

The Influences of the Subframe Flexibility on Handling and Stability Simulation When Using ADAMS/Car

Hongyuan Zang
Tongji University

Zhuoping Yu

Lu Xiong
Tongji University

ABSTRACT

To analyze the K&C (kinematics and compliance), handling and stability performance of the vehicle chassis, some simulations are usually performed using a multi-body dynamics software named ADAMS. This software introduces assumptions that simplify the components of the suspension as rigid bodies. However, these assumptions weaken the accuracy of the simulation of ADAMS. Therefore the use of flexible bodies in K&C and handling and stability simulation in ADAMS is needed to conduct more precise suspension system designs.

This paper mainly analyses the influences of the subframe flexibility on handling and stability simulation in ADAMS/Car. Two complete vehicle models are built using ADAMS/Car and Hypermesh. The only difference between the two models is the subframe of the front McPherson suspension. One of the subframes is simplified as a rigid body. The other one is a flexible body built using the MNF file from Hypermesh.

After that, the full-vehicle simulations for the two different models are performed in some operation conditions according to the passenger car test standards. With the characteristic values from the simulation results, the handling and stability performances of the two vehicles can be evaluated using evaluation standards. By comparing the characteristic values and evaluation scores of the two models, differences are observed. This implies that the flexibility of the subframe in a front McPherson suspension will influence the handling and stability performance of the vehicle when simulating in ADAMS/Car.

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INTRODUCTION

ADAMS (acronym of Automated Dynamic Analysis of Mechanical Systems) is a multibody dynamics simulation software equipped with Fortran and C++ numerical solvers. It is widely used for kinematic, compliance and vehicle dynamic simulation. In ADAMS, the components of the suspension are simplified as rigid bodies. This will degrade the accuracy of the simulation.

Therefore in some cases, flexible bodies are used when modeling in ADAMS. To build flexible bodies, the finite element models of the components will be used to calculate the modal neutral files (MNF). By importing the MNF to ADAMS, the flexible bodies then can be built. Different from rigid bodies, flexible bodies with the MNF contain the information of geometry (locations of nodes and node connectivity), nodal mass and inertia, mode shapes, generalized mass and stiffness for mode shapes. So the simulations with flexible bodies are more accurate.

In this paper, one front subframe is built with the rigid and also the flexible body in ADAMS. Together with other subsystems, two full vehicle models are then built. The only difference of the two vehicle models is the flexibility of the subframe. After that, some vehicle dynamic simulations are performed to compare the driving behavior of the two models and ultimately analyze the influence of the subframe flexibility on handling and stability simulation in ADAMS/Car.

MULTI-BODY MODELING

The multi-body modeling mainly includes the rigid body modeling and the flexible body modeling. The rigid bodies can be built in template in ADAMS/Car. To build the flexible bodies, MNF from a finite element (FEM) program are necessary. In this paper, MNF of the subframe is calculated in Hypermesh with the finite element mesh file, as shown in [Figure 1](#).



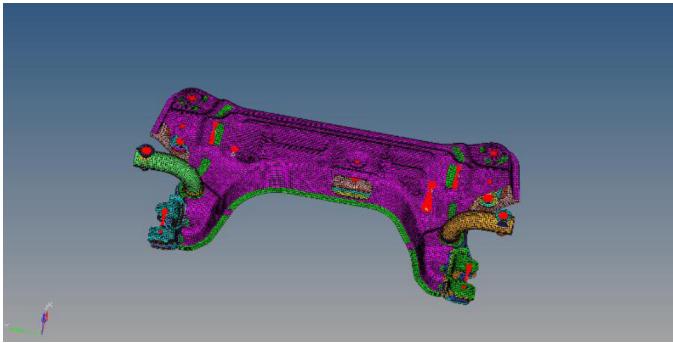


Figure 1. Finite element mesh file of subframe.

The MNF of the subframe from Hypermesh is then imported to ADAMS/Car. In ADAMS/Car, one front suspension with a rigid subframe and one with a flexible subframe are built. These two suspensions have the same parameters, except for the flexibility of the subframe. The rigid and flexible suspensions are shown in [Figures 2 and 3](#).

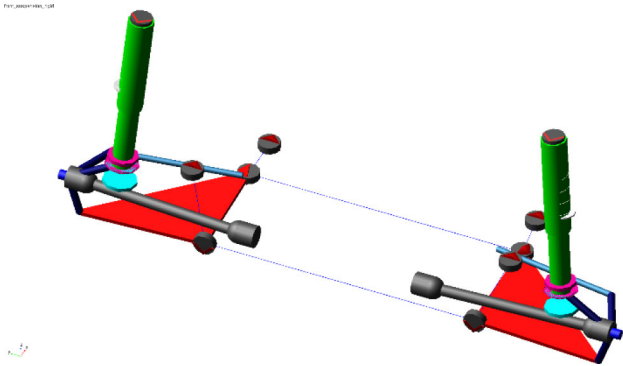


Figure 2. Front suspension template with a rigid subframe.

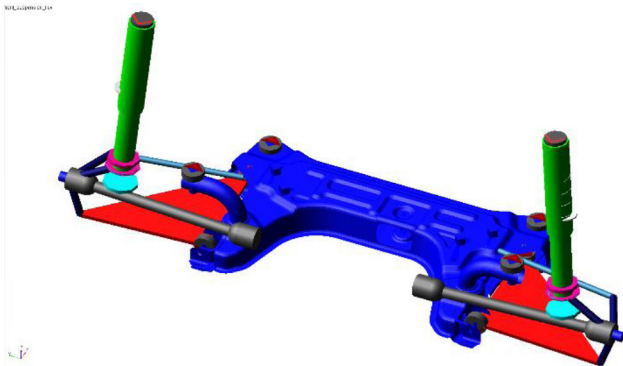


Figure 3. Front suspension template with a flexible subframe.

Using the two different front suspension subsystems, together with the same other subsystems, two full-vehicle models are then built. The full vehicle models used for handling and stability simulations are shown in [Figures 4 and 5](#).

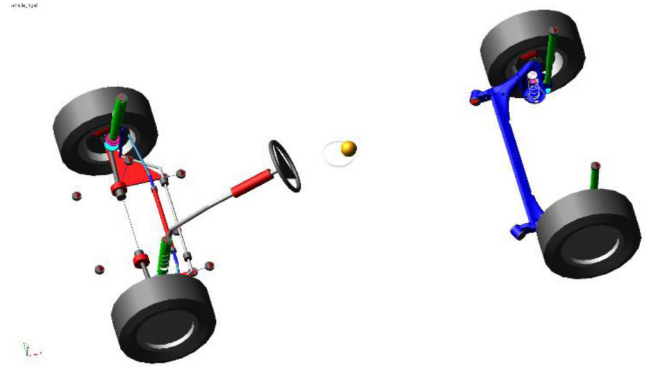


Figure 4. Full-vehicle model with a rigid subframe.

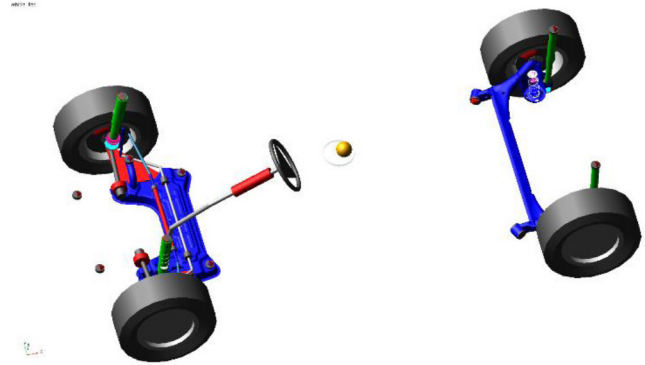


Figure 5. Full-vehicle model with a flexible subframe.

STEADY-STATE CIRCULAR SIMULATION

Simulation Strategy

The steady-state circular simulation is performed according to the controllability and stability test procedure standard GB/T 6323-2014 [3]. It's aimed to analyze the yaw response of the vehicle when in a steady state. Firstly the vehicle is driven at the lowest possible speed around a circle to select the steering wheel angle. Secondly the vehicle is stopped and then steadily accelerated with the steering wheel angle held constant at the pre-selected angle. The maximum rate of increase of longitudinal velocity shall be 0.25 m/s². The test shall be performed until the lateral acceleration is 6.5 m/s² or the vehicle is unstable.

According to the test procedure above, driver control files are then created in ADAMS/Car and simulations are performed with the files. For the two vehicle models, the lowest possible speed is 3 m/s and the circle radius is 20 meters.

Simulation Results

From the simulation results in ADAMS/Car, lateral acceleration, roll angle and vehicle velocity can be obtained. And other parameters can be calculated as follows:

$$R = \frac{V}{\omega}$$

$$\alpha_1 - \alpha_2 = \frac{180}{\pi} L \left(\frac{1}{R} - \frac{1}{R_0} \right) \quad (2)$$

R: steering radius;

L: wheel base;

$R_0 = 20$ m: selected circle radius;

$\alpha_1 - \alpha_2$: slipping angle difference between front and rear axles.

The results curves are shown in Figures 6, 7 and 8.

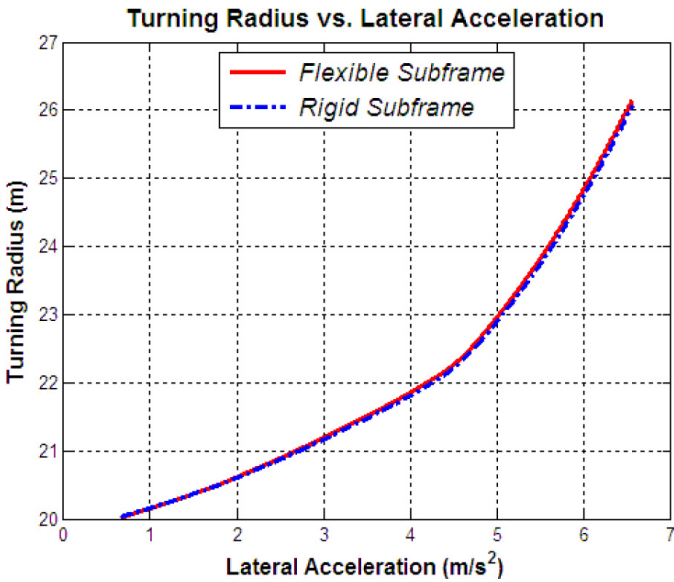


Figure 6. Steady-state circular: turning radius vs. lateral acceleration.

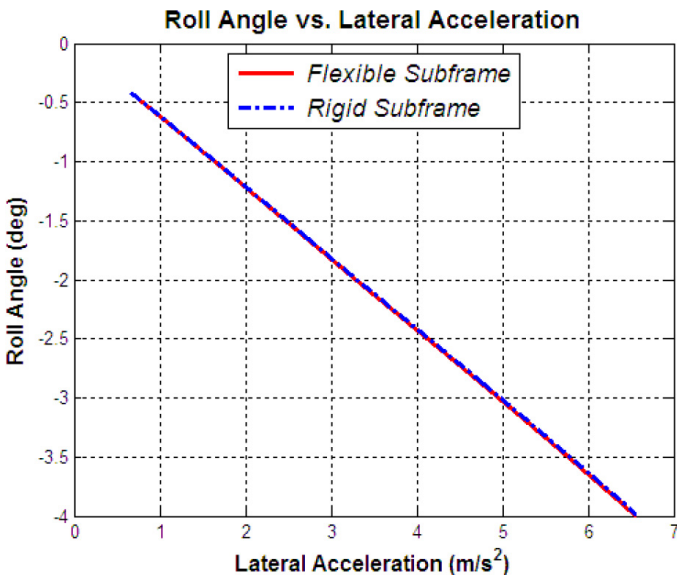


Figure 7. Steady-state circular: body roll angle vs. lateral acceleration.

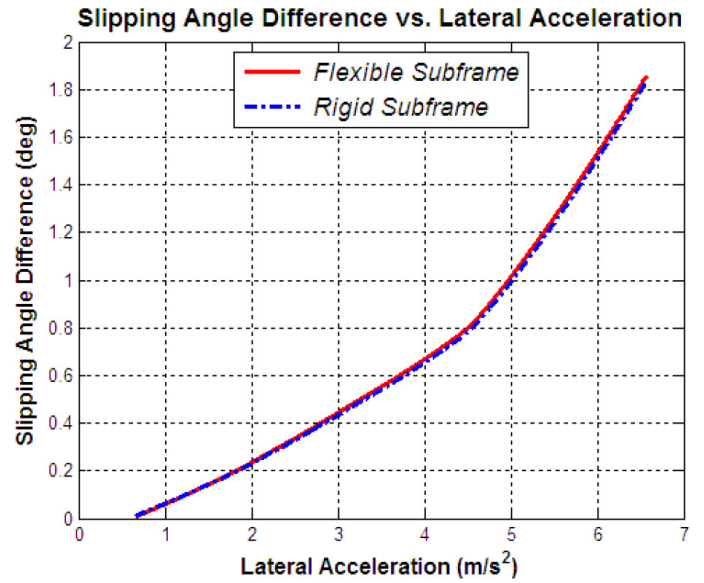


Figure 8. Steady-state circular: slipping angle difference between front and rear axles vs. lateral acceleration.

Model Performance Evaluation

According to QC/T 480 'Criterion Threshold and Evaluation of Controllability and Stability for Automobiles' [4], the steady-state circular driving behavior shall be evaluated by three parameters: lateral acceleration at neutral steer point, degree of understeer and roll rate of body. The limits of evaluation parameters are shown as Table 1.

Table 1. Limits of evaluation parameters.

Vehicle	Index					
	a_{n60} m/s ²	a_{n100} m/s ²	U_{60} (°)/(m/s ²)	U_{100} (°)/(m/s ²)	$K_{\phi 60}$ (°)/(m/s ²)	$K_{\phi 100}$ (°)/(m/s ²)
Maximum weight of passenger car, bus, freight car $\leq 2.5t$	5.0	9.8	1.0	0.4	1.2	0.7

Lateral Acceleration at Neutral Steer Point: a_n

Lateral acceleration at neutral steer point is defined as a_n : the lateral acceleration at the point, where the slope is zero in the curve of slipping angle difference between front and rear axles vs. lateral acceleration. The performance score is calculated as follows:

$$N_{an} = 60 + \frac{40}{a_{n100} - a_{n60}} (a_n - a_{n60}) \quad (3)$$

N_{an} : performance of the lateral acceleration at neutral steer point;

a_n : simulation result of the lateral acceleration at neutral steer point (a_n is taken as infinite when there is no definable value for a_n);

a_{n60} : lower limit of the lateral acceleration at neutral steer point;

a_{n100} : upper limit of the lateral acceleration at neutral steer point.

When N_{an} is more than 100, it is counted as 100.