SW160 Bogie Dynamics Analysis with Magic Formula Damper Model at CARS

China Academy of Railway Science (CARS), Beijing, P.R.China, 100081
Zhan Wenzhang Wang Chengguo Qian Lixin
ZF Sachs AG, Bogestrasse 50, D-53783 Eitorf, Germany
Richard Van Kasteel

[Abstract]: To meet with the demands of quasi-high speed coaches of China railway, Qingdao Sifang Works had designed a new bogie, SW160 bogie. Although the SW160 bogie had good quality of vertical comfortable quality, but the horizontal conformability needs to upgrade. A multibody SW160 bogie model base on ADAMS/Rail had been built, and a new model of damper by applied Prof. Pacejka's famous tire Magic Formula model was figure out and user subroutines were compiled and integrated into ADAMS/Rail, The bogie's comfortable quality results are simulated. Finally, a Sachs damper prototype designed by applying the Magic Formula theory will be installed on the bogie, and a test will hold on Xinan Jiaotong University testrig to validate this works.

Key Words: SW160 Bogie Magic Formula Damper Model Dynamics

INTRODUCTION

To meet with the demands of high-speed coaches of China railway, Qingdao Sifang Works had designed a new bogie can running at 160Km/h, named SW160 bogie. After several years running, the bogie is accepted by railway companies and passengers. Meantime, new appeals appear: firstly, although the SW160 bogie had good quality of vertical comfortable quality, but the horizontal conformability needs to upgrade. Secondly, China Ministry of Railway needs a higher speed coaches that can run at 200Km/h. This gives Qingdao Sifang Works a chance to redesign the SW160 bogie to meet this demanding. Hence, a multibody SW160 bogie model base on ADAMS/Rail had been built, and a new model of damper by applied Prof. Pacejka's famous Magic Formula tire model was figure out and user subroutines were compiled, a private ADAMS/Rail solver was created, and the bogie's comfortable quality results are simulated. Finally, a Sachs damper prototype designed by applying the Magic Formula theory will be installed on the bogie, and a test will hold on South West Jiao Tong University rolling test rig to validate this works.

RESEARCH CONTENT

This research is separate in to three steps. First of all, an ADAMS/Rail vehicle dynamic model was built, and the vehicle comfortable quality was evaluated to verify the bogie and vehicle model and suspension parameters. Meanwhile, a Magic Formula damper model based on the measurement results was figure out, and the damper's static/dynamic characteristics were well decrypting by the damper model. Finally, a damper subroutine were integrated into the SW160 bogie dynamic simulation model.

PART ONE: BOGIE/VEHICLE MULTIBODY DYNAMIC SIMULATION MODEL

SW160 bogie is a quasi-high speed bogie, designed for running at 160km/h, and using air-spring as secondly suspension buffer unit, a center-plate and two side-slip-supports are used to mount

the vehicle body and the bolster together, and a longitude pull-rod link the bogie with the bolster. Table 1 shows some data of the vehicle.

Table 1

Gross weight	55t	Bogie axis distance	2560mm
Bogie weight	7.0t	Max speed	160km/h
Axis weight	16.5t	Secondly longitudinal stiffness	4.5MN/m
Primary longitudinal stiffness	9MN/m	Secondly lateral stiffness	0.18MN/m
Primary lateral stiffness	4.5MN/m	Secondly lateral dampness	25kNs/m
Primary vertical stiffness	0.85MN/m	Secondly vertical stiffness	0.55MN/m
Primary vertical dampness	10kNs/m	Secondly vertical dampness	60kNs/m
Anti-roll stiffness	1.7MNm/rad		

The designer provides most parameters. Some complexly bodies are built by using Pro/E and UGII to get the mass property, as the figure 1. And the air spring's stiffness is measured and bushings' stiffness is tested too.

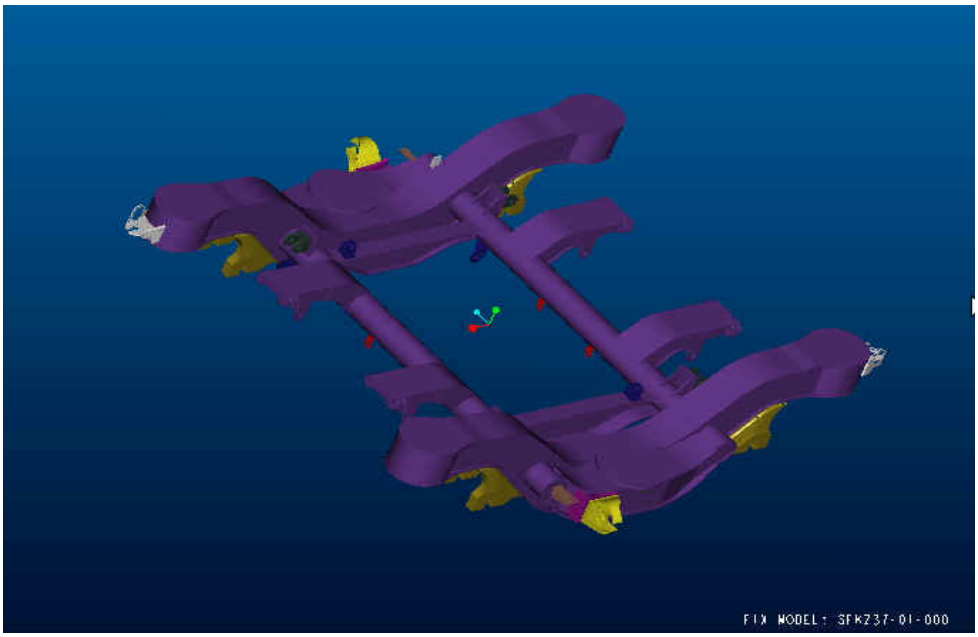

Fig.1 Bogie body 3D model

The figure 2 show the bogie's model built in ADAMS/Rail, using a lateral damper model provided by ADAMS/Rail. And figure 3 is the vehicle dynamic simulation model. And the simulating result running on a PSD track is figure 4.

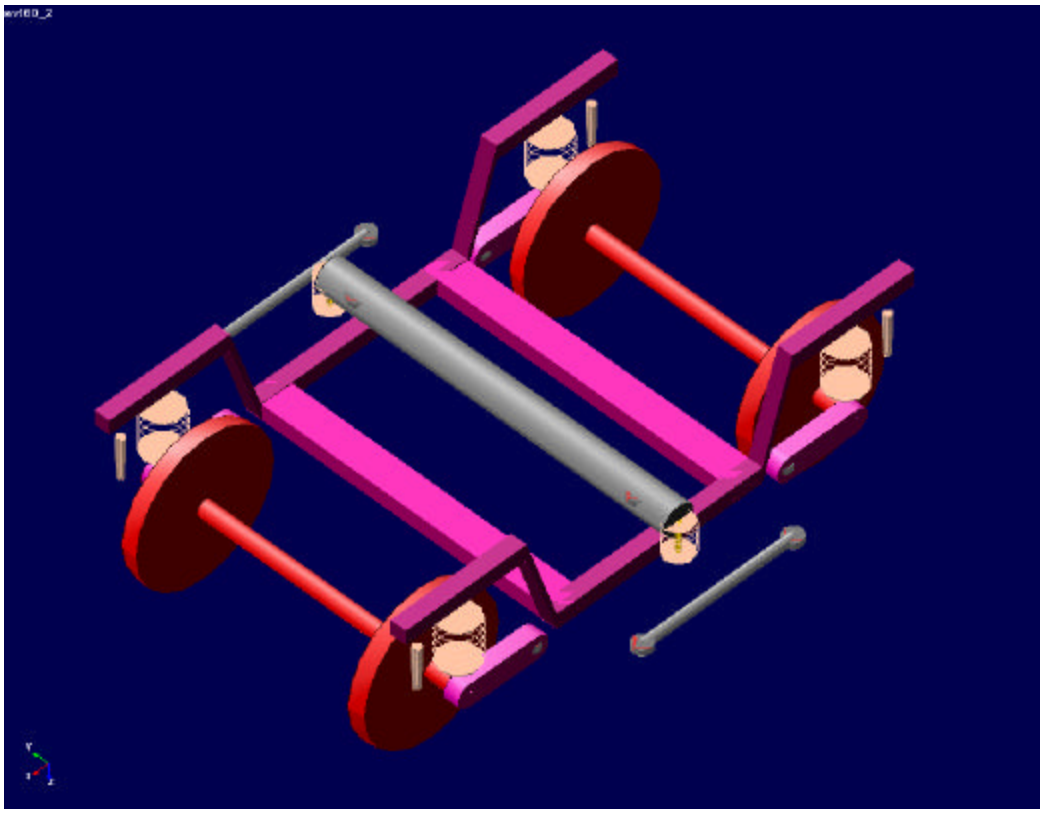

Fig.2 Bogie Dynamic Simulating Model

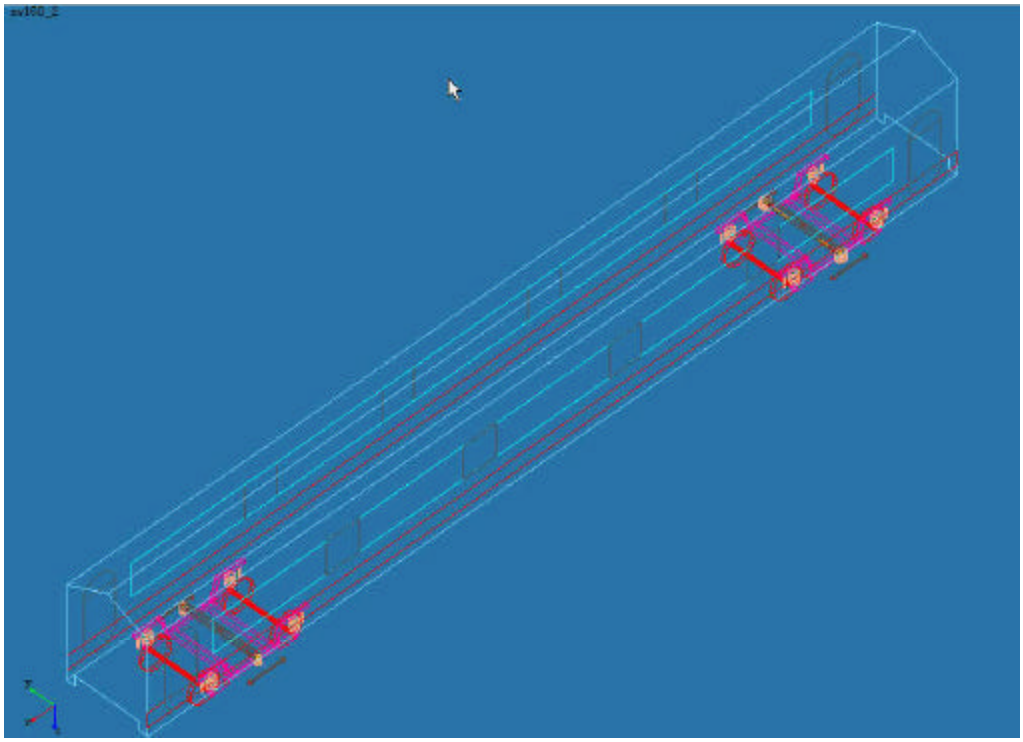

Fig.3 the vehicle dynamic simulation model

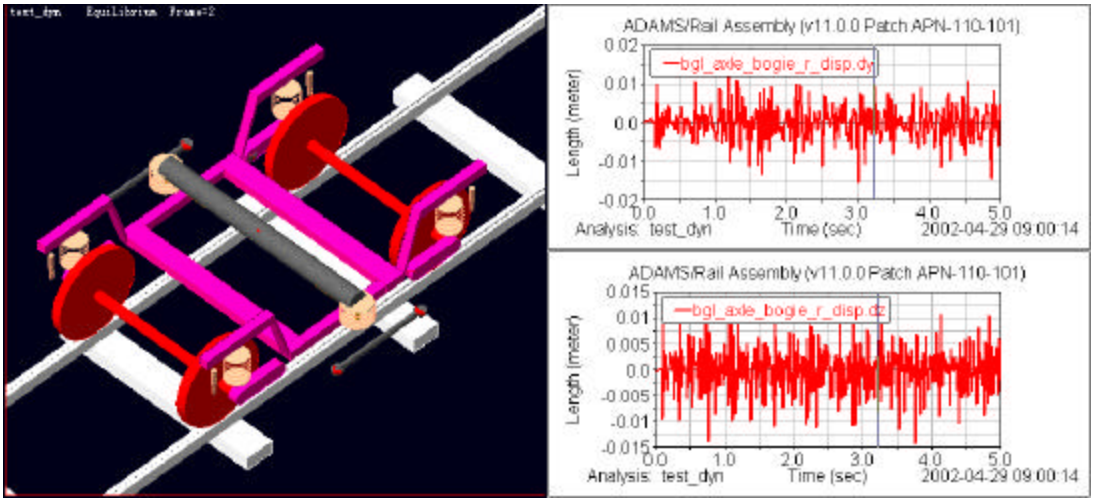

Fig.4 the vehicle dynamic simulation result

Finally the Stability quality at different velocity is simulated, as figure 5 show. And the figure 6 shows the test result. Comparing the simulation result with the test result, we can say the model can accurately responses the sw160 bogie's dynamics characteristics.

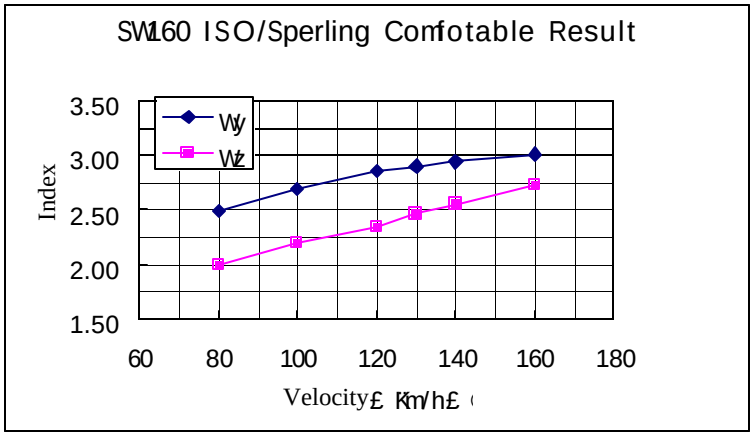

Fig.5 Stability quality simulate result

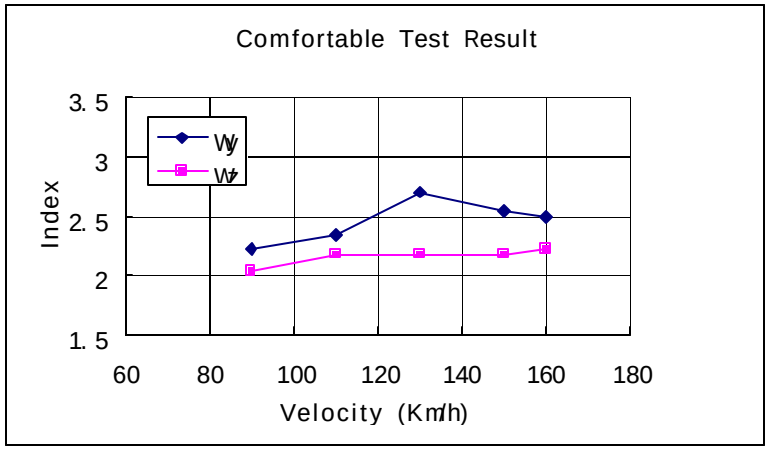

Fig.5 Stability quality test result

PART TWO: HYDRAULIC DAMPER STATIC/DYNAMIC CHARACTERISTIC MODEL—MAGIC FORMULA DAMPER MODEL

The hydraulic damper has almost same static/dynamic characteristic with the car tire's. Fig.6 show a typical car tire's cornering behavior while car turning. And Prof. Pacejka described this behavior with his famous MAGIC FORMULA tire model, see Fig.7, and it well accepts by the world. Fig.8 compare the tire's slip angle vs. lateral fore with the hydraulic damper's characteristic, and we now know it has same shape and we try using the tire MAGIC FORMULA model to simulate the damper's behavior too.

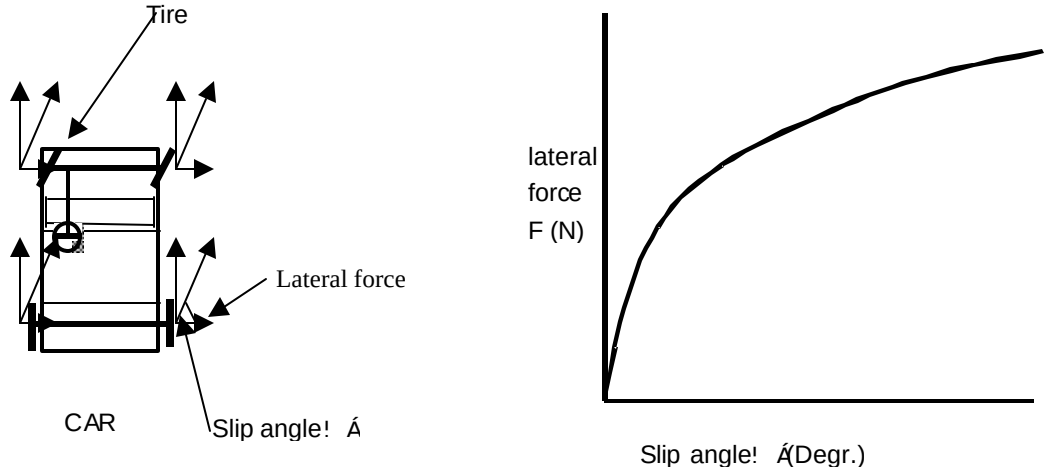

Fig.6 Tire lateral force vs. side lateral slip angle

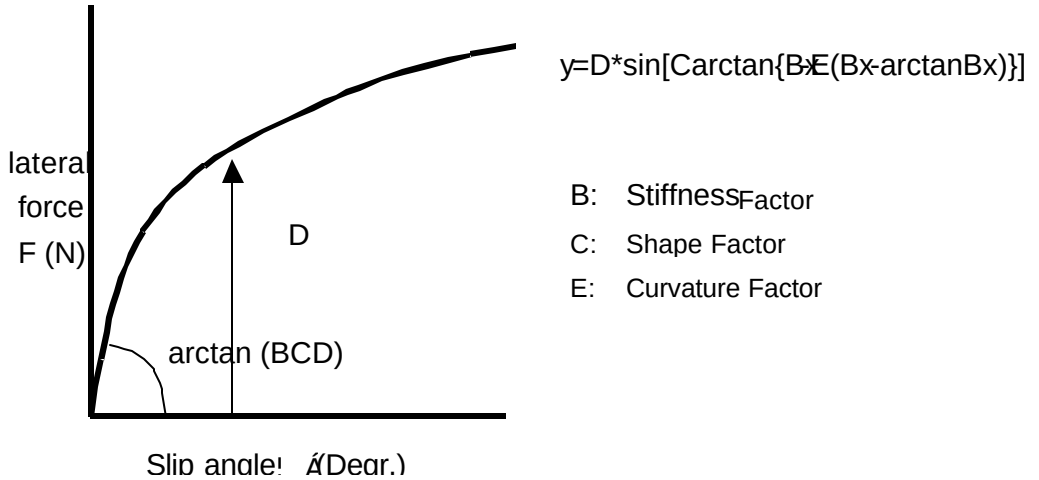

Fig.7 Tire magic formula model description

The follow is tire magic formula model:

F=D*sin[C*arctan{Bx-E*(Bx-arctan(Bx))}]

B: Stiffness Factor

C: Shape Factor

E: Curvature Factor

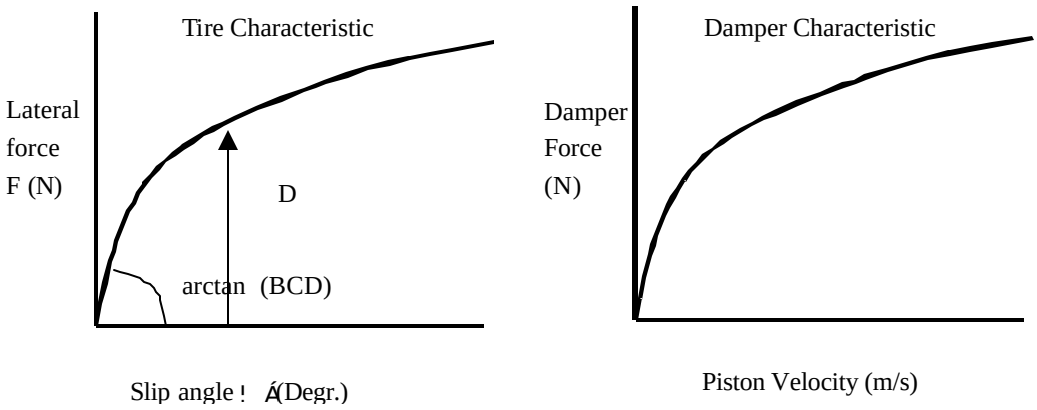

Fig.8 Tire characteristic vs. Damper Characteristic

And we can describe the Damper Characteristic by damper force vs. piston velocity:

x2 = x5/ (eps + x4)

Bx = B*x2y0=D*sin[C*arctan{Bx-E*(Bx-arctanBx)+G*arctan(Bx)}]

F = y0 + x*H B: Rate Factor

C: Shape Factor

E: Curvature FactorG: Blow Off Factor

H: Linearity Factor

eps: Orifice Factor

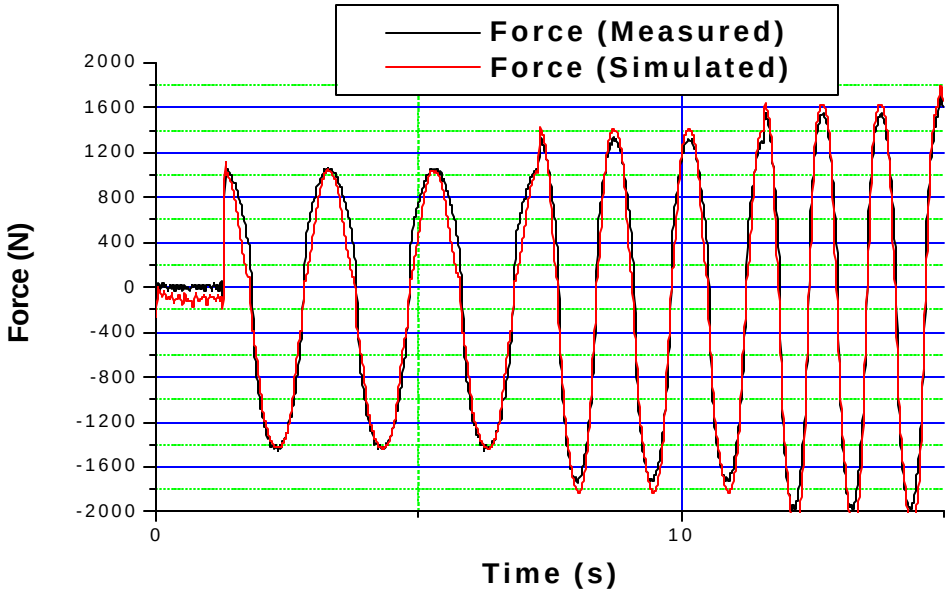

Fig.9 Damper magic formula model dynamics simulation (low frequency)

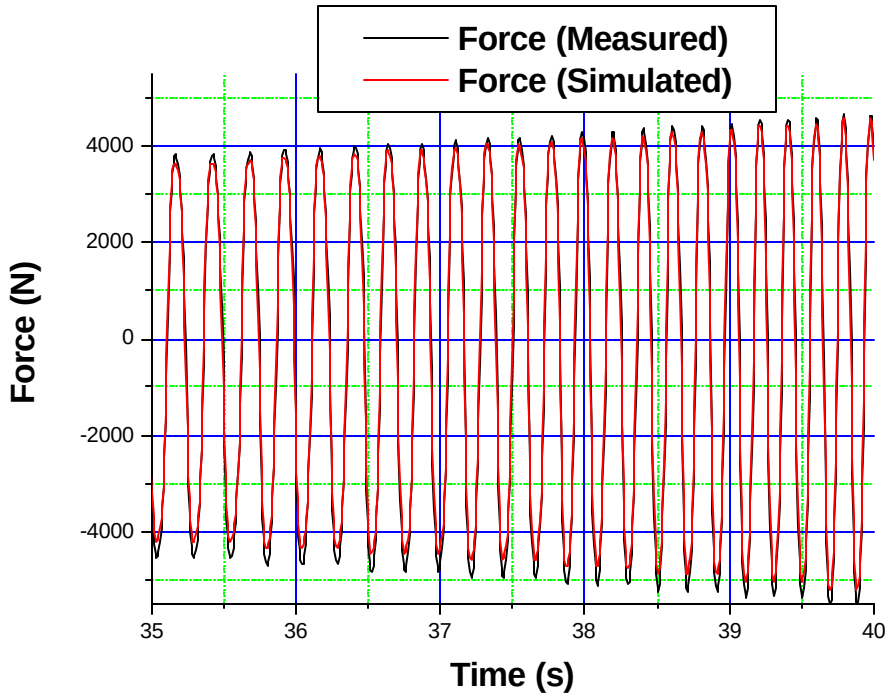

Fig.10 Damper magic formula model dynamics simulation (high frequency)

PART THREE: INTEGRATION OF MAGIC FORMULA DAMPER MODEL INTO ADAMS/RAIL BOGIE MODEL

After finished the above two parts work, a damper magic formula model had compiled with Digital Fortran and integrated into the SW160 bogie's ADAMS/Rail model, see Fig.11, and the bogie's secondly lateral dampers were replaced with the damper magic formula model.

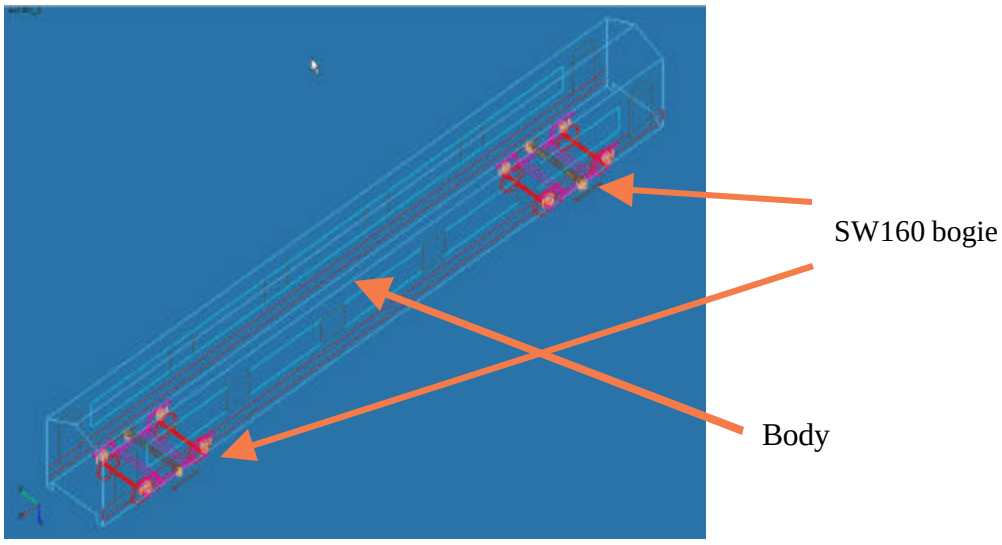

Fig.11 Damper magic formula model integrated into SW160 Bogie dynamics model

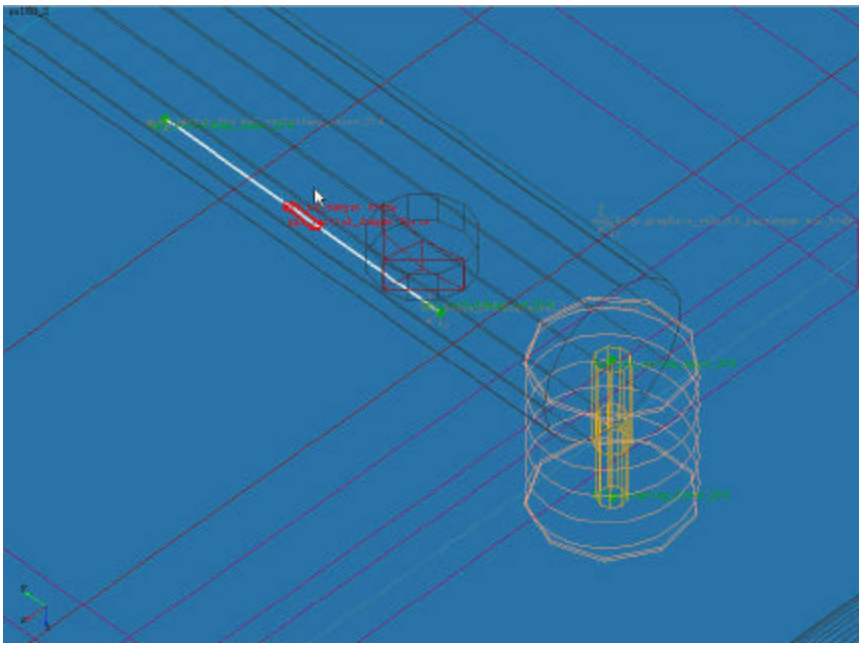

Fig.12 Damper magic formula model integrated into SW160 Bogie dynamics model (Local)

To verify the damper model, we had set the feedback force to zero, and we got the vehicle's dynamic result, see Fig.13.

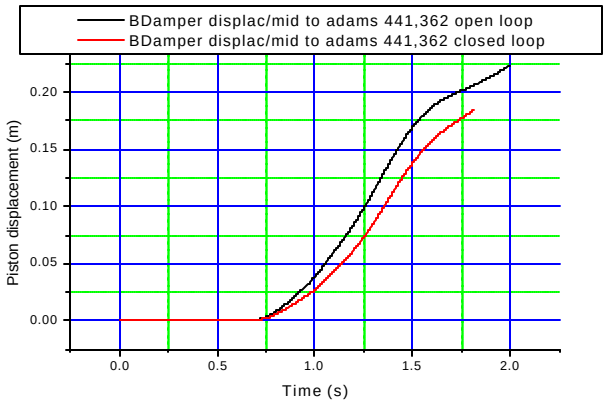

Fig.13 SW160 Bogie dynamics result without the Damper magic formula feedback force

And then we feedback the damper dynamic force to the bogie, and we got different results, it shows the damper model works well, as Fig.14 shows.

Finally, a Sachs damper prototype designed by applying the Magic Formula theory will be installed on the bogie, and a test will hold on South West Jiao Tong University rolling test rig to validate this works.

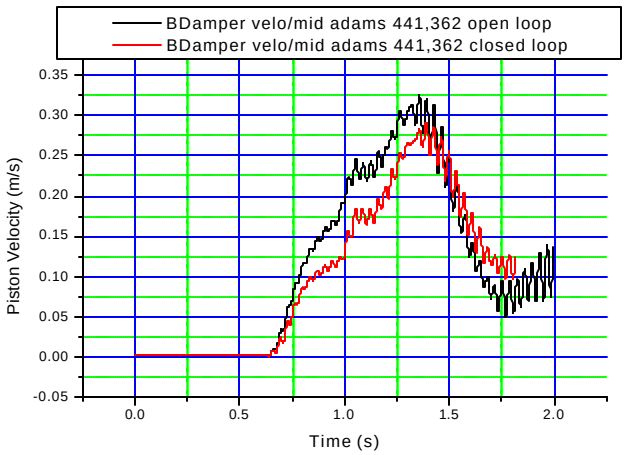

Fig.13 SW160 Bogie dynamics result with the Damper magic formula feedback force

CONCLUSION:

1. We had built a accurate Sw160 Bogie model, and got a good dynamic simulation result.
2. The damper magic model can simulated the true hydraulic damper's dynamic behavior sophistically.
3. We had succeed in integration of the damper magic formula model into ADAMS/Rail.

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