iteration technology,the road spectrum data of strengthen road surface A is reproduced on the test bench.Because the 6-DOF spindle coupled road simulation test is relatively popular in the industry,this paper don't describe the test bench construction,driver file development principle and other related content.The installation diagram of the test bench is as follows:

Figure 1. Diagram of test bench installation

Different from the road simulation method of passive suspension,the current data of semi-active suspension needs to be reproduced in the iteration process.The suspension test don't install the controller of the vehicle.Even for the vehicle test, the power will be cut off during the test and the vehicle controller can not work normally for safety considerations.At the same time,the current control logic of continous damping control shock absorber is often unknown because of supplier confidentiality.So it is short of the necessary input information.Based on the above reasons, the test team researched the control frame of the test bench and the working principle of the continous damping control shock absorber,clarified the interactive logic relationship between the electric control component of the continous damping control shock absorber and the test bench control system,solved the signal synchronization and developed a set of continous damping control shock absorber current control system independent of the vehicle which can reproduce the current signal in time and with high precision.In the process of road spectrum iteration,the data of each sensor and current can be reproduced with high precision.The control logic and the current reproduction results of the LF and LR continous damping control shock absorber for strengthen road surface A are as follows:

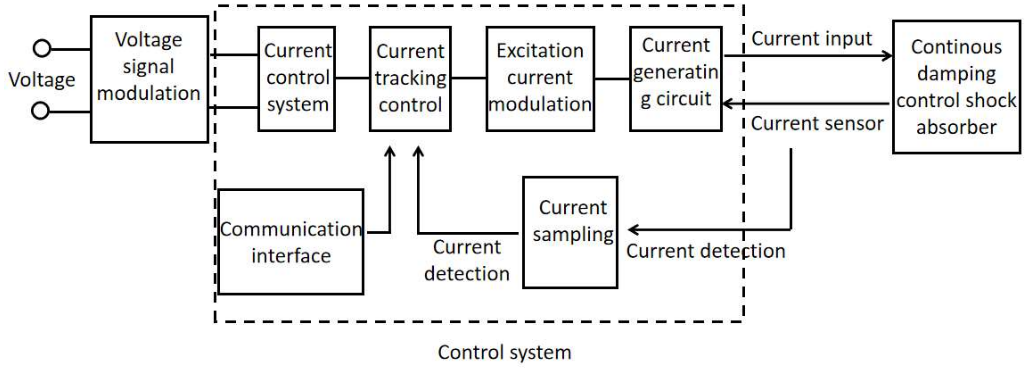

Figure 2. Control logic of continous damping control shock absorber current control system

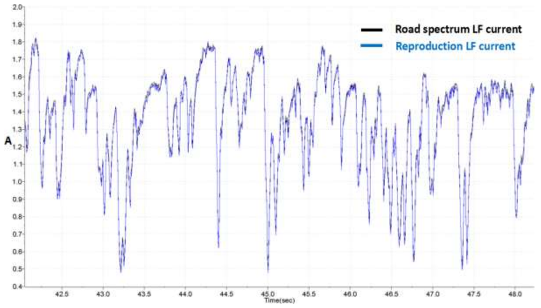

Figure 3. LF shock absorber current reproduction

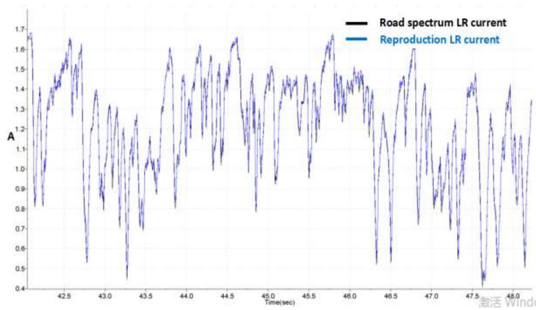

Figure 4. LR shock absorber current reproduction

4. Influence of Continous Damping Control Shock Absorber with Different Excitation Current on System FRF

A multi-input and multi-output nonlinear system is formed between the test sample and the test bench.In order to characterize the model characteristics of the test system,it is necessary to use random signal X(f) (generally white noise) that is the input to stimulate the test system and the response Y(f) of each key point of the test sample is the output.The relationship H(f) between X(f) and Y(f) is the FRF of the system and the H(f)-1 is the inverse FRF.The expressions are:Y(f)=H(f)*X(f) and X(f)=H(f)-1 *Y(f)[2].

The FRF is a mathematical model of the test system (actuator,bench fixture,test sample structure,etc.) that provides a stable mathematical approximation of the system over the entire target test frequency range,which can be simply understood as reflecting the input/output relationship between the test bench and the test sample.

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When solving the system FRF,different from the traditional passive suspension,the semi-active suspension requires current excitation of the shock absorber and the selection of excitation current amplitude needs further analysis.According to previous research results in the industry,the continous damping control shock absorber changes the overall damping characteristics and vertical damping force of the shock absorber by controlling the solenoid valve and the damping force of the shock absorber is inversely proportional to the applied current. That is, when the current decreases, the damping force increases,otherwise the damping force decreases [3].The change of suspension vertical damping is bound to have an impact on the system FRF,which will directly affect the quality of the FRF and affect the subsequent iteration.

In this paper,four kinds of constant current excites the continous damping control shock absorbers:0.3A,0.6A,1.0A and 1.5A.The FRF of the system under different current excitation is researched.In order to ensure that there is only one single variable in the system,the 20 control channels inherent in the test bench(excluding Brake control channels)choose the same white noise drive in the four groups of tests.The calculation frequency band is set to 0~50Hz.According to experience,in the subsequent iterations,the WFT signal is the most important signal among all sensor signals which directly reflects the stress state of the suspension.Therefore,this paper focuses on the relationship between the test bench control channel and the corresponding WFT signal in the system FRF under different current excitation.Through the analysis of 4 groups of FRFs,it is found that the relationship between the test bench control channels Long, Lat, Camber, Steer and the corresponding WFT signal Fx, Fy, Mx, Mz is less affected by different excitation currents of the shock absorber,and the amplitude of the system FRF is basically no difference.The relationship between the control channel Vert and the WFT signal Fz is obviously affected.Analyzing the vertical inverse FRF graph of left front and left rear, it can be found that:

From 0 to 30Hz,compared with the front suspension,the excitation current has more influence on the FRF of the rear suspension and the curve change is more obvious.The inverse FRF of the front and rear suspension presents a three-stage distribution.

From 0 to 10Hz, the larger excitation current, the larger amplitude of the inverse FRF.

From 10 to 20Hz,the smaller excitation current,the larger amplitude of the inverse FRF

From 20 to 30Hz, the larger excitation current, the larger amplitude of the inverse FRF.

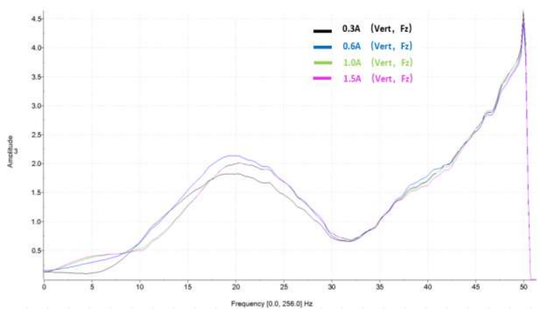

Figure 5. Relationship between LF control channel Vert and WFT LF Fz

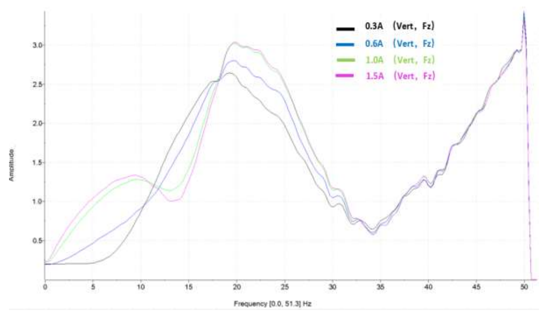

Figure 6. Relationship between LR control channel Vert and WFT LR Fz

5. Road Spectrum Data Analysis

Through the frequency domain conversion of the road spectrum data of the strengthen road surface A,it can be seen that the amplitude of the WFT Fz channel is higher in the low frequency segment 0~5Hz.According to experience,in the process of iteration,the convergence rate of WFT Fx, Fy, Mx and Mz is fast,while the convergence rate of WFT Fz is slow.Therefore, in order

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to reduce the number of iteration steps,quickly complete the iteration work and reduce the accumulation of damage to the sample,the inverse FRF with large vertical amplitude in the low frequency segment should be selected.Therefore, this paper selects the FRF solved under 1.5A current excitation for subsequent iteration.

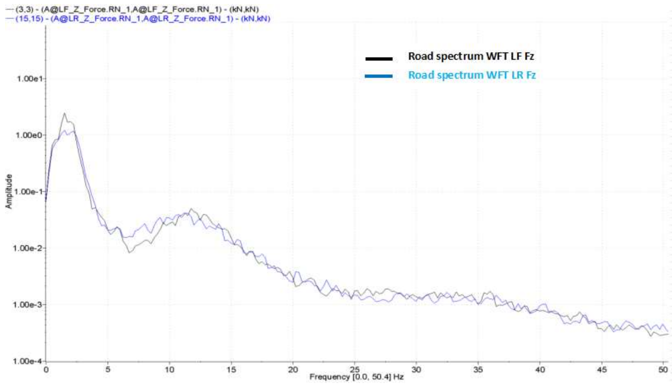

Figure 7. LF and LR WFT Fz channel data frequency domain diagram

6. Iteration Result

The road spectrum data of the strengthen road surface A was iterated, and the iteration was completed in the final 23 steps.The WFT signal and current signal were repeated well.The WFT RMSerror was below 10%.The iterative results were shown as follows:

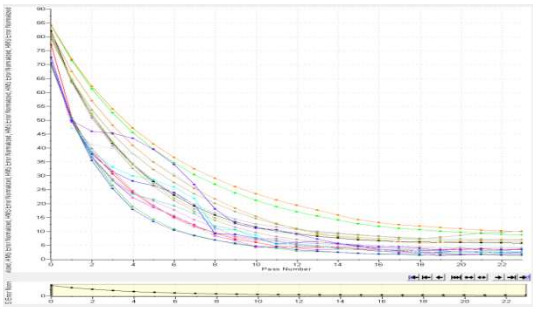

Figure 8. WFT RMSerror iteration result

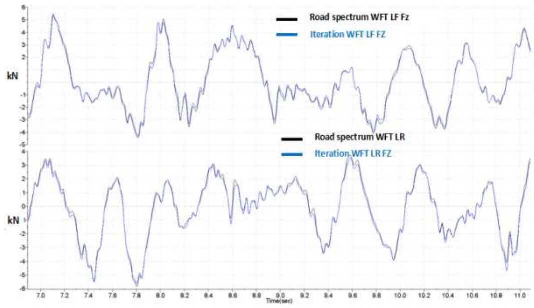

Figure 9. WFT Fz iteration detail diagram

7. Iteration Result

The continous damping control shock absorbers current control system can reproduce the current signal well and provides a test basis for the assessment of semi-active and active suspension on the 6-DOF spindle coupled road simulation test bench.

Under different current excitation,the continous damping control shock absorbers will have a significant impact on the vertical FRF of the system.When solving the system FRF,it is recommended to select several groups of excitation currents for testing.

Before iteration,focus on the vertical frequency domain data composition,then select a more appropriate excitation current which can be more reasonable iteration.

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