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Three-dimension design of EPS

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ABSTRACT: Electric power steering (EPS) is powered by electromotor directly. It can operate and provide correspondent power according to driving conditions of automobile and driver's operations, which will make auto more handy and stable when steering with slow speed. Based on Multi-body Dynamics theory, multi-body dynamics model of complete vehicle is built and simulated by ADAMS. The front suspension model, rear suspension model and steering system model is included in this model. According to these models, handiness and stability of steering system is evaluated in this paper. And a linear assistance characteristics is determined.

Key words: EPS, multi-body dynamics model, ADAMS, assistance characteristics

I. Introduction

EPS is a kind of steering system powered by electromotor directly. Compared with traditional Hydraulic Power Steering(HPS), EPS has many advantages, eg. Start to power only when necessary. Total weight and oil-consumption have been decreased because of no hydraulic pump. Have a great performance of power under any driving conditions. And reduce the disturbance on steering system caused by road roughness. No oil hydraulic circuit and no oil leakage.

II. Modeling

2. Vehicle model based on ADAMS

2.1 The main parameters of vehicle model

Table 1 - Main parameters of vehicle model

	Parameters name	Value
Front wheel alignment parameters	kingpin inclination angle	10.0°
	kingpin caster angle	2.5°
	front-wheel camber	1.0°
	toe-in of front wheel	0.2°
dimension parameters	wheel base	2600mm
	Front/rear tread	1650/1650mm
	Kingpin length	330mm
	Cross arm length	350/500mm
mass parameters	curb weight	2010kg

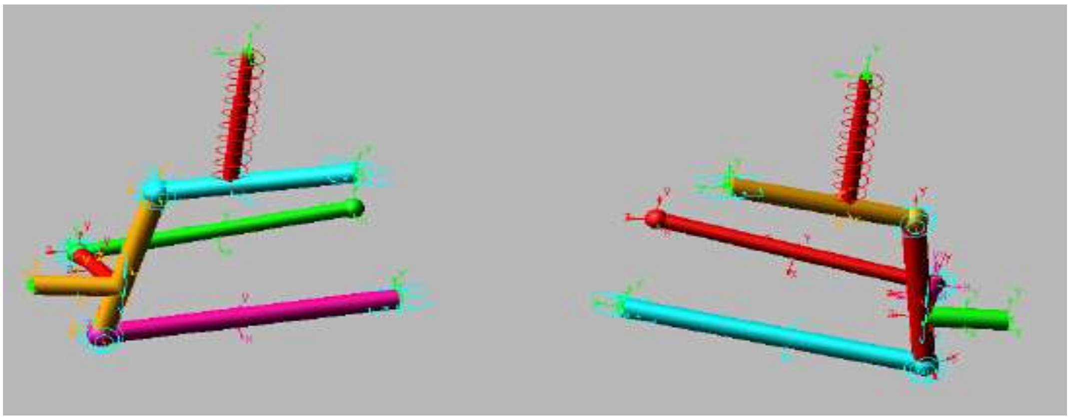
2.2 The establishment of simulation model

The simulation model builded by ADAMS includes automotive chassis model, wishbone type independent front suspension model, steering system model and Oblique arm type rear suspension model. The simulation of vehicle dynamic can be analyzed by vehicle model builded. As shown in the picture1, modeling coordinate is described by vehicle coordinate.

Picture 1Three-dimensional vehicle coordinate system

2.3 Wishbone type independent front suspension model

Front suspension model consists of top crossbeam, bottom crossbeam , knuckle assembly, Steering linkages and damper. King pin, arm and knuckle are fixed joint, and they can be seen as knuckle assembly. Vehicle chassis can be simplified as a sphere which has mass and rotational inertia. Top crossbeam uses revolute joint and spherical joint to connect to car body and knuckle assembly, and bottom crossbeam is also. Top crossbeam uses spring to connect to chassis, and knuckle assembly uses spherical joint to connect to steering linkages. Just as shown in picture 2.



Picture 2 Wishbone type independent front suspension model

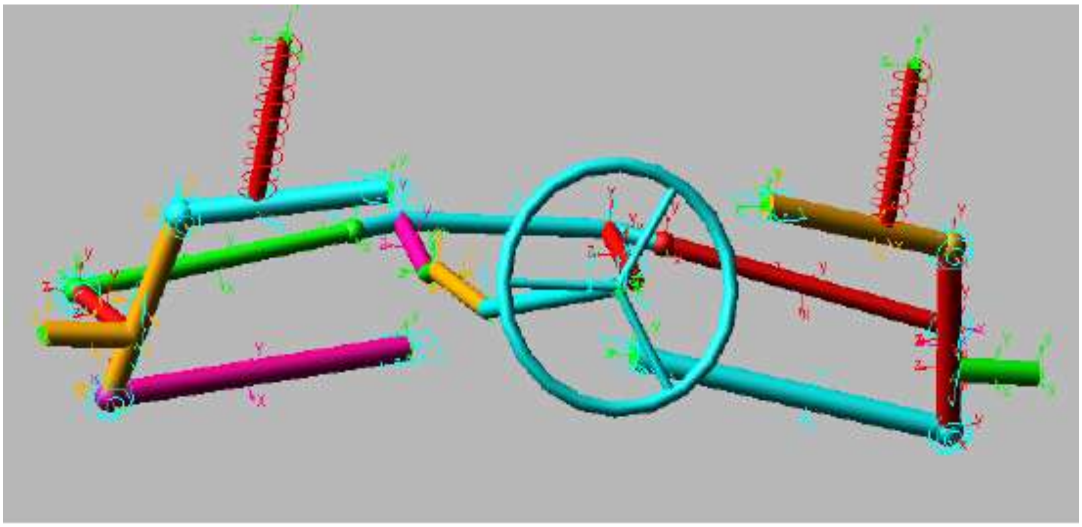
2.4 Oblique arm type rear suspension model

Rear suspension model is a kind of oblique arm independent suspension. It consists of left and right oblique arm and damper. Left and right oblique arm use rotational inertia to connect to chassis. Since the focus of this paper is studying steering system, this simplified model is accepted. As shown in picture 3.

Picture 3 Oblique arm type rear suspension model

2.5 Steering system model

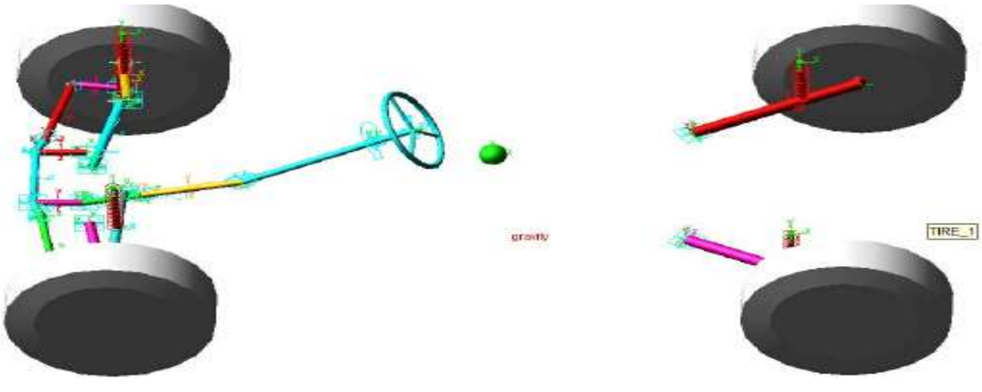
Steering system consists of steering wheel, steering column, steering inner articulated shaft, knuckle assembly, pitman arm and intermediate draw bar. Because EPS system is equipped with torque sensor between steering wheel and steering column, the steering wheel and steering column are connected flexibly, which connected with torsional spring-damper. Steering wheel uses rotational inertia to connect to car body. Steering shaft uses cylindrical pair to connect to car body. Steering inner articulated shaft uses cardan joint to connect to steering shaft and knuckle assembly. Pitman arm connects to car body and intermediate draw bar with rotational inertia. Intermediate draw bar connects to left and right steering linkages with cardan joint. As shown in picture 4.



Picture 4 Steering system model

2.6 Multi-body dynamics model of complete vehicle

On the basis of front and rear suspension model and steering system model, we need add parameters of wheel and road to the model we build, then we get the multi-body dynamics model of complete vehicle. As shown in the picture 5. There are 22 rigid bodies, 10 rotational inertias, 7 sphere joints, 5 cardan joints, a composite pairs and a kinematics driver in this model. There are 15 degrees of freedom in this model. They are 6 degrees of freedom of car body; 4 rotational freedom of wheel; 2 rotational freedom of left and right cross arm of front suspension; 2 rotational freedom of left and right oblique arm of rear suspension and a rotational freedom of wheel.



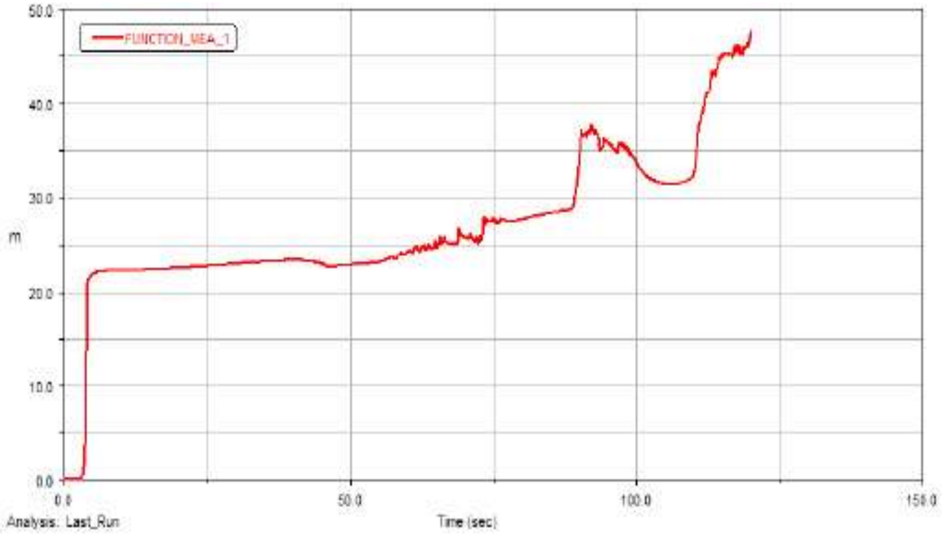
Picture 5 Multi-body dynamics model of complete vehicle

III. Simulation on steady steering performance of auto model

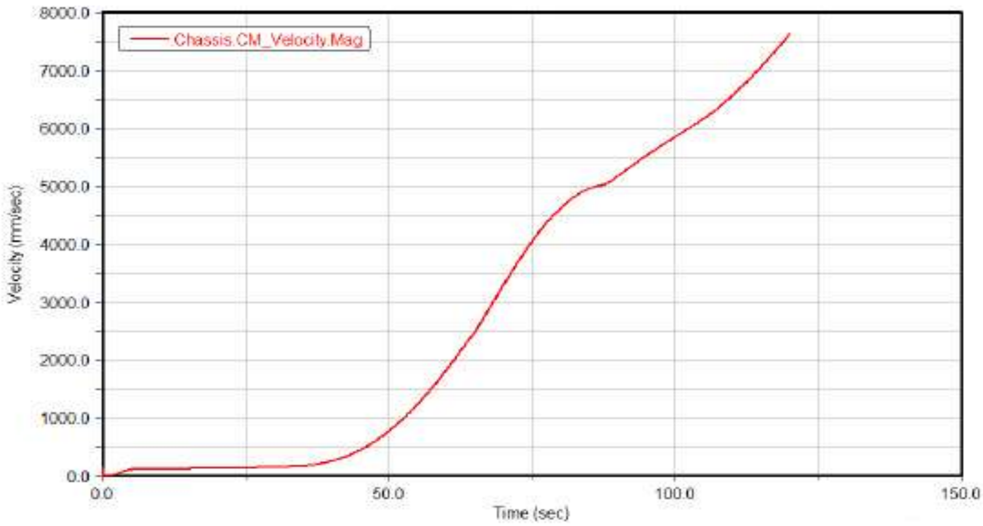
Steady steering performance is a main topic of vehicle handling stability, which is related to the driving safety directly. Because of the unsuitable parameters, some automobiles show deficient steering performance with a low side acceleration, but show over steering performance with a large side acceleration. Over steering will cause auto drift and sharp turn, which will lead to serious accident. It's important for steering stability to study steady-state steering performance.

Driving torque is applied to two rear-wheels with the function of 'step(time,0,0,6, 30000) +step (time,6,0,400,1200000)'. This driving torque will make auto speed up in a steady acceleration. Turning the steering wheel to 120° within 1 second and maintaining this angle, which will make auto get into steady state. A rotary motion is exerted to steering wheel with a function of 'step(time,2,0,4,120d)'. Defining the measurement function of speed as 'SQRT(VX(Chassis.om)**2+VZ(Chassis.cm)**2)*3.6/1000' and defining the measurement function of turning radius as '(VM(Chassis.om)/(WY(Chassis.cm)+1E-006))/1000'.

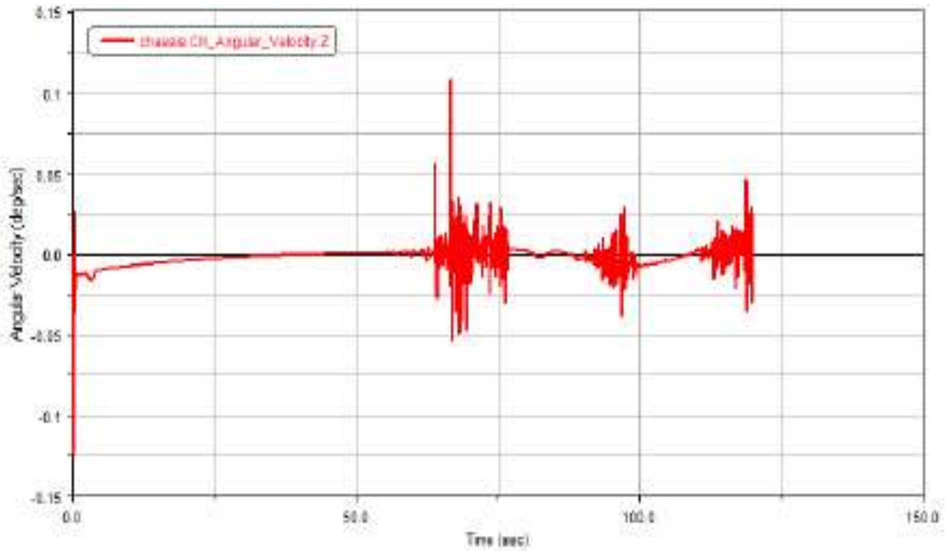
Setting the end time of simulation to 120 seconds and the step of simulation to 0.01second. Vehicle model is simulated under these parameters. Simulation conclusion is shown from picture 6 to picture 9.



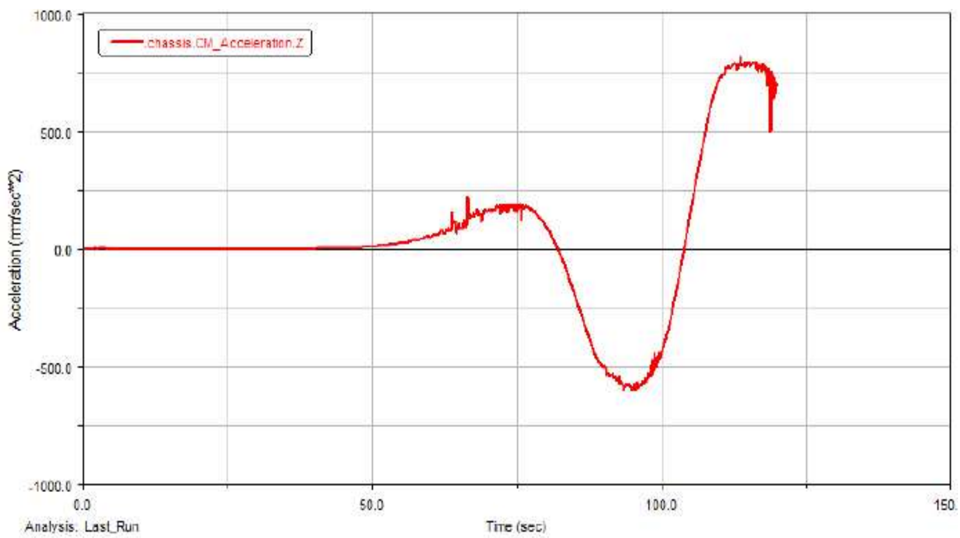
Picture 6 Curve of turning radius



Picture 7 Curve of speed



Picture 8 Curve of centroid yaw velocity



Picture 9 Curve of side acceleration

From these tables, we can learn that turning radius becomes bigger gradually as speed increases. It shows that this vehicle model has the obvious performance of deficient turning.

Multi-body dynamics automobile model is builded by ADAMS to study the simulation of EPS system. Twisted bar spring model and simplified steering torque model is used to simulate the assistance characteristic of EPS system. Simulation conclusion shows that the vehicle model we build has obvious performance of deficient steering. And it also shows that virtual prototype has a large similarity with real auto, which lay a foundation for the study of assistance performance.

IV. Simulation on linear assistance performance curve

Linear assistance performance curve is adopted to simulate. Related data are listed in table 2. According to the data in table 2, the smallest steering torque (T_{d0}) is 1.0Nm, the biggest steering torque (T_{dmax}) is 45.0Nm, that is T_{d0}=1.0Nm and T_{dmax}=45.0Nm. When T_{d0}>=1Nm, EPS starts to power. When T_{d0}>=8Nm, steering torque(T_{dmax}) is the biggest, 45Nm. When speed V is equal to 0Km/h, the slope is the biggest. When

V>=80Km/h, the slope is the smallest.

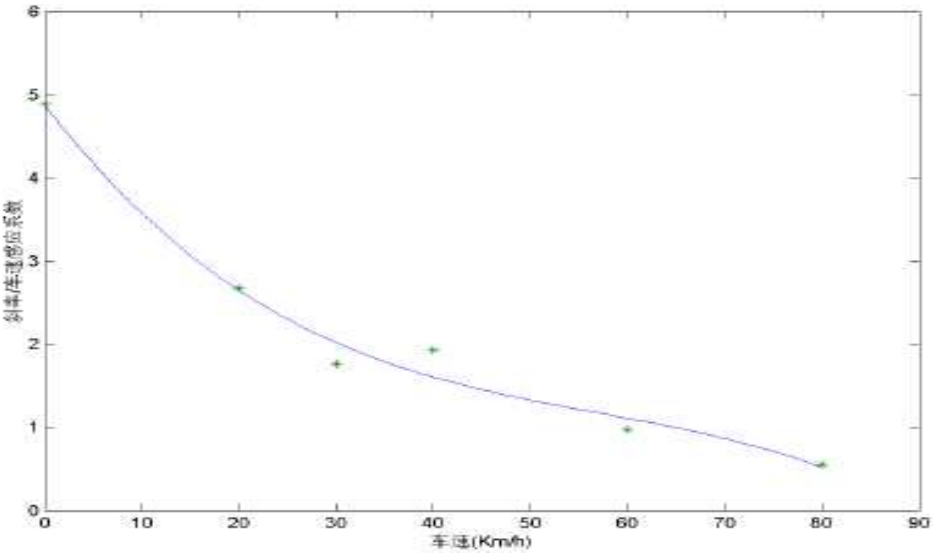
Table 2 - Slope in different speed

Name	Value					
Speed v/(km/h)	0	20	30	40	60	80
Slope K（v）	4.89	2.67	1.76	1.93	0.97	0.55

According to the table 2, we can fit polynomial with formula 1.

$$K(V)=P_0+P_1V+P_2V^2+P_3V^3 \quad (1)$$

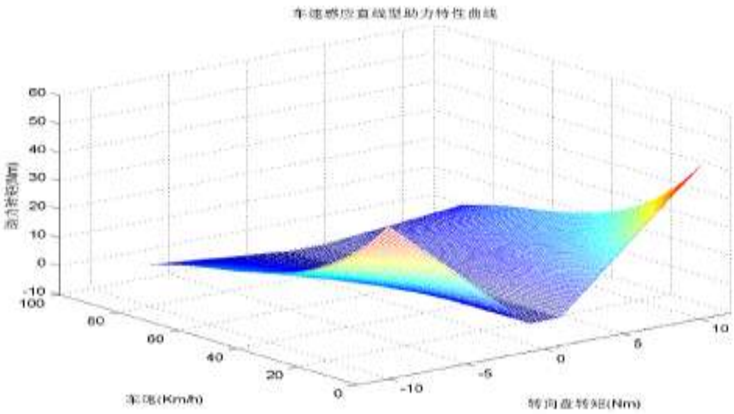
The result shows that the slope, K(V), decreases gradually as the speed increases. Just as shown in picture 10.



Picture 10 Relations between slope and speed

According to the table 2 and the fitting polynomial, the three-dimension picture of linear assistance characteristic curve is shown in picture 11. We can draw three conclusions from the simulation result.

1. Traveling trace of vehicle is in line with pre-designed trace. Model has a great following performance.
2. Yaw velocity, side acceleration and car body roll angle all become small to a certain extent.
3. EPS is beneficial to the improvement of vehicle stability.



Picture 11 Three-dimension picture of linear assistance characteristic curve

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