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Design and Analysis of the Suspension for Electric Tractor

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Abstract. Aiming at the problems that the existing electric tractors have large ground clearance and high center of gravity,and easy rollover during driving, a double wishbone independent suspension is designed for a certain type of electric tractor. The virtual prototype model of the suspension is built by ADAMS software, and the simulation analysis and optimization are carried out to find a set of optimal wheel positioning parameters to ensure that the electric tractors have good steering stability and smooth running, which has a certain guiding effect on actual production.

1. Introduction

In recent years, due to the advantages of zero emissions, simple structure and light body of the new energy vehicles, pure electric vehicles have gradually become hotspots [1]. The electric tractor truck is a new type of aerial work equipment that directly installs the lifting platform on the electric vehicle and uses its own power to drive the lifting platform. It is widely used for installation and maintenance of high-altitude equipment in warehouses, airports, terminals [2], because of its low pollution, good mobility, fast walking speed and high safety. At present, the design of electric tractor trucks basically refers to the traditional fuel-powered tractor, but the traditional fuel-fueled vehicles need to consider the obstacle-obstructing ability of the vehicle body and the heat dissipation of the engine. The design of the ground clearance is large, resulting in the high center of gravity of the vehicle. In addition, under the premise of the same carrying capacity, the weight of the body of an electric tractor is generally lighter than that of a fuel tractor. Therefore, when the tractor encounters bump and other working conditions during driving, the light body and high center of gravity are highly susceptible to safety accidents, such as rollover [3]. It is of great practical significance to carry out the vibration reduction design of the electric tractor to improve its running stability and steering stability.

Since the electric tractor requires relatively high operational stability [4-7], the double wishbone independent suspension can be used instead of the existing integral front axle structure. At present, there are two basic methods for determining the original size of the vehicle suspension. The first method, according to the front axle size of the existing vehicle, the suspension of other mature applications is scaled down to be the initial size, such as a commercial small car; The other method, the suspension model is directly established using the dynamics simulation software according to the existing front axle dimensions of the tractor, and then the coordinates of the kingpin points are adjusted manually using the control variable method. The general fluctuation range of the adjusted kingpin and wheel positioning parameters can be within the design requirements, but there will be one or two parameters that are difficult to control within the ideal range. Therefore, the objective function needs to be established using

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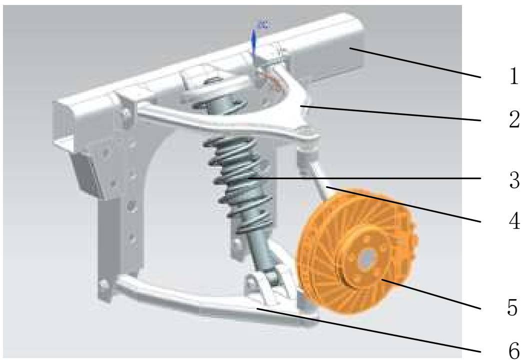
the optimization simulation module of the software, and finally a set of reasonable parameters are obtained.

Due to the mature application of the structure of the double wishbone independent suspension, it is mainly focused on the application in a certain engineering practice. It is important to establish the design model rapidly and accurately, so the method that theoretical modeling is built first and then software-assisted optimization is carried out is adopted. Firstly, the spatial analysis model of the suspension kingpin is established by geometric method. Then, 3D model of the suspension is drawn in the solid works according to the independent suspension parameters of the existing small tractor and the virtual prototype model of the suspension is built by ADAMS software. Analysis and optimization is carried out to find a set of optimal wheel positioning parameters to ensure that the electric tractor has good steering stability and smooth running.

2. 3D solid modeling

In Solidworks, the three-dimensional solid model design of the front wheel double wishbone independent suspension of the electric tractor was carried out. The result is shown in Figure 1. The model is mainly composed of the frame, the upper cross arm, the shock absorber, the kingpin, the hub and the lower cross arm.



1- frame; 2- upper cross arm; 3- shock absorber; 4- kingpin; 5- hub; 6- lower cross arm

Figure 1. 3D diagram of double wishbone suspension

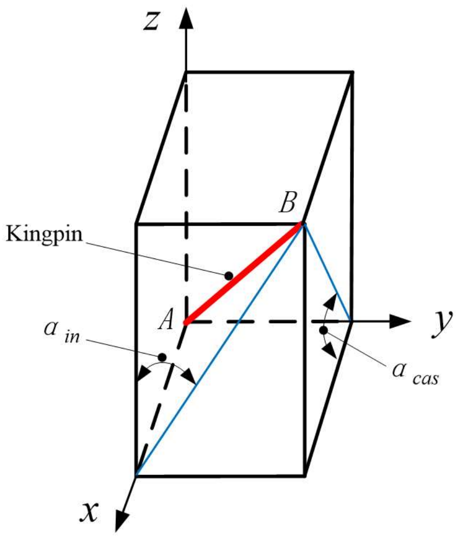


Figure 2. Schematic diagram of kingpin space state

3. Geometric modelling and analysis

In order to find out the geometric relationship between the spatial location of the kingpin and wheel alignment parameters,the model of the kingpin space coordinate system shown in Figure 2 is established with the lower cross arm outer fulcrum as the coordinate origin. In Figure 2, αin is kingpin inclintion angle and αcas is caster angle.

3.1. Creating coordinates of hard points

Referring to the suspension design of the existing small tractor, and the front axle size of the lift tractor, the basic size of the suspension model of the electric tractor is preliminarily determined, and then the coordinates of the hard point and the three-dimensional model are created according to the general method of the suspension design. Hard point coordinate values are shown in Table 1.

Table 1. The coordinates of hard points

hard points	X	Y	Z
L_1	0.00	0.00	0.00
L_2	231.57	59.85	-37.21
U_1	22.78	165.67	6.65
U_2	198.79	196.32	26.47
T_1	-13.31	60.38	-86.67
T_2	210.56	110.88	-127.87
K_1	8.44	56.43	2.27
K_2	-131.54	53.98	1.78

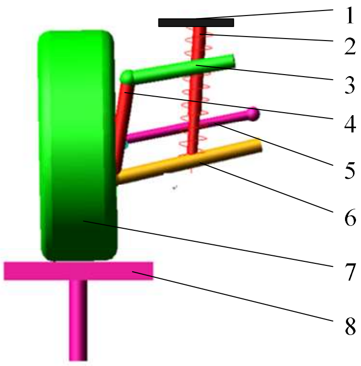
Note:

L1 - lower cross arm outer fulcrum; L2 - lower cross arm inner fulcrum; U1 - upper cross arm outer fulcrum; U2 - upper cross arm inner fulcrum; T1 - tie rod outer fulcrum; T2 - tie rod inner fulcrum;

K1 - Knuckle inner node; K2 - Knuckle outer node;

3.2. Establishing 1/2 prototype model

According to the hard point coordinate values in Table 1, a 1/2 prototype of the double wishbone independent suspension for the electric traction is established in ADAMS/View, as shown in Figure 3. The model consists of 9 moving members (excluding ground), 4 ball pairs, 3 fixed pairs, 2 rotating pairs, 2 moving pairs, 1 point-plane constraint and 1 driving pair. The model has two degrees of freedom in total.



1-frame; 2-shock absorber; 3-upper cross arm; 4-kingpin; 5-tie rod ; 6-lower cross arm; 7-hub; 8-vibration platform

Figure 3. Half prototype model

4. Kinematics simulation analysis

During normal driving, the double wishbone independent suspension of electric tractor, as the transmission device between the wheel and the frame, is subjected to the continuous excitation of the road surface, resulting in the relative position between the tire and the body changing constantly, thus causing the continuous change of wheel alignment parameters[8-9]. The running stability and steering stability of the vehicle during driving are mainly determined by four indicators: the kingpin inclination angle (α_{in}), the kingpin caster angle (α_{cas}), the front wheel camber angle (α_{cam}) and the front wheel toe angle (α_t). The permitted ranges of the indicators are shown in the following table[9-10].

Table 2. Permitted range of design indicators

α_{in} /(°)	α_{cas} /(°)	α_{cam} /(°)	α_t /(°)
7 ~ 13	0 ~ 5	-1 ~ 4	4 ~ 6

In ADAMS, the variation function of each index with the wheel jump is established. The displacement of the upper and lower excitation is ±50mm and the excitation function is F=50*sin(360d*time)[11]. The simulation results are shown in the following figures.

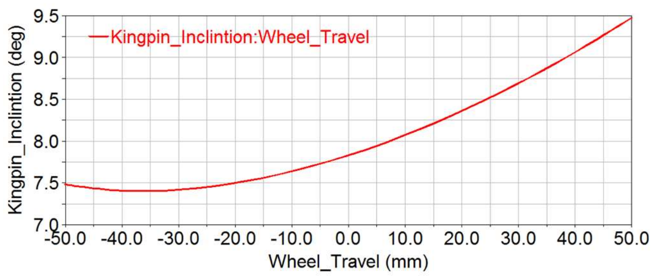


Figure 4. Variation curve of kingpin inclination angle.

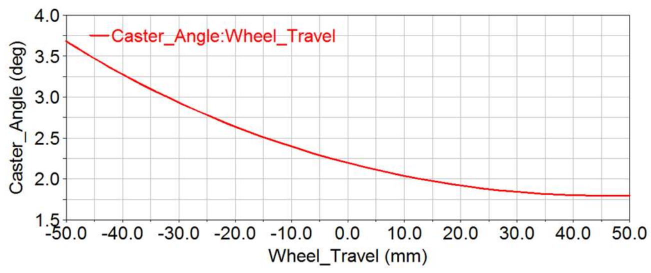


Figure 5. Variation curve of kingpin caster angle.

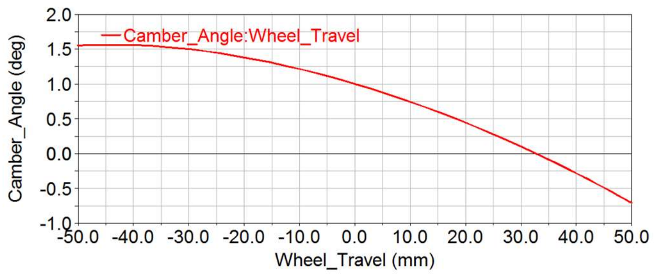


Figure 6. Variation curve of wheel camber angle.

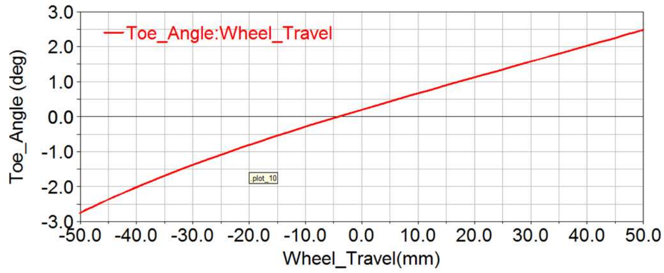


Figure 7. Variation curve of wheel toe angle.

From the above simulation curves, it can be seen that the kingpin inclination angle, wheel camber angle and kingpin back inclination angle are within a reasonable range,when the excitation range is given.But the front bundle angle is beyond a reasonable range, which needs to be optimized.

5. Optimal design

In the design of double wishbone independent suspension, the length of upper and lower wishbones and the inclination angle between them and the lateral plane of the automobile are the main factors that affect the front girdle angle of the wheel[12]. The length of the upper arm and the lower arm and the inclination angle between the upper arm and the lower arm and the lateral plane of the automobile can be adjusted by adjusting the inner hinge point of the upper arm and the space position of the inner hinge point of the lower arm.

The determination value of the wheel toe angle is chosen as the objective function.When the other conditions remain unchanged, the values of X, Y and Z of the inner hinge point of the upper arm and the inner hinge point of the lower arm are set as the design variables respectively,and the initial value, upper limit and lower limit are assigned to them(floating 15% basis of the initial value),and then parameters optimization is carried out .The optimization result is shown in Figure 8. (The solid line is the one that has not been optimized, and the dotted line has been optimized).

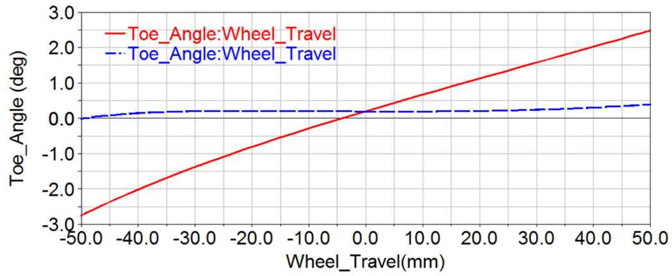


Figure 8. Comparison of toe angle in curves.

According to Figure 8, the range of the toe angle of the wheel is reduced from -2.75º~2.48º to -0.01º~0.39º, which basically achieves the optimization purpose and meets the design requirements of the steering stability and the running stability of the electric tractor.

6. Conclusion

In this paper, the double wishbone independent suspension is designed for the current small electric tractor with poor steering stability, poor running stability and easy rollover after bumping.A virtual prototype model of double wishbone independent suspension of electric tractor is established by mechanical system dynamics software ADAMS. The model is optimized and analyzed,and a set of suspension parameters which meet the actual requirements of engineering are obtained. The kinematics characteristics of electric tractor are improved, and the basis for the suspension design of electric tractor is provided.

Acknowledgments
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References

[1] Zhu Canjin, Lu Mai, Dong Xuwei. Safety Evaluation of Electromagnetic Exposure for Electric Power Cable of Battery Electric Vehicle [J]. Automobile Technology,2018(03):16-20.
[2] REN Xiao-hong, MEI Jing, CHEN Li. Structure optimization and the finite element analysis of aerial work hydraulic lifting platform [J]. Heavy Machinery, 2017, (01):87-90.
[3] Murilo M B, Alcir J M, Guilherme A M, et al. Vibration levels emitted by agricultural tractors [J].African Journal of Agricultural Research, 2017, 12(39), 2919-2925.
[4] PEI Lei, DING Zheng-long, CHEN Cheng. Design and analysis of double wishbone independent suspension for large-scale tractor based on ADAMS [J]. Journal of Machine Design, 2012, (11):53-56.
[5] Deng Zhaowen,Xu Chengqiang,Wang Baohua. Optimization design and stiffness calibration of suspension system for FSAE racing car [J]. Journal of Chinese Agricultural Mechanization, 2015,(06):207-211.
[6] Daniel A. Mántaras,Pablo Luque,Carlos Vera. Development and validation of a three-dimensional kinematic model for the McPherson steering and suspension mechanisms[J]. Mechanism and Machine Theory . 2004 (6)
[7] YUAN Jie, LIU Qing-song, QIAN Jian-hua. Overall Dynamics Modeling Analysis and Simulation of Mobile Vehicle Body with Suspension [J]. Journal of Machine Design,2016, (06):36-40.
[8] William F. Milliken, Douglas L. Milliken. Race car vehicle dynamics[M]. U. S. A: Society of Automobile Engineers, 1995.
[9] Li M L, Zhang G W. Simulation and optimization of FSAE racing Suspension[J]. Applied Mechanics and Materials, 2013, 21(9): 58～62.
[10] Slättengren J. Utilization of ADAMS to Predict Tracked Vehicle Performance[J]. Construction Machinery & Equipment, 2003.
[11] HE Yao-hua, MIN Bin-yun. Optimization of Wishbone Independent Suspension Based on ADAMS [J]. TRACTOR & FARM TRANSPORTER, 2006, 33(6):73-74.
[12] Li Xinyao,Zhang Yin,Zhou Liangsheng. Characteristic Analysis and Calculation of Wishbone Independent Suspension with Torsion Bar [J]. AUTOMOTIVE ENGINEERING, 2003, 25(1):15-19.