

Chapter 131

LEV Suspension System Design and Development

Hsing-Hui Huang, Ming-Jiang Tsai and Hong-Kai Yu

Abstract In this study, the vehicle suspension system design and analysis procedure have been proposed for the Light-weight Electric Vehicles. The objective for the suspension design is quick handling and stably riding performance with LEV system. The contents include the suspension design and mechanical dynamic simulation. In the vehicle quasi-static test simulation, the suspension parameters were compared with new model LEV_2 and the mule car model LEV_1. Through mechanical dynamic simulation, the suspension parameters have been clearly discussed and improved with camber angle change, toe angle change, caster angle change and roll center height change.

Keywords Rigid body motion · Suspension design · K&C test

131.1 Introduction

Vehicles have become indispensable to people's lives, and greatly change people's transportation. It is also expand people's living area, to make life more convenient and efficiency. The vehicle suspension systems design procedure has been proposed for Light-weight Electric Vehicles. The LEV can drive in industrial estate and campus with no license. It can provide a convenient and low energy consumption of transport.

In this paper, the contents including the benchmarking of LEV, systems layout, static load analysis, MBD system building, and mechanical motions. In the analysis of mechanism, some revise of the suspension parameters also find out for improving the performance according to the design procedure.

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131.2 Background

In Europe, the LEV can be driven in campus with no license. In other words, it can provide convenience and does not produce exhaust pollution of transportation.

The objective of the LEV are handling and riding performance. By minimize the amount of camber change in the design to reduce uneven wear and reduce energy loss, double A-arm suspension system of front independent suspension system have been selected. The characteristics of this kind of suspension system are with smaller track changes and angle changes than other suspension types. Then the shock absorber actuator friction resistance as well as its control arm can be configured to block the sub-frame generated vibration and noise when traveling, so that double A-arm suspension may have a better steering performance and ride comfort.

K&C testing is one of the methods to validate the design of the chassis. K&C tests are quasi-static test; loads and displacements are applied to a vehicle in very slowly to capture the suspension parameter and force–displacement relationships [1–8].

Evaluate vehicle handling characteristics of the vehicle dynamic behavior is also very important. With the increasingly developed, Computer Aided Engineering (CAE) is available for the vehicle kinematics simulation and the dynamic behavior of the vehicle design evaluation. By simulated vehicle suspension system, the periods for develop a new vehicle can effectively be shorten, but validate the model with experimental results has become an important issue.

131.3 Suspension Design

For the vehicle suspension system design, design requirements and market positioning have to be list first. Then the location of the powertrain and whether power-assisted in steering systems have also been considered in suspension design. Generally, based on different chassis configuration parameters are within the design reference values. The design of vehicle specifications as EC regulations L6 level from the LEV_2, refer to vehicle types of tests have been completed for the mule car, LEV_1. The basic model can be used to design more competitive and were be analyzed and compared.

Refers to EC regulations, L6 level of the technical specifications are laid down as followed and Table 131.1:

1. Max. Weight : under 350 kg
2. Max. Speed : under 45 km/h
3. Body Geometry : L-4000*B-2000*H-2500 (mm).

Table 131.1 Vehicle specifications table

Specifications	Unit	LEV_1	LEV_2
Curb weight	kg	547.9	420
Length	mm	3190	3250
Height	mm	1910	1800
Width	mm	1780	1400
Wheelbase	mm	2600	2600
Turning circle	m	4.74	–
Tires	in.	13	13
F. Suspension	–	Double A-arm	Double A-arm

Table 131.2 System weight evaluation

System evaluation	Weight (kg)	Classification item
Body structure	100	Body structure and joints = 86 kg Disassemble roof structure = 14 kg
Powertrain system	70	Motor = 25 kg Transmission = 35 kg ECU module = 10 kg
Chassis system	130	Suspension system = 100 kg Steering system = 15 kg Braking system = 15 kg
Exterior and interior	50	Exterior and interior = 50 kg
Total	350	(Not including battery)

EC have a clear specification the body weight for the L6-Level of LEV, its empty weight (without battery) should not exceed 350 kg. Table 131.2 list the evaluate weight for this our design.

In suspension system, the layout of hardpoints through the CAD software is shown in Fig. 131.1. The following processes with double A-arm suspension system [9].

1. Decide dimensions and vehicle bracket (based on customer and market demand).
2. Select tires and wheels specifications.
3. Decide wheel center position (A) and track specifications.
4. Set roll center (B) and the instantaneous center position (C).
5. Calculate the lower ball joint position (D), inclination angle, and scrub radius.
6. Calculate the ball joint position (E), caster angle, and caster moment arm.
7. Based on the use of space, determines the control arm inner position (F), (G).
8. Calculations the Ackerman geometry for determining the knuckle arm position (H).

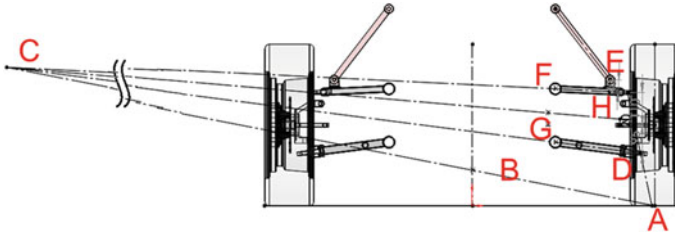


Fig. 131.1 Suspension design with LEV_2

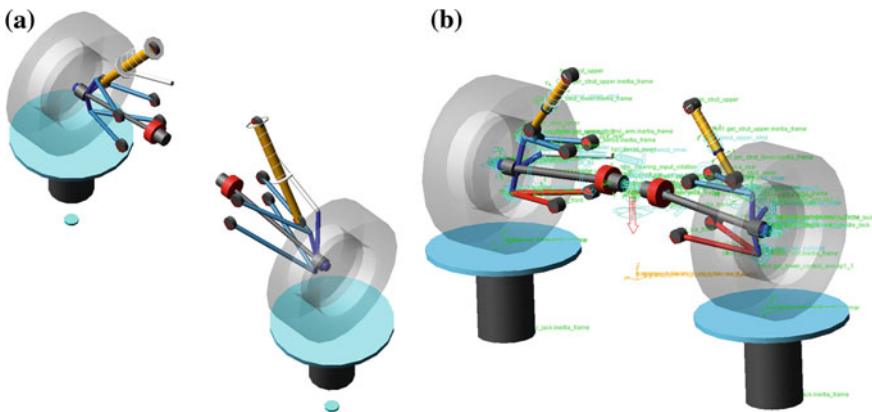


Fig. 131.2 Front suspension model. a LEV_1, b LEV_2

131.4 Vehicle Model

Using ADAMS simulation software for rigid body motion, as shown in Fig. 131.2, can help designers to conduct various static motion parameters for analyzing and comparing with K&C test platform for model comparison adjustments.

131.5 K&C Testing

The design of the vehicle chassis system based on models of market, consumer and costs, and other factors that determine the various subsystems (such as suspension systems, steering systems and brake systems, etc.). According to the design requirements, the basic design parameters have been set, such as track, wheelbase and roll center height. Confirm the basic suspension parameter, the 1/2 suspension model can be built as shown in Fig. 131.3. The suspension parameters and force-displacement relationships then can be capture by quasi-static analysis.

Fig. 131.3 Parallel motion

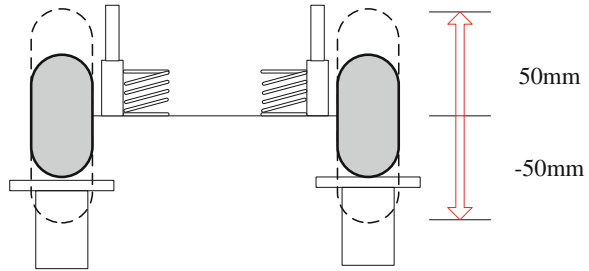


Table 131.3 Suspension characteristic target in parallel motion

Parameters	Unit	Target		Ideal value			
		Front	Rear	Front		Rear	
				Low	High	Low	High
Toe change	°/mm	0.0043	0.0015	0	0.006	0	0.0074
Camber change	°/mm	0.015	0.0225	0.0075	0.02	0	0.0074
Castor change	°/mm	-	-	Low	High		

Table 131.3 shows the ideal targets of suspension parameter designs according to parallel motion analysis. The parameter change gradient is related to vehicle performance.

131.6 K&C Data Discussion

In kinematic motion, the camber change is too large in the mule car model, LEV_1. So the study model LEV_2 improved these suspension parameters. Double A-arm suspension system, using upper and lower control arms, control tire vertical displacement, lateral displacement and camber changes. In Fig. 131.4, the models of camber change in LEV_2 is about 0.98 to -1.28° ; and the LEV_1 is 1.82 to -1.89° . The camber change gradient from $-0.0371^\circ/\text{mm}$ in LEV_1 improved to $-0.0225^\circ/\text{mm}$ in LEV_2.

In mule car model LEV_1, the toe angle have large changed with different loading. It may induce the tire rolling resistance and noise. In LEV_2, the suspension design tries to improve this situation. The hardpoints of tie rod inner and the tie rod outer are moving with suspension moving path when the wheel vertical movement. As shown in Fig. 131.5, LEV_2 model with the toe angle change ranged is about -0.01 to 0.18° , that is better than LEV_1 model, toe angle change

Fig. 131.4 Camber change curve

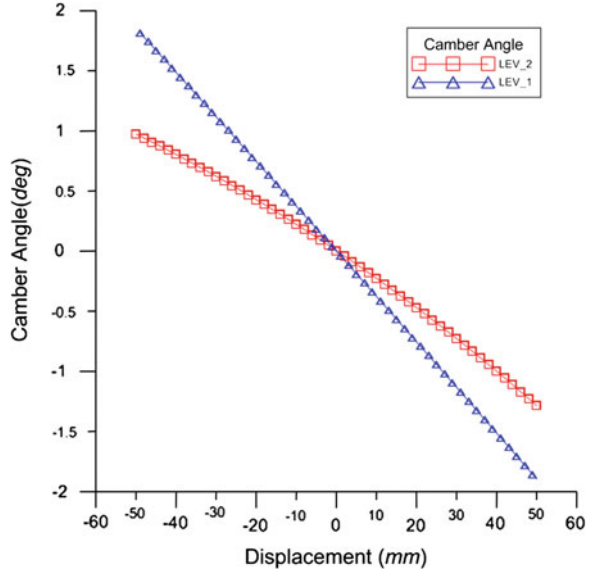
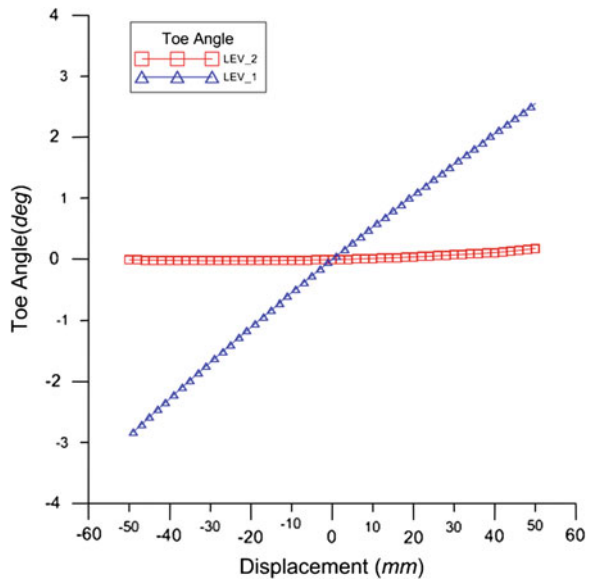


Fig. 131.5 Toe change curve



ranged from -2.83 to 2.56° . Wherein the gradient $0.0538^\circ/\text{mm}$, improved to $0.0017^\circ/\text{mm}$.

Caster angle is related to the vehicle performance of straight forward, result in model LEV_1 has not response the cornering precisely and road driving

Fig. 131.6 Caster change curve

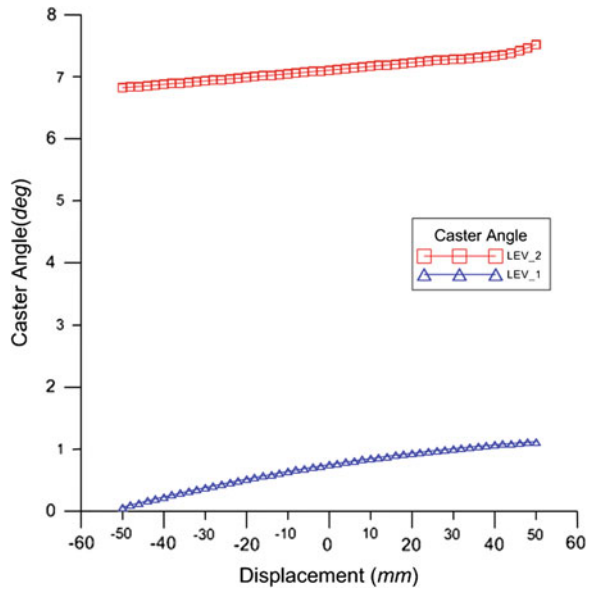
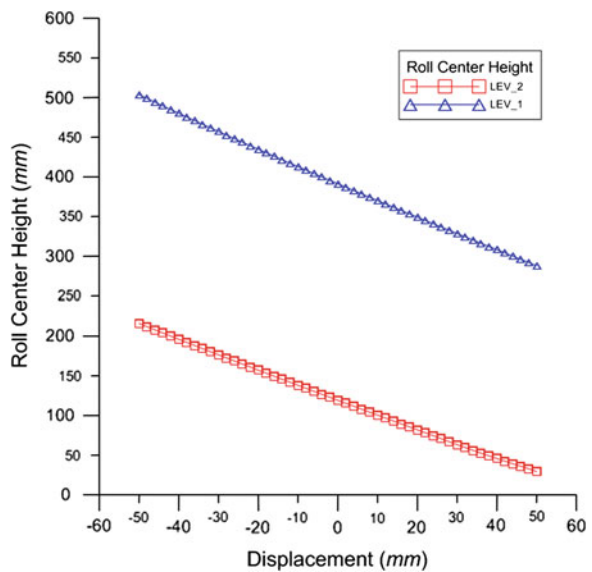


Fig. 131.7 Roll center height change curve



uncertainty problem. Then the caster setting has been revised then the caster change gradient improved. The analysis result, as shown in Fig. 131.6, the mule car model LEV_1 caster angle change in 0.07–1.12° with wheel vertical displacement. That is why the mule car is in cornering problem. The caster angle of model LEV_2

changes about $6.82\text{--}7.52^\circ$ with wheel vertical displacement. The changes are in the design range which improved vehicle straight stability. The caster changes gradient improves from 0.0106 to $0.0070^\circ/\text{mm}$.

Roll center height in LEV_1, as shown in Fig. 131.7, the variation range is about $503.85\text{--}288.23$ mm. This roll center height is more suitable for high chassis of the vehicle models. The model of LEV_2 with lower chassis height should be design with lower roll center height about $216.21\text{--}29.59$ mm, as shown in Fig. 131.7, which comply with LEV_2 lower center of gravity, reducing the roll moment arising rollover risk.

131.7 Conclusion

The effects of suspension design parameters on chassis have been investigated with rigid body motion analysis. The chassis characteristic have been obtained according to parallel motions. It can improve driving performance and riding comfort with low tires wear. The rigid body motion help engineers to find the problems with mechanical motion interference, and check the efficiency with improvement.

By the design process, the reliability of front suspension can be established for further analysis with steering system. The kinematic and force-torque through the movement then can simulate and confirmed. Finally compose with rear suspension system brake system body and powertrain system conduct with system integration can then achieve the target for full vehicle simulation.

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