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The Rideability Simulation Analysis of Triangular Track Conversion System Based on Multi-Body dynamic Modeling

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ABSTRACT: The triangular track conversion system can be quickly swapped on the tyres, exerts a smaller ground pressure with greater adhesion to solve the problem of the vehicle traversing rough and difficult terrain. First, establish a multi-body dynamic model of the track conversion system in Multi-body dynamic environment and then program the macro commands to add many complex contact forces of the dynamic model. Then using the method of a physical prototype obstacle test, verify the correctness of the simulation model. Finally simulate and analyze the straight driving performance of an engineering vehicle assembled with the track conversion system, through the measurement of unladen and laden conditions of driving wheel driving torque, acceleration, track dynamic tension, the centroid vertical acceleration, for research tracked vehicle's ride comfort and stationarity.

KEYWORDS: Triangular track conversion system; Virtual modeling; Rideability; Multi-Body dynamic.

INTRODUCTION

The triangular track conversion system is a special crawler device with the tyres and the tracks on them, which can be rapidly swapped. It is used to solve the problem of the vehicle traversing rough and difficult terrain, such as beaches, marshes, deserts, snow and gravel [1-3]. Compared to the regular track, triangular track conversion system has a better ability to adapt to difficult terrain and a smaller turning radius. Compared to the ordinary tyres, the triangular track conversion system has more contact area and less ground pressure, important advantages. Enhanced adhesion and improved traversing vehicle ride comfort on difficult terrain, as well as stable traction [4-6], as shown in figure 1.

Figure 1. Engineering vehicle equipped with the track conversion system in operation.

Virtual prototype simulation method is often used in the performance simulation of vehicles, which determines errors in the theoretical calculation, and also saves the cost of traditional physical prototype testing [7-9].

We establish a multi-body dynamic model of the track conversion system in ADAMS environment. Then using the method of a physical prototype obstacle test, verify the correctness of the simulation model. Based on the rideability simulation of the vehicle assembled with track conversion system, measure the driving wheel driving torque,

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acceleration, track dynamic tension, the centroid vertical acceleration in unladen and laden conditions, for establishing the tracked vehicle's ride comfort and stability.

ESTABLISH THE MULTI-BODY DYNAMICS MODEL BASED ON ADAMS

Because ADAMS modeling is obviously insufficient, especially for a complex model with a curved shape, the virtual prototype of the track conversion system is established in Solidworks, which after simplifying can be imported into ADAMS by IGS format [10].

Because the model is simplified, its mass is far different from the actual, so on the frame increase a matching block, adjust the mass and centroid position [11-13].

Then add the constraints and kinematic pairs. In this model, in addition to the tensioning device and the central independent swing suspension added to the moving pair, between the other parts are also added the revolute pair [14].

Track conversion system simulation model is shown in figure 2.

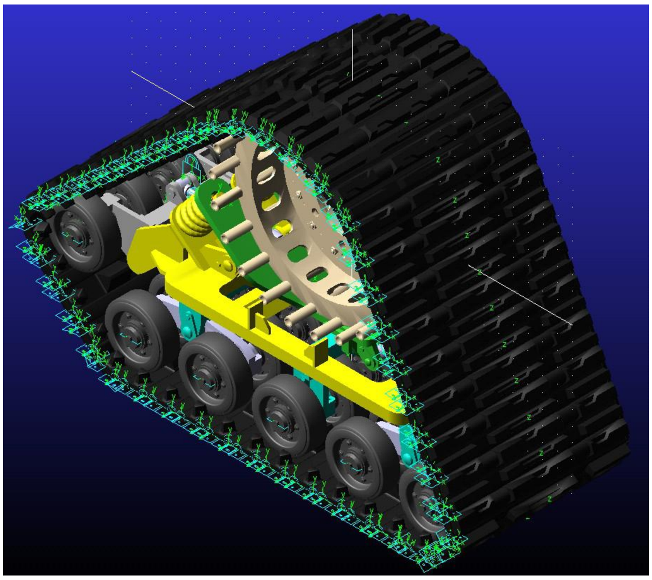

Figure 2. The track conversion system virtual simulation model.

In the process of track conversion system virtual modeling, adding all kinds of forces is the key, which mainly are the contact force between components. The motion relationship is defined by various constraints. In the ADAMS/View, if there are no contact forces between the various components of the track conversion system, then those between each other will have a direct influence, so the contact force is necessarily to be added [13, 15, 16].

There are many track treads in the track conversion system. With the vehicle moving, each track tread between with the ground, road wheel, driving wheel will produce many contact forces. Therefore, using conventional methods to apply a contact force one by one, is not accurate, and also difficult to achieve.

In this paper, we are using macro commands of ADAMS to add variety and complex contact forces [17, 18]. Calculations of contact force required parameters are shown in Table 1

Table 1. Calculations of contact force required parameters.

Parameters	track treads between driving wheel	track treads between road wheel	track treads between ground
Stiffness	1.0E+007	1.0E+006	3.5E+004
Damping	10000	1000	35

Force Exponent	2.2	2.2	1.5
Penetration Depth	1.0E-004	1.0E-003	1.0E-003
Coulomb Friction	On	On	On
Static Coefficient	0.15	0.2	0.4
Dynamic Coefficient	0.1	0.15	0.3
Stiction Vel.	0.1	0.1	0.1
Friction Vel.	1.0	1.0	1.0

Using the contact force between track tread and ground as an example, the macro commands are as follows. The contact force of track tread between other parts can be modified to bold fonts:

```
variable set variable_name=$_self.num integer=1
for variable_name=bbb start=1 end=34
interface command_builder
interface dialog execute dialog=.gui.contact_cre undisplay=yes
contact create      &
contact_name=.MODEL_1.(eval("contact_ground_"//$_self.num))      &
      adams_id = (eval($_self.num+5000))      &
i_geometry_name=.MODEL_1.(eval("tracklink1_"//$_self.num)).shell1      &
j_geometry_name=.MODEL_1. ground.BOX_348&
      stiffness = 35000      &
      damping = 35      &
      dmax = 0.1      &
      exponent = 1.5      &
augmented_lagrangian_formulation = no      &
      coulomb_friction = on      &
      mu_static = 0.4      &
      mu_dynamic = 0.3      &
      stiction_transition_velocity = 0.1      &
      friction_transition_velocity = 1.0
variable set variable_name=$_self.num integer=(eval($_self.num+1))
end
variable delete variable_name=$_self.num
```

VERIFY THE CORRECTNESS OF THE SIMULATION MODEL BY TESTING

In order to verify the virtual prototype model of the track conversion system correctness based on ADAMS, we are using testing and virtual simulation for verification.

(1) Physical prototype testing

A vibration sensor is fixed at one end of the axle which is assembled with the track conversion system assembly, as shown in Figure 3. The prototype is placed on the road surface with different obstacles and the track conversion system vibration is measured, as shown in Figure 4.

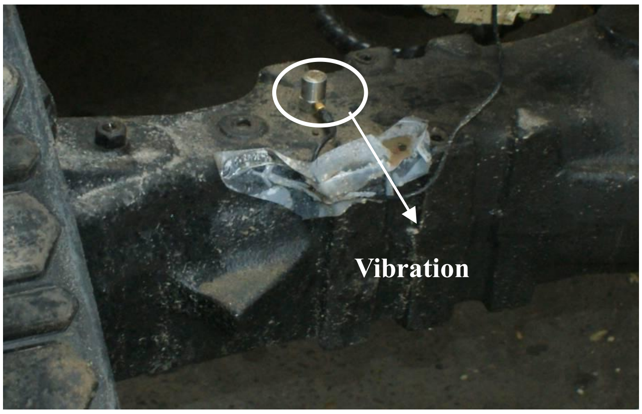

Figure 3. A vibration sensor is fixed at one end the axle.

Figure 4. Physical prototype obstacle test.

(2) Virtual prototype multi-body dynamic simulation

The obstacles arranged in the obstacle test, corresponding to the obstacles in ADAMS, and using the virtual prototype model above established a multi-body dynamic simulation. The position of the vibration sensor in the obstacle test establishes a MARKER point on one side of the drive wheel and fixed to the drive wheel, so that the vibration of the MARKER point can be measured afterwards.

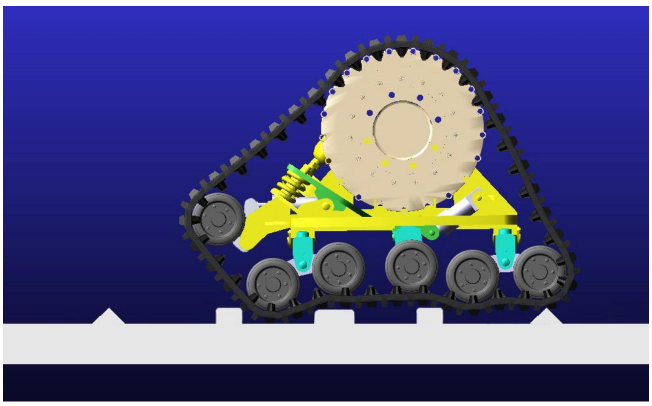

Figure 5. Virtual prototype multi-body dynamic simulation.

(3) Test and simulation data comparison

Physical prototype testing and virtual prototype simulation data combined with the acceleration unit as "g". Using time-domain analysis, an acceleration response curve is established, as shown in Figure 6.

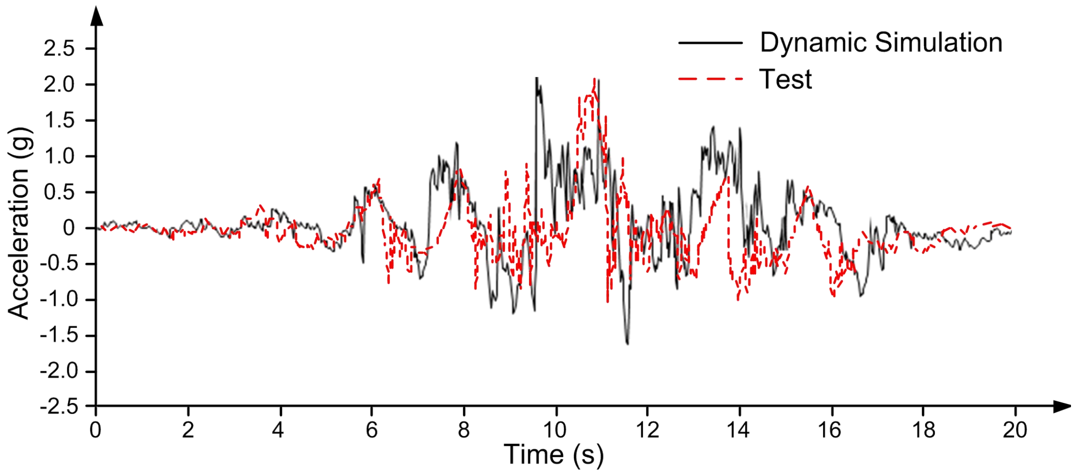

Figure 6. Acceleration response curve in time-domain.

It can be seen from Figure 6, that when the track conversion system crosses different obstacles, the acceleration response curves of prototype testing and virtual simulation are nearly identical. Therefore, we conclude that the multi-body dynamic simulation model is correct.

THE STRAIGHT DRIVING PERFORMANCE SIMULATION OF A VEHICLE ASSEMBLED WITH TRACK CONVERSION SYSTEM

The straight driving performance of an engineering vehicle equipped with the track conversion system mainly measured by the vibration of the body's feedback and the stability of the process of moving, related to centroid vertical acceleration, and amplitude of vibration [13]. Because the rideability of the vehicle will be significantly different under different loads or speeds, so the simulation analysis for the above conditions are different [19].

Laden and Unladen Driving Torque Simulation

As shown in Figure 7, curves A and B were the right front wheel driving torque of the vehicle with both unladen and laden conditions, driving at speed of 10km/h.

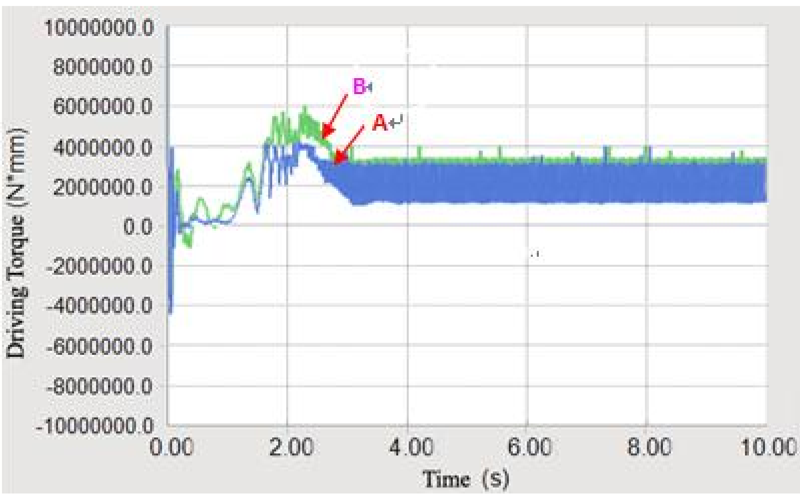

Figure 7. Unladen (A) and laden (B) driving torque.

According to the analysis of the curves, the driving torque of the vehicle in the acceleration phase when laden is greater than when unladen, and it is a shock attenuation process, which reached a maximum in the acceleration process. When the vehicle continued to accelerate, driving torque also entered a stable state. The slight fluctuation is mainly affected by the meshing. The driving torque when laden is greater than when unladen during smooth driving.

Laden and Unladen Acceleration Performance Simulation

Shown in Figure 8, acceleration performance of the vehicle when both unladen and laden accelerating from 0 km/h to 10 km/h. We can see that the two curves coincide and are smooth, and that the acceleration process is flat. Looking at the acceleration, we can see that the vehicle has a good acceleration ability and traction, which is the advantage of the track conversion system. Therefore, whether unladen or laden, the vehicle has a good dynamic performance, and the load effect on the acceleration performance is very small.

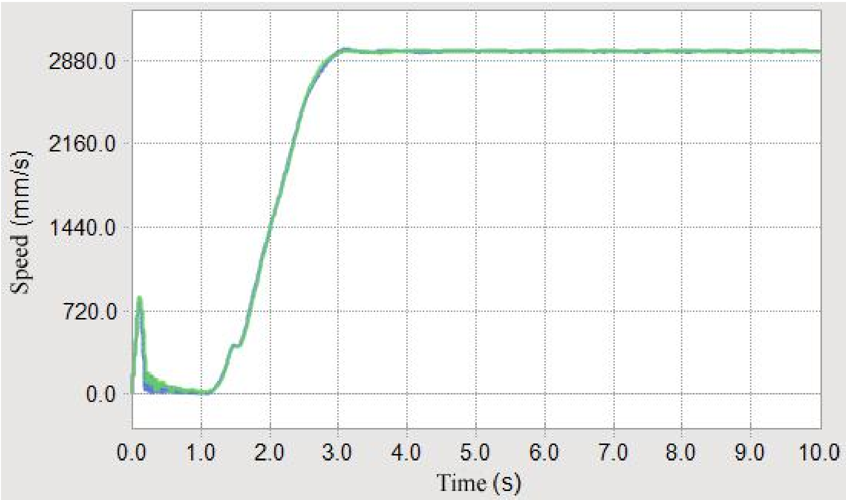

Figure 8. Laden and unladen acceleration performance.

Laden and Unladen Track Tension Simulation

Shown in Figure 9, curves A and B were the track tension of the vehicle under unladen and laden conditions, accelerating from 0 10km/h to 10km/h. The curves of dynamic track tension change periodically, changed by the track dynamic change and the polygon effect. Because the two curves nearly coincide, it shows that the vehicle load condition effect on track dynamic tension is negligible very small and so this factor can be ignored.

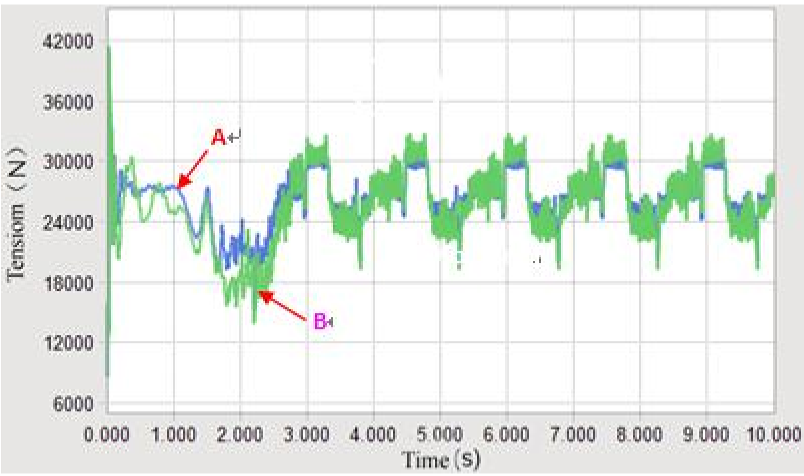

Figure 9. Laden and unladen track tension.

Laden and Unladen Centroid Vertical Acceleration Simulation

Shown in Figure 10, curves A and B were the centroid vertical acceleration of the vehicle under unladen and laden conditions, accelerating from 0 km/h to 10km/h. According to analysis of the curve, the centroid vertical acceleration of the vehicle at a constant speed when laden is smaller than when unladen. This shows that different loads have a certain impact on ride comfort of the vehicle. RMS acceleration when unladen driving at around 3045mm/s^2, and when laden at approximately 2455 mm/s^2, are both within a reasonable range. Therefore, we conclude that the vehicle equipped with the track conversion system provide a comfortable ride.

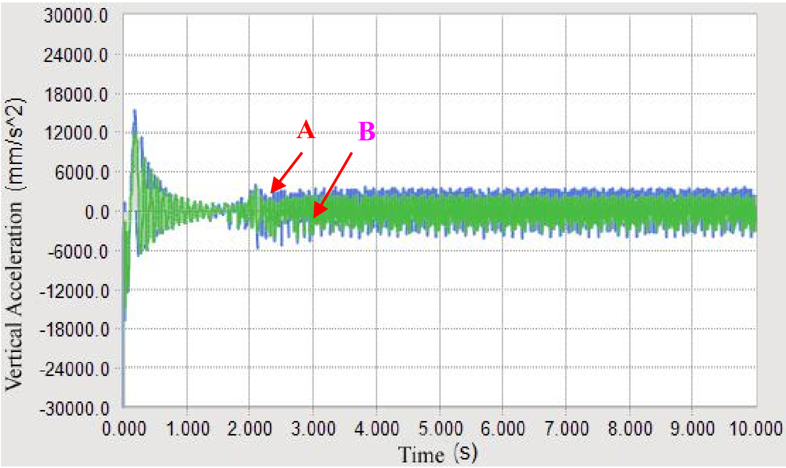

Figure 10. The vertical acceleration of the vehicle centroid.

CONCLUSION

We established the virtual simulation model of the track conversion system in the ADAMS environment, using macro commands of ADAMS to add variety and diverse contact forces. We verified the correctness of the simulation model by the physical prototype obstacle test, got the driving torque, acceleration performance, track dynamic tension and centroid vertical acceleration curves with unladen and laden conditions.

(1) Through the unladen and laden driving torque simulation analysis, we can see that the vehicle during the acceleration phase produced smooth driving, and that the driving torque when laden can be greater than when unladen, and that greater speeds increases this.

(2) Through the acceleration performance simulation, the acceleration performance of the vehicle produces smooth ride, both unladen and laden. The vehicle assembled with the track conversion system has a good acceleration ability and traction, and the load effect on the acceleration performance is negligible.

(3) Through the track dynamic tension simulation analysis, the loading conditions have a negligible effect on the track conversion system dynamic tension and so can be ignored.

(4) The centroid vertical acceleration simulation analysis shows that the vertical acceleration of the vehicle centroid in the constant speed driving stage when laden is smaller than when unladen, which means that the loads affect the ride performance of the vehicle.

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REFERENCES

[1] Z. N. Hu, "Optimization Design in the Driving Gear Wheel Axle of Triangular Rubber Track Conversion," Advanced Materials Research, vol. 308-310, pp. 513-516, 2011.

[2] H. Zhongming, Y. Kai, and W. Shengjun, "Development and Application of replaceable rubber track system," China Rubber Industry, vol. 56, pp. 764-767, 2009.

[3] Y. LiHao, W. ShengJun, and W. YouJun, "Status and Developing Tendency of Tracked Wheel Conversion Technology," Development & Innovation of Machinery & Electrical Products, vol. 24, pp. 80-82, 2011.

[4] G. Brazier, "Belted track assembly," US Patent 528133 S, Sept. 12, 2006.

[5] R. S. Hansen, " Apparatus for Converting a Wheeled Vehicle to a Tracked Vehicle," U.S. Patent 478808 B2, Sept.

05, 2014.

[6] R. Bessette, "Traction assembly with endless track having variable ground-contacting area," US Patent 8007058 B2, Aug. 30, 2011.

[7] J. Wang, J. Chen, S. Ouyang, and Y. Yang, "Trajectory tracking control based on adaptive neural dynamics for four-wheel drive omnidirectional mobile robots," Engineering Review, vol. 34, pp. 235-243, 2014.

[8] Y. Li and S. Frimpong, "Dynamic modelling and virtual prototype simulation of dump truck-haul road interactions," International Journal of Heavy Vehicle Systems, vol. 15, pp. 416-432(17), 2008.

[9] J. Novak-Marcinčin, "Application of the Virtual Reality Modelling Language in Automated Technological Workplaces Design," Engineering Review, vol. 27, pp. 1-6, 2007.

[10] H. Li, H. Zang, Y. Cao, and S. He, "Virtual Prototyping of Climbing Mechanism in Vertical Pipeline Based on SolidWorks and MCS.ADAMS," in *Education Technology and Computer Science (ETCS), 2010 Second International Workshop on*, 2010, pp. 99-102.

[11] B. J. Liu, C. Chen, and Y. F. Si, "Application Research on Vehicle Steering Stability Based on ADAMS/CAR," Applied Mechanics & Materials, vol. 730, pp. 289-292, 2015.

[12] R. R. Teixeira, S. R. D. S. Moreira, and S. M. O. Tavares, "Multibody Dynamics Simulation of an Electric Bus," Procedia Engineering, vol. 114, pp. 470-477, 2015.

[13] M. Mahmoodi-Kaleibar, I. Javanshir, K. Asadi, A. Afkar, and A. Paykani, "Optimization of suspension system of off-road vehicle for vehicle performance improvement," Journal of Central South University, vol. 20, pp. 902-910, Apr 2013.

[14] Y. F. Zhu, Y. Zai, and X. Guo, "Simulation of Running System of Tracked Vehicle's Performances Based on ADAMS," Drive System Technique, vol. 22, pp. 29-31, 2008.

[15] Z. S. Li, H. T. Wu, and H. B. Liu, "The Dynamic Simulation of Contact Force between Wheels and Ground Based on ADAMS," Advanced Materials Research, vol. 510, pp. 437-441, 2012.

[16] S. Faik and H. Witteman, "Modeling of impact dynamics: A literature survey," in *2000 International ADAMS User Conference*, 2000.

[17] W. Sui, "Research on Dynamics Simulation of Crawler Travelling Mechanics of Large Mining Excavator," M.S. thesis, May. JinLin University, ChangChun. China, 2007.

[18] J. Ling, "Optomal Design about Crawler Board of EBZ-135 Cantilever Type Roadheader," M.S. thesis, Jun. Taiyuan University of Technology, Taiyuan. China, 2010.

[19] Z. Xiaoyang, S. Beibei, S. Qinghong, and C. Nan, "Vehicle and terrain interaction based on Adams Matlab co-simulation," Journal of Southeast University (English Edition), vol. 25, pp. 335-339, 2009.