

Some typical applications with UM software in China



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Hello, everyone. I am glad to be here to introduce our research results with UM software, and thanks to give me the chance to communicate with experts . My name is Shulei Sun, now I am associate professor in Xihua University in China. I have used UM software more than 10 years since my P.H.D research on heavy haul train in Southwest Jiaotong University. So I am glad to share some typical application which I was involved in.

1 Crawler excavator

2 Virtual-track Bus



Today here, I will briefly introduce two new typical applications with UM software in China, which were done by our research team. The two applications include different industries with comparison of the simulation and real world test, including crawler excavator and virtual-track bus. We also did many simulation and test work on railway transportation, especially on heavy haul train and longitudinal dynamics, but here we just introduce the two new applications.

PART 1

Crawler Excavator

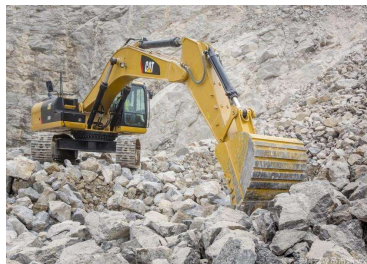
Shulei Sun, Lifei Lei, Haibo Huang, et al. Construction method for accelerated fatigue reinforced pavement of crawler excavator based on user operating condition, Journal of Mechanical Engineering, 2022, 58 (16)
(in Chinese: 基于用户作业工况的履带式挖掘机加速疲劳强化路面构建方法, 机械工程学报)

Firstly I will introduce the crawler excavator application with UM. The research results will be published in a Chinese journal, the name of the paper is Construction method for accelerated fatigue reinforced pavement of crawler excavator based on user operating condition.

Problem:

- Complex and changeable loads and operating conditions;
- Fatigue damage of structural components;
- There is no any accelerated fatigue test method and reinforced pavement for excavator.

Therefore, we use the simulation and test method to study the accelerated fatigue reinforced pavement.



Fatigue cracks of the fuel tank

Let's see the problem about crawler excavator what we had.

As an all-terrain construction machinery, crawler excavators are subjected to complex and changeable loads during long-term service, which cause serious safety accidents such as fatigue damage.

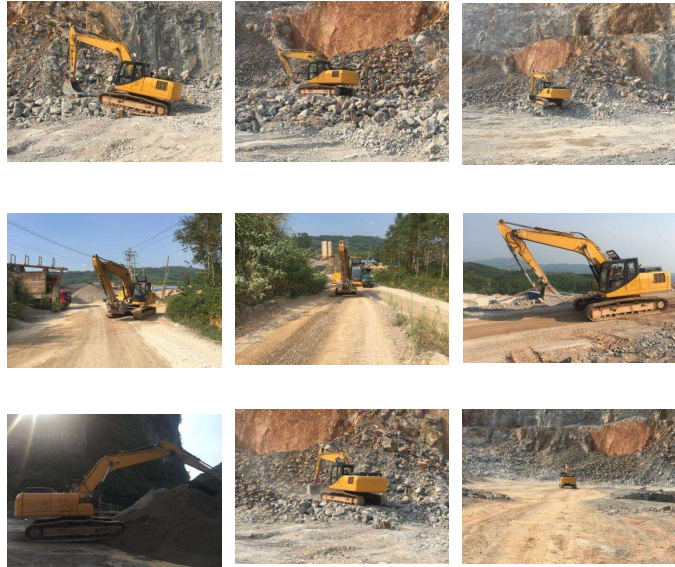
Due to the large number of degrees of freedom, the variety of road excitations, and the changing operating conditions, it is difficult to determine the load conditions to test, and there is no effective method for accelerated fatigue simulation and test.

As we know, there are different reinforced pavement for automobiles fatigue test. But there is no any reinforced pavement for crawler excavator. So we want to provide a method to reduce the test time and cost. A pavement construction method for accelerated fatigue test of crawler excavator based on user operating conditions is proposed here.

In this study, we take the fuel tank with prominent failure problem as an example. we use the simulation and test method to study the accelerated fatigue reinforced pavement.

Working condition:

- User working condition investigation and data feedback;
- About 16,000 operating hours when the crack occurred;
- Nine user working conditions were defined and used.

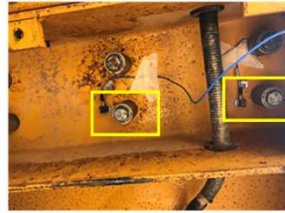
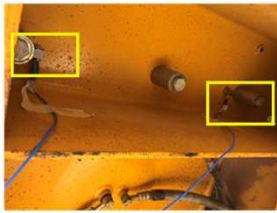


Firstly, according to the user working condition investigation and data feedback, the fuel tank developed a fatigue crack when these excavators operated about 16,000 operating hours.

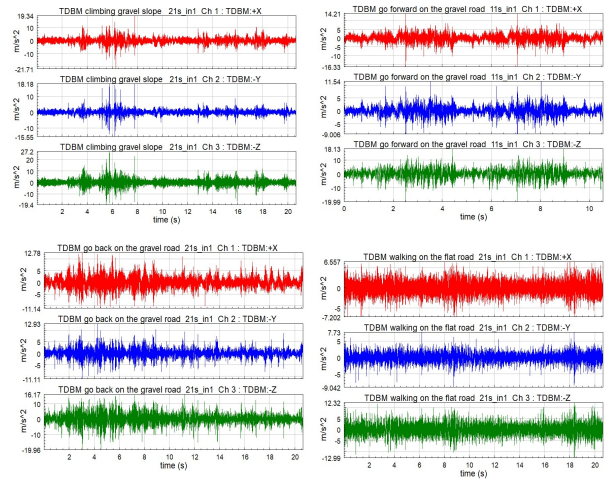
We defined and designed a total of 9 user working conditions based on the test ground and excavator development experience, such as climbing gravel slopes condition, road construction condition, driving ahead on flat road condition.

Test and data collection:

- PCB triaxial accelerometer;
- the connection position between the fuel tank base and the frame.



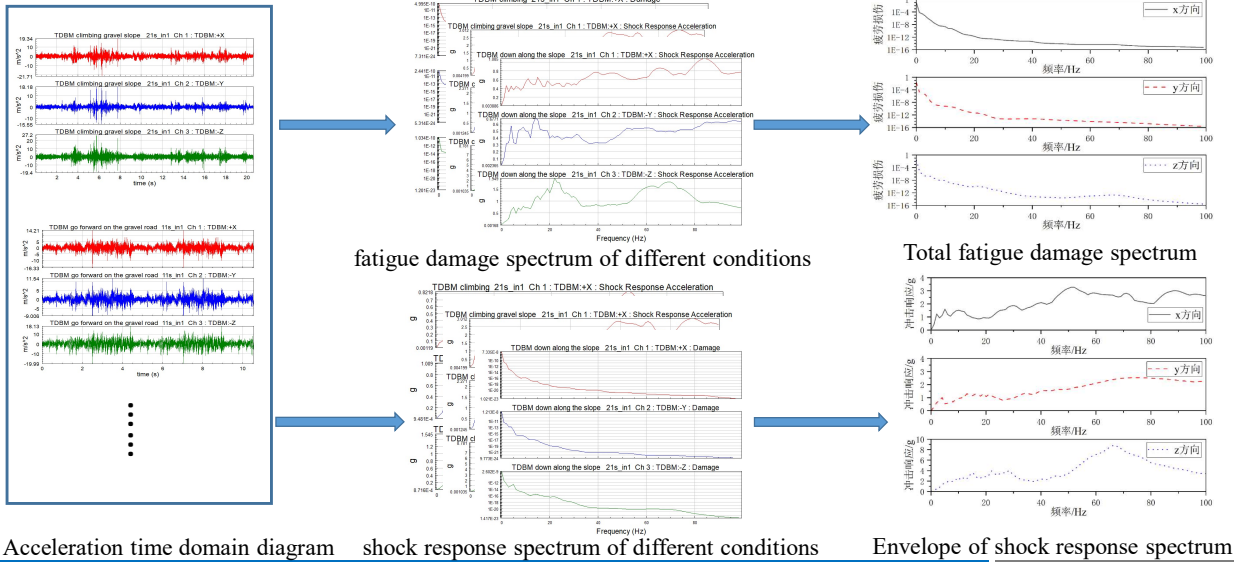
Sensor installation location



Acceleration in different conditions

In the test, we used PCB accelerometer to collect the vibration data. And the sensors were mounted on the connection position between the fuel tank base and the frame.

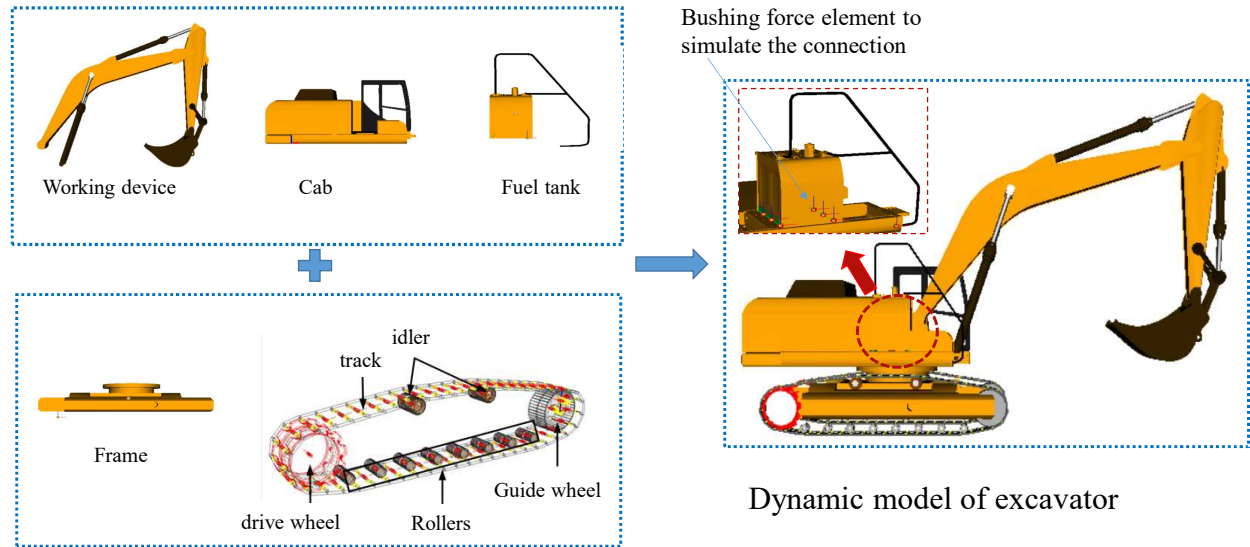
Calculate the total fatigue damage spectrum



Acceleration time domain diagram shock response spectrum of different conditions

Envelope of shock response spectrum

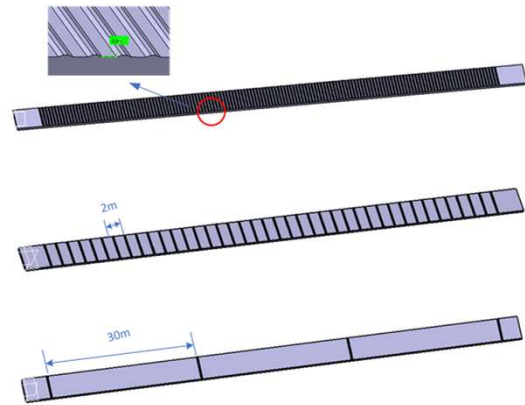
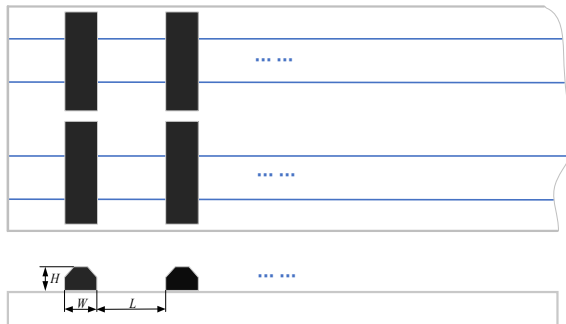
Based on the linear cumulative damage principle, we use the vibration data to calculate the total fatigue damage spectrum and shock response spectrum. Total fatigue damage spectrum is used to judge whether the fuel tank will be damaged.

Dynamic model of excavator

According to the dynamics parameters, we establish the dynamic model of the crawler excavator, including frame, cab, working device, fuel tank, and track. Because we need to consider the fuel tank fatigue problem, we use the bushing elements to simulate the connection between fuel tank and the frame body.

Reinforce pavement model

- Bump height: H
- Bump width: W
- Bump gap: L

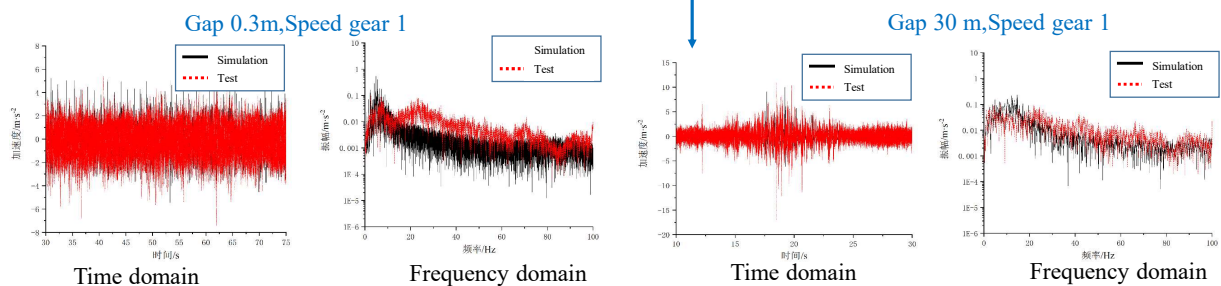
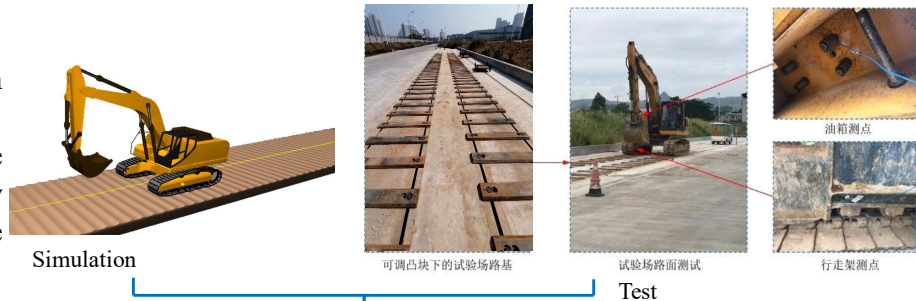


In this research, one of the most important part is to construct the virtual reinforced pavement. We used different kinds of bumps with different bump height, width and gap.

I think it is very important to use the virtual pavement method. If we don't do that, we need to build many combination of real reinforced pavement, and it will need a lot of money, time and energy.

Model validation

- Real test pavement with two kinds of bump;
- Good agreement in time domain and frequency domain, except around the engine operating frequency.



We constructed two kind of real test pavements, to test the excavator and valid the dynamic model, including narrow bump gap and wide bump gap.

From the figure, we can see that the vibration between simulation and test is close from an engineering perspective.

Because we haven't consider the engine motion and vibration, there are some difference around the engine operating frequency and doubling. Because we study the pavement excitation problem, therefore, the dynamic model of excavator and the pavement model have the accuracy to meet engineering requirements.

After the validation by the test, we can use simulation method to carry out various combinations of working conditions, and find out the optimal combination to construct the real reinforced pavement.

This method can reduce a lot of time and cost for the test.

Optimized reinforce pavements combination

- Combination is consisting of different of pavement and speed gear;
- Different cycle times for every pavement.

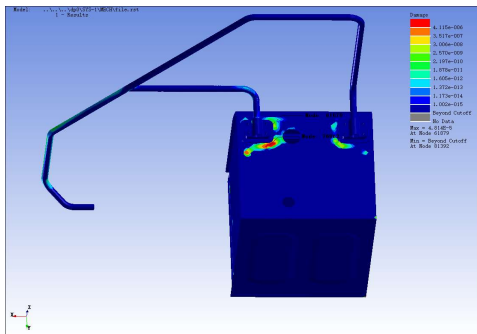
	pavement	gear	Cycle times	Reinforce ment factor
Condition combination	0.3m gap	1	7766	15.1
	2m gap	1	8291	
	15m gap	1	1008	



We use the simulation method and provide an optimized combination of pavements, including different bump, gear and cycle times.

Fatigue analysis with FE

- Damage position is the same with real crack;
- Test time with the reinforced pavement can be shorten to one-fifteenth.



At last we use finite element to simulate the fatigue life under the loads from the UM dynamic simulation. We can see that the damage position is the same with the real crack. And the test time with the reinforced pavement can be shorten to one-fifteenth.

Therefore, the construction method can be used to solve the excavator fatigue problem. We provide a new method for accelerated fatigue test of excavator machine and its key component.

PART 2

Virtual-track Bus

Simulation Research on Running Stability and Ride Comfort of Four-group Virtual Train, Xihua University master degree thesis, 2021 (in Chinese: 四模块虚拟轨道列车行驶稳定性及平顺性仿真研究)

Structural strength analysis of large axle load independent suspension of four-module virtual rail train, Xihua University master degree thesis, 2022 (in Chinese: 四模块虚拟轨道列车大轴重独立悬架结构强度分析)

In the second part, I will introduce another type of vehicle named virtual-track bus or virtual-track train. Maybe the English name of this vehicle is not accuracy because it is a very new and novel transportation.

The research results have been published in my two students' master thesis. One thesis name is Simulation Research on Running Stability and Ride Comfort of Four-group Virtual Train, another name is Structural strength analysis of large axle load independent suspension of four-module virtual rail train.

Virtual-track Bus

- Consisting of four or three articulated vehicles with tires;
- 6-axes and 12 wheels, and all of the wheels can be actively steered;
- Self-driving with the virtual-track (the line on the road);
- Can drive in two direction.



As a new type of transportation, the virtual-track Bus now has been already operating in several cities in China, such as Yibin City, Sichuan Province.

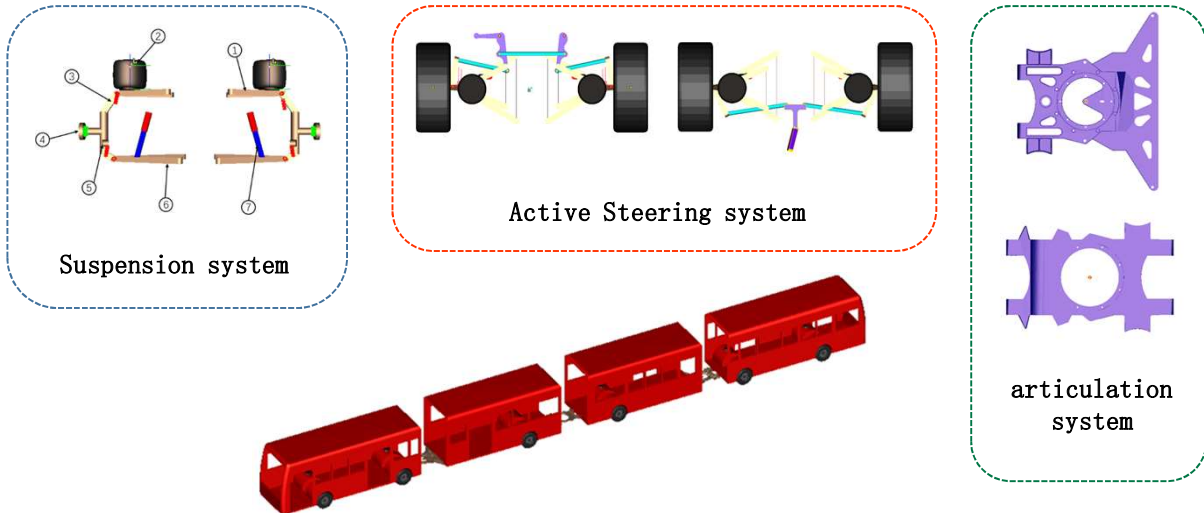
There are several features on the vehicle.

It is consisting of four or three articulated vehicles with tires, and can carry more than 300 passengers.

It has 6-axes and 12 wheels, and all of the wheels can be actively steered; The Virtual-track Bus has the function of self-driving with the virtual-track;

It can drive in two direction, so it doesn't need to turn around.

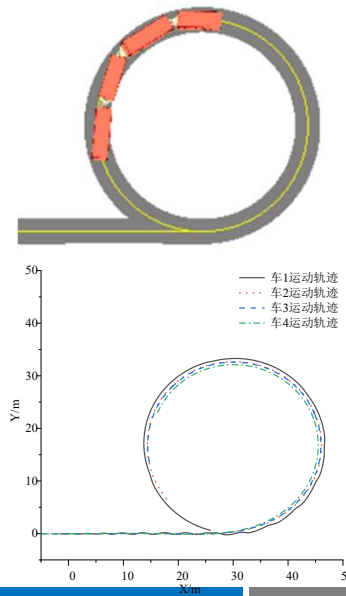
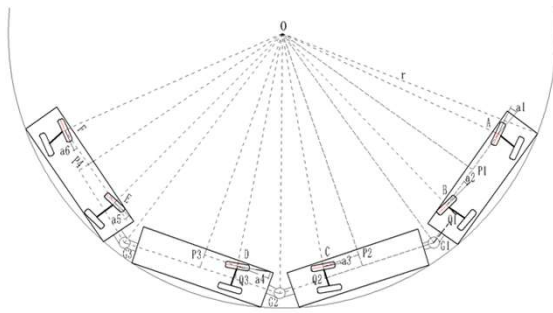
Dynamic model in UM



In this report, We take four articulated virtual-track bus as an example. Firstly, We build the dynamic model with UM software, including suspension system, active Steering system, articulation system.

The active steering control method

- Simple control method based on Ackerman;
- Co-simulation between UM and Simulink.

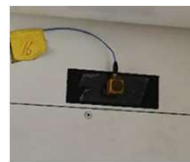
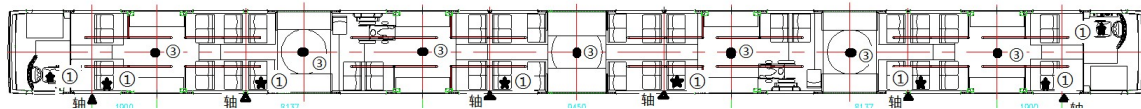


The difficulty of this type of vehicle is the active steering control method. We use the steering control method based on Ackerman angle, which is implemented in Simulink. And then we use co-simulation between the UM and Simulink.

From the figures, we can see that the control method can make the bus follow the trajectory well.

Vehicle ride simulation and test

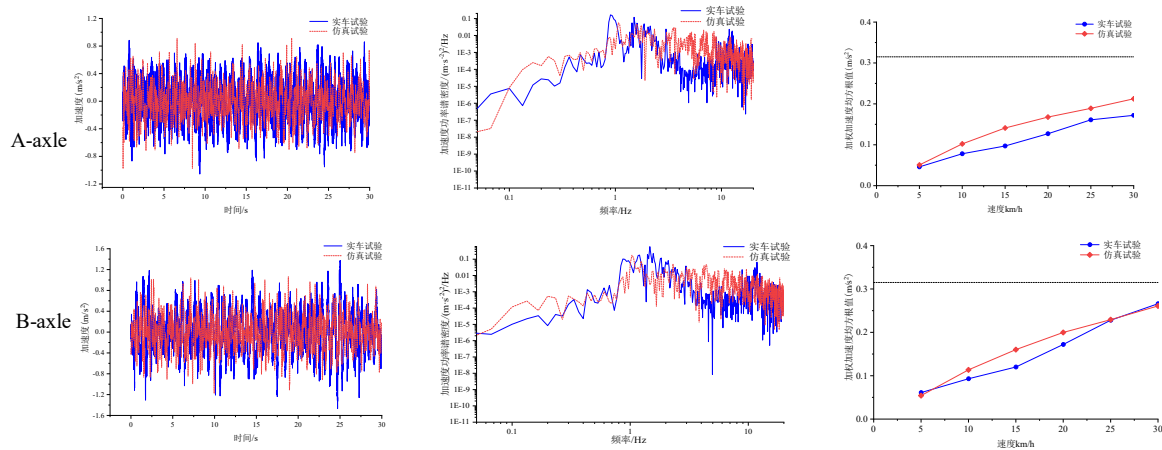
- Reference standard: GB/T4970-2009 'Automobile Ride Test Method', including pulse input and random input;
- Simulation and test speed: 5km/h、10km/h、15km/h、20km/h、25km/h、30km/h;
- Test position: center of the every vehicle floor, and the position on and above the axles.



According to a Chinese standard 'Automobile Ride Test Method', we simulated and tested the acceleration in different position of the bus, in order to validate the dynamic model. Because of the limitation of the road, the bus speed were from 5km/h to 30km/h.

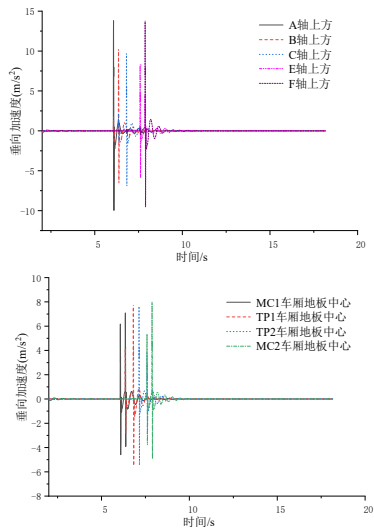
The test position were located on the center of every vehicle floor, and on and above the axles.

Vehicle ride simulation and test



This is the simulation results and test results of random input. From the results, we can see that results are close in the time domain and frequency domain. But there are also some difference, we think this is because that the tire parameters were not accuracy.

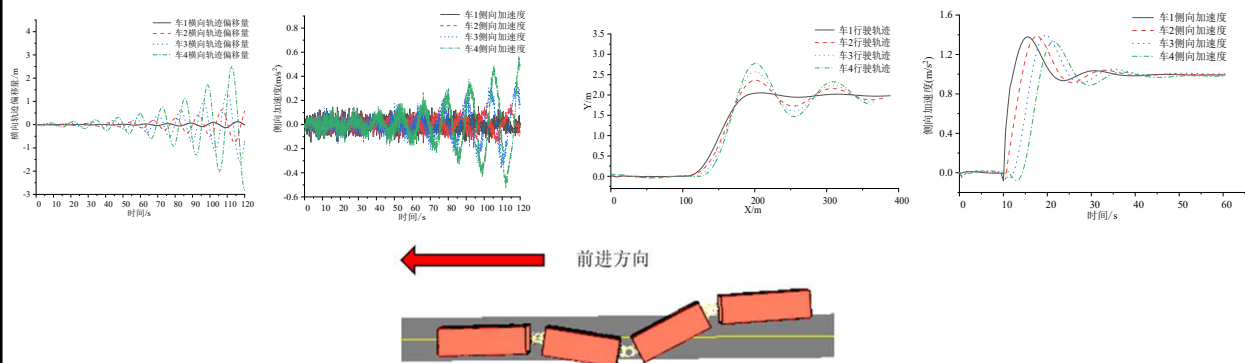
Vehicle ride simulation and test



This is the pulse input simulation and test.

Vehicle stability analysis

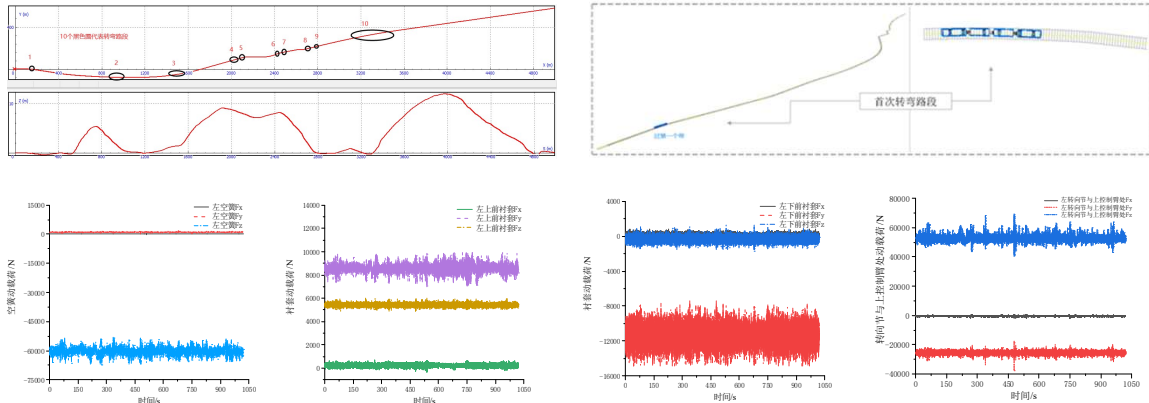
- straight driving simulation;
- single lane changing simulation;
- Steering step input simulation.



Besides the vehicle ride simulation, we also did vehicle stability analysis about this bus. The simulation conditions includes straight driving simulation, single lane changing simulation, step Input simulation.

Real path simulation and dynamic load

- Simulated the bus operating with the real driving path;
- Provided dynamic load of suspension.



We also simulated the bus operating with the real driving path, including different curves, and provided the dynamic load of suspension component, which is useful for the structure design.



Thanks!

If there is any question, please contact with me and I am
glad to communicate and cooperate with you.
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