

Non-independent Suspension Dynamics Analysis Basic on Rigid-flexible Coupling Model

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Abstract – Virtual prototype technology software Adams/car and FEA analysis software Ansys are used to set up a bridge non-independent suspension's multi rigid bodies and rigid-flexible coupling model. The rigid-flexible coupling model will give a better reaction of the suspension kinematic feature as a result of comparing the kinematics simulation and the experimental result. This method can improve calculation accuracy, provide the technology support for dynamics simulation and the physical prototype manufacturing.

Keywords – Dynamics Analysis, Non-independent Suspension, Rigid-flexible coupling model.

I. INTRODUCTION

Chassis tuning is a necessary part of the development of the car, and an important guarantee of ride comfort and handling stability. However, the prophase of chassis tuning required design optimization of prototype, design optimization requires precise kinematics simulation model. In conventional kinetic studies, the complex motion suspension systems often models based on multi-rigid-body kinematics system, while ignoring the elastic deformation of the components of the suspension system, but these variants exist, and elastically deformable affects the output of the system [1]. With the development of flexible body dynamics and related software, it is feasible that the suspension system into a flexible coupling model rigid body kinematics simulation provides technical support. It provides the technical support for suspension kinematics simulation with a rigid-flexible coupling model.

II. DISCRETE MULTI-FLEXIBLE MODEL THEORY

A. Coordinate of Multi-flexible Model

Flexibility is the theory that several finite element nodes with degrees of freedom of the discrete unit represent an infinite number of degrees of freedom of the object [2]. These nodes' elastically deformable can be approximately represented by a linear combination of a small number of modes. If the position of the object in coordinate system can be expressed by Cartesian coordinates $X = (x, y, z)$ in the inertial coordinate system and Euler angle $\Psi = (\psi, \theta, \varphi)$ that can react rigid model orientation. The modal coordinates (n is the number of modal coordinates) is represented by $q = (q_1, q_2, \dots, q_n)^T$, the generalized coordinates can be selected as

$$\xi = \{X, \Psi, q\}^T = \{x, y, z, \psi, \theta, \varphi, q_i\} \quad (1)$$

(i=1,2,...,n)

Any node (such as the point j) of the flexible body position vector can be expressed as

$$r_j = x + A(s_j + \Psi_j q) \quad (2)$$

In the formula, A represents the object coordinate system to transform matrix inertial reference frame; s_j is the location of the node, of which j is not deformed in the object coordinate system; Ψ_j expresses the corresponding node, of which j is mobile automatic degree of automatic modal matrix sub-blocks [4].

B. Flexible Methods

ADAMS creating flexible body includes two methods: One is using flexible functionality of ADAMS, adopting tensile mode directly-direct flexible methods. However, this method is only for the components what relatively simple in structure and shape, the accuracy is relatively low. The second method is to generate neutral modal file and import the mathematical model established by three-dimensional software into the corresponding finite element analysis software, then to make the relevant definitions and mesh. Finally, the corresponding mode is calculated and generate neutral modal file MNF [3]. The relatively high accuracy method focuses on the components what relatively complex in structure and shape. The second method is used herein.

III. CONSTRUCTION OF THE BRIDGE TYPE NON-INDEPENDENT SUSPENSION

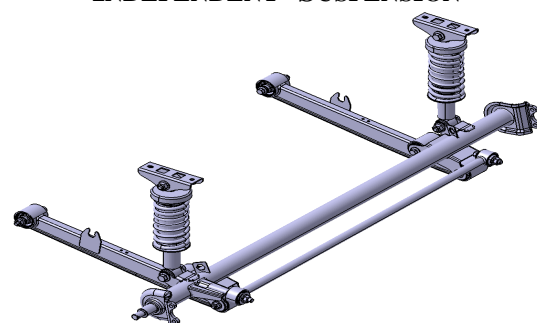


Fig. 1. Mathematical model based on Caita

The structure of the bridge type non-independent suspension is one end of two trailing arms connected to the whole axis by two bushings, the other end is connected to the vehicle body by the trailing arm bushings by bushings. Lateral rod is also such a structure that spreads some lateral thrust. Its structure is simple, low cost, reliable, long life, generally as the principal choice for a rear axle drive suspension

A. Construction of Multi Rigid Virtual Prototype Models

First step is to determine the corresponding hard point coordinates based on the CATIA mathematical model, then to establish the bridge type non-independent suspension's two trailing arms, the whole rear axle, lateral thrust levers and wheels and other parts. The establishment of shock absorber's damping model in suspension adopts damping characteristic curve of benchmarking test car's modifying the properties file to accomplish. Suspension springs uses the coil spring with linear rigidity. Each connection adopts the bush. Bush's data is obtained through experimental tests. Finally, we establish a connection between the various components according to the relevant connection pair, and match the corresponding mounting and communicators, complete components suspension model is shown in Fig. 2 below.

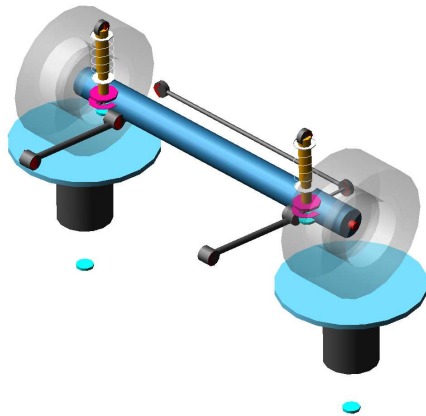


Fig. 2. The bridge type non independent suspension based on multi rigid bodies

B. Construction of the rigid-flexible coupling virtual Prototype models

The structure of the bridge type non-independent suspension is relatively simple. In the actual process of movement, gearbox, drive motor as an integrated whole axes, as the main carrier components, the force is relatively complex, it will have a huge impact on lateral forces on the suspension conditions, longitudinal force working conditions and aligning torque conditions. It was chosen the whole bridge to take the Flexibility Analysis Object.

Rear axle's flexible processing: Adopt higher accuracy generating modal neutral file methods. Import the modulus from CATIA into ANSYS for related geometry cleanup. Set material related properties. Elastic modulus is 210000 Pa, Poisson ratio is 0.3, the material density is $7.9g/cm^3$. Meshing, a total of 5906 nodes and 14793 units; Then make the appropriate mode calculate to generate neutral modal file MNF. Since the first six order modal close to the rigid body, we just select order mode numbered 7-12. Modal calculation results are shown in Table 1:

Table 1: Font styles for a reference to a journal article.

Level	7 Rank	8 Rank	9 Rank	10 Rank	11 Rank	12 Rank
Frequen-cy /Hz	111.24	112.87	312.95	317.31	412.12	595.67

Import neutral modal MNF files generated in ANSYS into ADAMS/CAR to replace the original rigid body. Construction of the flexible body rigid coupling model virtual Prototype bodies is shown in Fig. 3.

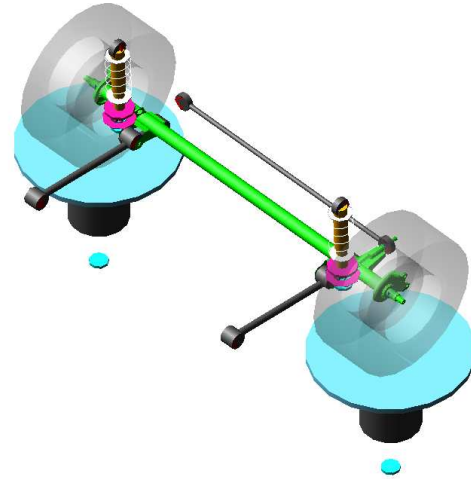


Fig.3. The flexible body rigid coupling model virtual Prototype bodies

IV. SIMULATION RESULTS AND ANALYSIS

Elastic Kinematics of the suspension system can describe the wheel alignment parameters change characteristics when a suspension under the influence of external forces and torque. In this paper, the prototype adopts same loading as the suspension K & C test bench. Load three different working conditions lateral force, longitudinal force, aligning moment on the Wheel pick, pay attention to the curve of the wheel alignment parameters and displacement.

A. Lateral Force Simulation Results and Analysis

Load (-1500N, 1500N) lateral force on wheel pick, the simulation results are compared with the experimental values as shown in Fig. 4, Fig. 5:

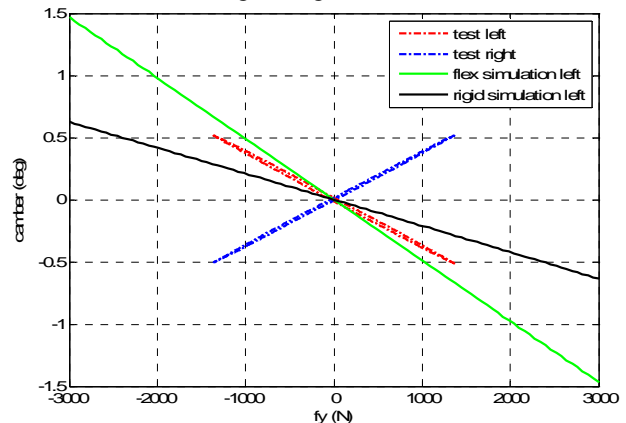


Fig. 4. Camber angle vs Synthetic lateral force

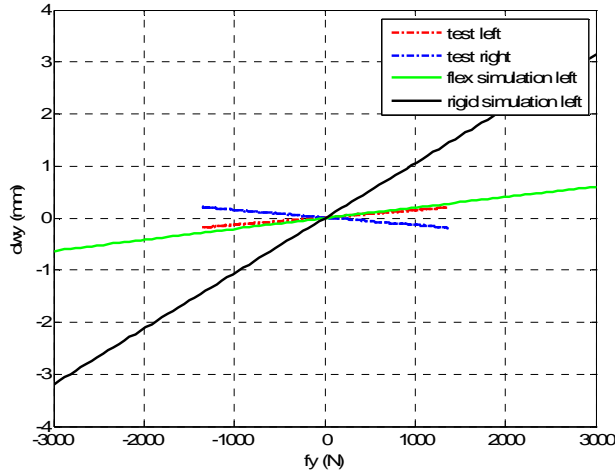


Fig. 5. Lateral displacement of the wheel center Vs reverse side force

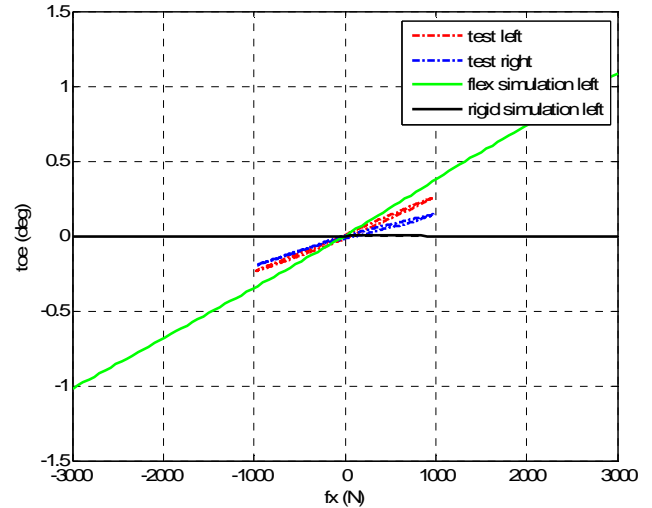


Fig. 6. Toe angle Vs Longitudinal Force

In the process of moving, car is affected by the lateral force, axis has large deformation, Combine camber angle changes cooperating with the initial targeting parameters. We hope Camber angle has a negative gradient to increase the span of the wheels pick. Relatively gently gradient change is better, it is conducive to lateral force support, and less prone to slip. Suspension lateral flexibility slightly larger is better, it is conducive to the degree of understeer, and too easily lead to dynamic multi-degree turn, making the car left and right yaw, lateral stability is not conducive.

Table 2. Lateral force Simulation results and calculation

Result	Body model	Multi - rigid Body model	Experimental values	Accuracy improvement
Camber gradient (deg/KN)	0.209	-0.429	-0.397	39.3%
Suspension lateral flexibility (mm/KN)	0.105	0.1705	0.1604	28.2%

B. Longitudinal Force Simulation Results and Analysis

Load (-1500N, 1500N) lateral force on wheel pick, the simulation results are compared with the experimental values as shown in Fig. 6, Fig. 7:

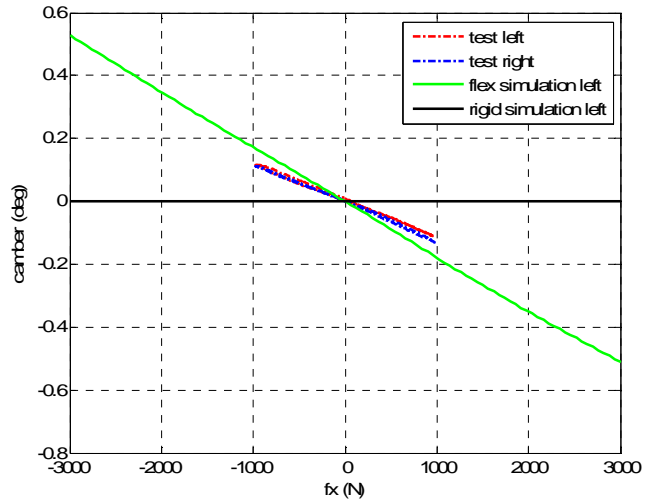


Fig. 7. Camber Vs Longitudinal Force

In the process of moving, car is affected by the lateral force. We hope to the toe angle to have a forward trends change. Camber angle remained relatively less change, reducing the tire wear, keep maximum adhesion and maintain the braking direction, not cause left and right yaw.

Table 3. Longitudinal force Simulation results and calculation

Result	Body model	Multi - rigid Body model	Experimental values	Accuracy improvement
Toe Gradient (deg/KN)	0.0081	0.362	0.2508	52.4%
Camber gradient (deg/KN)	0.0017	0.175	0.1173	49.4%

As can be seen from Table 3 the toe angle gradient of Multi-rigid Body model is 0.0081 deg/KN. The toe angle gradient of rigid-flexible coupling model is 0.362 deg/KN, it is much closer to the test value 0.2508 deg/KN. Model

accuracy was improved by 52.4%. Analysis of the longitudinal force camber change is that a multi-body dynamic model of suspension's Camber angle gradient is -0.0017 deg/KN, and rigid flexible coupling model of suspension's Camber angle gradient is -0.175 deg/KN. The latter is much closer to the test value -0.1173 deg/KN. Model accuracy was improved by 49.4%. Therefore, the change of rear axle has a significant role on braking stability. The deformation of rear axle cannot be ignored.

C. Aligning Torque Simulation Results and Analysis

Load (-1500N, 1500N) lateral force on wheel pick, the simulation results are compared with the experimental values as shown in Fig. 7, Fig. 8:

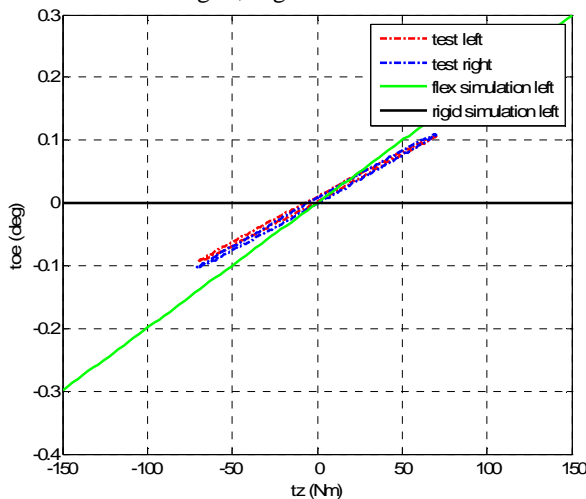


Fig. 8. Camber angle vs aligning torque in the same direction

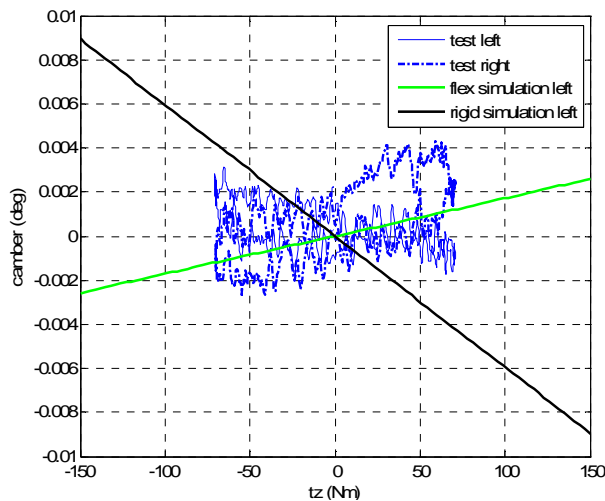


Fig. 9. Toe angle Vs Aligning torque in the same direction

In the process of moving, car is affected by the aligning torque. We hope to the toe angle to have a forward trends change. Camber angle remained relatively less change, cars have insufficient degree turn. It will contribute to stabilize the steering and maintain a straight line driving stability. Or it will cause oversteer, and prone to drift, even very serious consequences.

Table 4. Aligning torque Simulation results and calculation

Result	Body model	Multi - rigid Body model	Experimental values	Accuracy improvement
Toe steering gradient (deg/KN*m)	0.012	1.731	1.643	93.9%
Camber steering gradient (deg/KN*m)	0.1597	0.0169	0.0276	*

As can be seen from Table 4 the toe angle gradient of Multi-rigid Body model is 0.012 deg/KN*m. The toe angle gradient of rigid-flexible coupling model is 1.731 deg/KN it is much closer to the test value 1.643 deg/KN. Model accuracy was improved by 93.9%. Analysis of the gradient of the camber angle under the aligning torque is that a multi-body dynamic model of suspension's Camber angle gradient is -0.1597 deg/KN, and rigid flexible coupling model of suspension's Camber angle gradient is 0.0169 deg/KN. The latter is much closer to the test value 0.0276 deg/KN. Model accuracy was improved by 49.4%. The result of rigid flexible coupling model has the higher accuracy.

V. CONCLUSION

The flexible multi-body theory is used to set up a rigid-flexible coupling model and a multi-body model. These models are used to figures the curves of the toe angle gradient, extraversion gradient, suspension lateral gradient. The curves are used to make a comparative analysis with the experimental curve to get the result that the rigid-flexible coupling model is more accurate than the body model. Using the flexible axis to replace the integral shaft on the bridge non-independent suspension can make the process of analysis more reliable and the dynamic simulation of the physical prototype better. Because of the flexible parts of the suspension can make a difference of the suspension performance, setting up a rigid-flexible coupling model is necessary in solving the actual calculation, analysis and the non-accurate problem.

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