Design and Optimization of FSAE Race Car suspension system *

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Abstract. In this paper, FSAE race car is taken as the research object, dynamic performance of the suspension system is studied. 3D model of the whole vehicle suspension system is built by using 3D modeling software, and the kinematics simulation is carried out. On the basis of this, ADAMS is used for dynamic simulation, the changes of kingpin inclination angle, kingpin caster angle, camber angle, front wheel toe angle and ground point lateral slip amount of front wheel with wheel beat is analyzed, and the outer wheel angle has been optimized and designed. The results show that the designed suspension system meets the design requirements.

1. Introduction

In recent thirty years, the FSAE tournament developed rapidly and had been extended to 15 countries, it attracted hundreds of universities from around the world to participate in. In 2003, Japan held a FSAE and it marked the FSAE into Asia, the support and attention of Asian countries to the event promotes the development and progress of the Asian FSAE. China began to introduce the event in 2010 and held the first game in Shanghai, it attracted attention of many car manufacturers and participation in domestic colleges and universities.

The event requires each team to design and manufacture the formula small racing car according to the rules of the event and the racing car manufacturing standards [1,2,3,4,5]. As a result, the performance of the car has a decisive effect on the results of the competition. Especially, the suspension system is an important mechanism to realize the ride comfort and handling stability. For this, the study of the suspension system of the car and the optimization design is to ensure the basic performance of the car [6,7].

Ruan established double wishbone independent suspension model by Adams and analyzed the suspension performance curve [8,9]. Liu of Hunan University used ADAMS to establish the car suspension model, analyzed and optimized the front suspension on the basis of system dynamics theory and also study in the typical operation stability simulation [10].

In this paper, the vehicle suspension system model is constructed, and the optimization design of the front suspension is carried out.

2. Three dimensional model construction of vehicle suspension system

The natural frequency of the suspension system has an important influence on the ride comfort of the vehicle. When the car is doing a freedom vibration of single degree, the natural frequency of the suspension system is called the bias frequency. The size of the bias frequency is directly related to the suspension performance. If the bias frequency is low, the suspension is soft, the car is comfortable, and the other side is hard, the suspension is hard, and the car is good to control. For the racing car, the car ride comfort requirements can be reduced, this paper set the bias frequency of front suspension fn1=2.3Hz, the bias frequency of after the suspension fn2=2.5Hz, quality on the spring m_s=270kg. After the bias frequency is determined, the static deflection of the suspension is determined, and the ride comfort of the suspension can be calculated.

Other main parameters of the suspension system are shown in Table 1.

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Table 1 Structural parameters of suspension system

Parameter name	Front suspension	Rear suspension
Roll center height /mm	22	35
Push rod length /mm	320	340
Upper arm length /mm	335	220
Lower arm length /mm	340	225
Caster angle /(°)	1.22	0.0
Kingpin inclination angle/(°)	1.6	1.2
Front toe angle/(°)	2.0	0.5
Camber angle of wheel /(°)	-2.0	-1.0

The design of the front and rear suspension assembly drawing according to the parameters is shown in Figure 1.

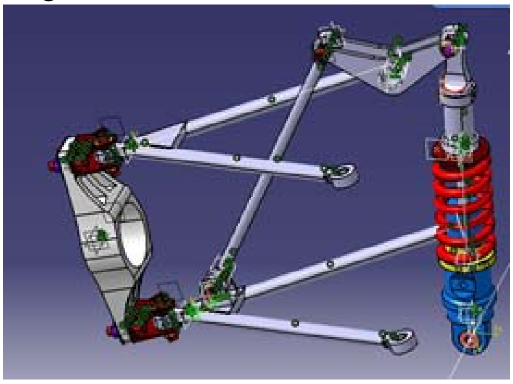

Figure 1. Drawing of front suspension assembly

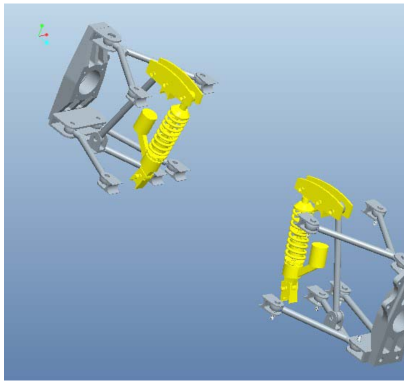

Figure 2. Assembly drawing of front and rear suspension

On this basis, the three-dimensional model of the vehicle suspension system is designed, the vehicle assembly is carried out and the kinematics simulation analysis is carried out. The assembly is shown in Figure 3.

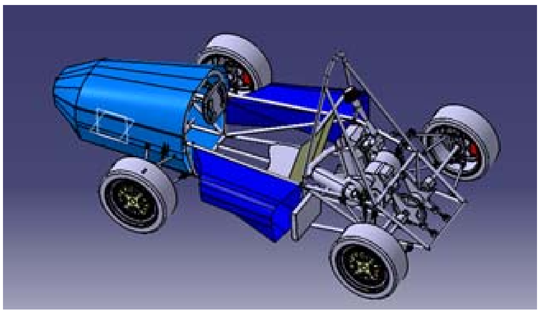

Figure 3 Assembly drawing of vehicle

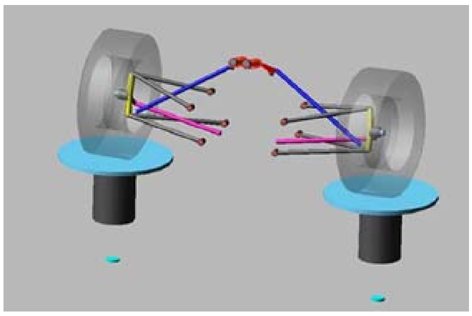

Figure 4 Dynamic model of racing car front model

3. Example analysis

3D model of full-vehicle suspension system has been built, and the kinematics simulation analysis is performed in the second section of this paper. The results show that the designed suspension system meets the requirements of the racing car structure. Based on this, the dynamic simulation of the front suspension system is carried out by using Adams software, its dynamical model is shown in Figure 4. In order to make the kinematic simulation analysis easier, the dynamic characteristics of the suspension system are neglected, and the model is simplified in this paper. Specific assumptions are as follows:

(1) the various parts of the front suspension model built are rigid bodies;

(2) the gap between the spare parts and the friction force are neglected;

(3) The damping characteristics of the front suspension shock absorber are simplified to linear

features.

The simulation analysis is performed on the change of kingpin inclination angle, kingpin caster angle, front wheel camber angle, front wheel toe angle and the Lateral slip of front wheel when wheel vibrating. Simulation results are shown in Figure 5-9.As shown in Figure 5, Wheel is two-way beating. When wheel beating is positive, Kingpin inclination angle decreases first and then increases with the wheel travel .when wheel beating reverses, kingpin inclination angle increases with the increasing of the amount of wheel travel. The change of kingpin caster angle is same as the kingpin inclination angle(Figure 6).Regardless of positive or reverse beating, front wheel camber angle and front wheel toe angle decreases with the increasing of the amount of wheel travel(Figure7-8).

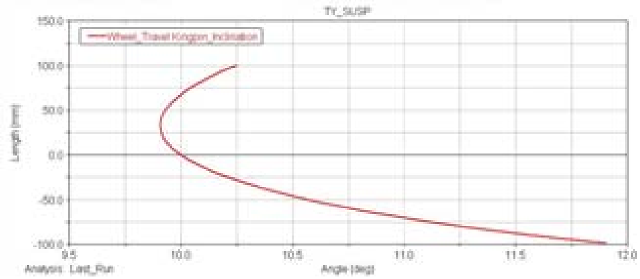

Fig.5 Kingpin clination angle

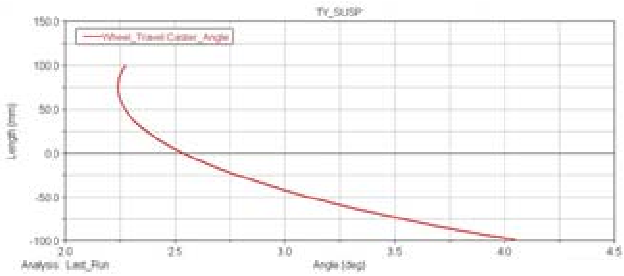

Fig.6 Kingpin caster angle

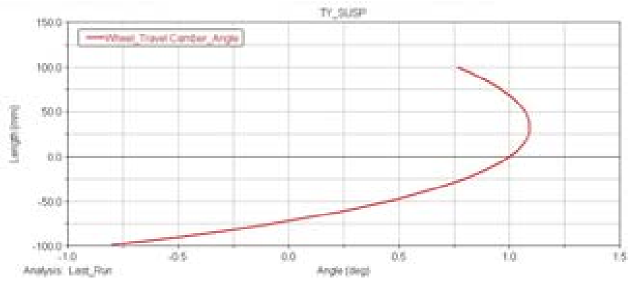

Fig.7 Front wheel camber angle

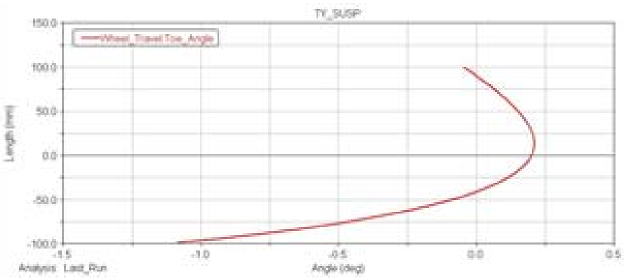

Fig.8 Front wheel toe angle

Optimizing the front suspension system with ADAMS/Insinght module. Due to the high demand of the steering and braking conditions on the front suspension, if the front suspension can meet the performance requirements, the suspension system will also meet the performance requirements. The optimization results of wheel camber angle are shown in Figure 10.From the graph, we can see that the wheel camber angle has been improved obviously. Camber angle is reduced by 11.87% after data processing, the results meet the design requirements.

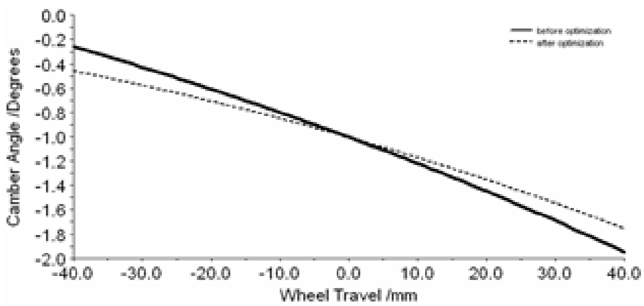

Fig.9 Optimum curve of wheel camber angle

4 . Summary

This paper takes FSAE race car as research objective, built the 3D model of full-vehicle suspension system and performed the kinematics simulation analysis. The results show that the designed suspension system meets the requirements of the racing car structure. On this basis, the dynamic simulation and optimization design of the front suspension system was carried out. The simulation analysis is performed on the change of kingpin inclination angle, kingpin caster angle, front wheel camber angle, front wheel toe angle and the Lateral slip of front wheel when wheel vibrating, and optimization design of wheel camber angle was performed. The results show that the performance of the suspension system meets the design requirements.

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