Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2020, 7(7):67-71

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

The Design of Active Air Suspension System

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Abstract Reasonable steering mechanism can improve vehicle roll and stability. A set of active air suspension system is designed for a heavy truck, and an arrangement structure of double bridge and four air bags is proposed.

Keywords Double bridge four airbags, Active air suspension, Steering mechanism, Air spring, Shock absorber

Introduction

In recent years, due to the rapid development of logistics, express and other industries, the market demand for heavy vehicles has been kept at a high level. And the vehicle body movement and vehicle driving safety and comfort are determined by the suspension performance. The traditional passive air suspension can not satisfy the real-time adjustment of heavy vehicle under multiple working conditions, while the active air suspension can adjust the body height according to the charging and discharging of heavy vehicle under different road conditions [1]. When the load, speed or unpredictable changes in the factors such as roads, active air suspension can according to these changes through various control strategies timely adjust the suspension damping and stiffness, makes the vehicle handling stability and ride comfort under any driving conditions can reach the best state, enhance driving comfort and safety [2]. Therefore, it is of great significance to strengthen the research on the design, manufacture and vehicle matching of active air suspension.

Composition of active air suspension

Active air suspension system is mainly composed of air spring, shock absorber, guiding mechanism, height sensor, ECU, solenoid valve and other structures.

(1) Air spring

The air spring ACTS as a "cylinder," varying the stiffness by adjusting the amount of compressed air inside the spring. Common types of air spring are capsule type, membrane type, compound type, because the stiffness of the capsule type air spring is large and variable, the most used is the capsule type air spring, the capsule type air spring is mainly composed of the upper cover plate, rubber buckle, waist ring, base and so on.

(2) Shock absorber

The role of shock absorber is to accelerate the attenuation of the body and frame, improve the ride of the vehicle. It is connected with the upper part of the car body, and the lower part of the car bridge. The most commonly used is two-way action cylinder shock absorber, the main components have piston rod, stretch valve, flow valve, compression valve, compensation valve, upper and lower support, cylinder, etc..When in the compression stroke, the flow valve and the compression valve open, the damping is small. When in stretch stroke, the compensation valve and stretch valve open. The shock absorber contains an electric motor, which can adjust the size of the shock absorber's air vent, so as to change the shock absorber's damping and realize the change of the attenuation force. The damping force control of shock absorbers can be divided into low, middle and three levels.

(3) Steering mechanism
The vehicle is not only affected by the vertical force, but also the lateral force will affect the ride comfort. Reasonable guide mechanism can eliminate vertical and lateral forces, improve the stability and ride.

(4) Height sensor
The traditional air suspension control adopts the height valve for mechanical control, while the height sensor can be automatically adjusted to maintain different heights. The height sensor can be divided into analog type and digital type, as well as linear displacement type and angular displacement type. The most commonly used is the photoelectric digital body height sensor. The combination of the conduction and cut-off of the photoelectric coupler is used to detect the body height, and the sensing body height is transmitted to the ECU in real time.

(5) Electronic control system
Electronic control system (ECAS) includes ECU, body height sensor, Angle sensor, suspension control actuator and a series of solenoid valve system.ECU is electronic control unit, body height above the sensor installed on each wheel, and perception of body height real-time transmission to the ECU, the ECU after judgment, control air compressor and the exhaust valve, air compressor is used for compressed air and pass the compressed air to air spring and shock absorber air chamber, so as to realize air spring is deflated, optimal body height. The height of the body has three different states: standard, raised, and only raised rear wheels. The stiffness can be adjusted according to different working conditions.
Height control is when the airbag inflates, the body rises, the speed decreases, which can improve the vehicle's passability. When the airbag is deflated, the body is lowered and the vehicle's center of gravity is lowered, contributing to vehicle stability at higher speeds. For heavy vehicles, the body height can be changed to facilitate loading and unloading. Stiffness adjustment is when heavy vehicles have high requirements for comfort, the air spring can be adjusted soft to overcome the discomfort caused by road bumps. When heavy vehicles for handling requirements are high, the air spring can be adjusted hard, can reduce the body roll [3].
Damping adjustment is a shock absorber containing throttling hole by adjusting the throttling hole can adjust the size of the damping force, the smaller the diameter of the throttling hole, the greater the damping force. The speed sensor and acceleration sensor transmit the information such as the vehicle speed and acceleration to the ECU. After the ECU receives the information, the optimal damping force is obtained and the solenoid valve sends out signals to adjust the throttle hole.

Design of active air spring
（1）Air spring stiffness calculation
As shown in FIG. 2, assuming the action of load F on the air spring, then:

$$F = (P - 1)A \tag{1}$$

$$p = p_0 \left(\frac{V_0}{V}\right)^k \tag{2}$$

Where, p and V are the absolute pressure and volume of the gas at any position;Is the absolute pressure and volume of the gas at the static equilibrium position; A is the effective area of the spring; K is the polytropic index. When the automobile vibration is slow, k=1; when the automobile vibration is intense, k=1.4.
The stiffness of the air spring is the derivative of load F to vertical displacement.

$$C = \frac{dF}{df} = \left(p_0 \frac{V_0^k}{V^k} - 1\right)\frac{dA}{df} - Akp_0 \frac{V_0^k dV}{V^{k+1} df} \tag{3}$$

Stiffness at static equilibrium can be obtained as follows:

$$C_0 = (p_0 - 1)\frac{dA}{df} + kp_0\frac{A^2}{V_0} \tag{4}$$

Stiffness is related to the rate of change of effective area and gas solvent. In order to obtain soft stiffness, the gas volume should be increased. Considering the problem of layout space, the method of adding auxiliary gas chamber is adopted to solve the problem.At the static equilibrium position, the vibration frequency is as follows:

$$n_0 = \frac{1}{2\pi}\sqrt{\frac{g}{A}\frac{dA}{df} + \frac{p_0 kgA}{(p_0 - 1)V_0}} \tag{5}$$

In order to obtain a lower vibration frequency, dA/df reduce, or V_0 increase, and the shape of the air bag, air pressure, and increase can be increased by the auxiliary air chamber to achieve the purpose, but the volume of the auxiliary air chamber should not exceed three times the original air bag volume.

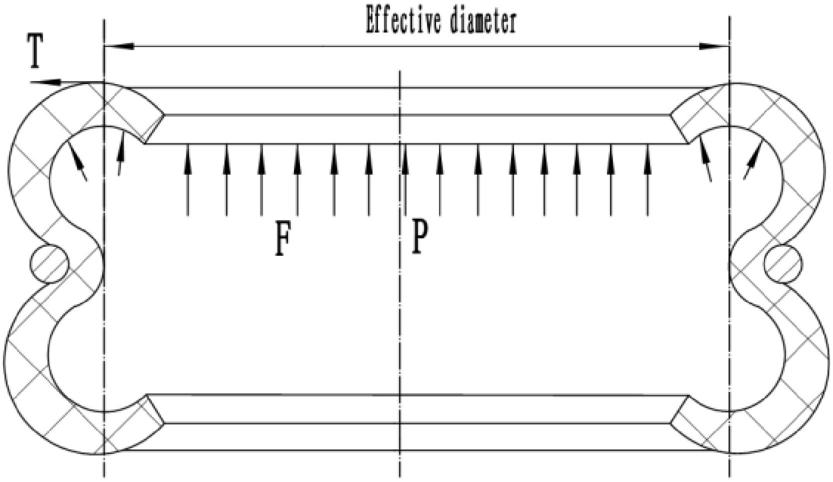

Figure 1: The diagram of air spring force

（2）Shock absorber damping calculation

Before the shock absorber unloading valve is opened, the relationship between resistance F and vibration velocity V of shock absorber is as follows:

$$F = \delta v \tag{6}$$

Where, δ is the damping coefficient of shock absorber.

When the suspension is damped. The vibration of spring mass is periodic attenuation vibration. The relative damping coefficient is used to evaluate the speed of vibration attenuation.

$$\psi = \delta\ (2\sqrt{cm_s}) \tag{7}$$

m_s is the spring mass, and C is the vertical stiffness of the suspension system. The larger the ψ is, the faster the vibration attenuation will be. Generally speaking, the relative damping coefficient of stretch stroke is larger than that of compression stroke.

When designing the relative damping coefficient of shock absorber, in order to avoid suspension collision, $\psi_Y = 0.5\psi_S$.

The maximum unloading force of the stretch stroke is as follows:

$$F_0 = \delta_0 v_x \tag{8}$$

The working cylinder diameter of shock absorber D is as follows:

$$D = \sqrt{\frac{4F_0}{\pi[P](1-\lambda^2)}} \quad (9)$$

[p] is the maximum allowable pressure of the working cylinder, take 3~4MP; λ is the ratio between connecting rod diameter and cylinder diameter, generally λ=0.4~0.5.

(1) Design of guiding mechanism

The guidance mechanism adopts the upper "V" push-down "U" arm arrangement structure, and the upper part adopts the "V" type structure, which can improve the lateral force received by the vehicle in the process of driving. The transverse stabilizer bar adopts the "U" arm, which is connected with the torsion bar in the hexagonal interference mode and bolted at the shaft end to provide double connection strength and super large roll stiffness, and good roll stability. Compared with the traditional air suspension scheme, the weight can be reduced by 30%-50%, and the weight can be reduced by more than 10% compared with similar structures at home and abroad.The smaller underspring mass will enable the suspension system to have better dynamic response, so as to achieve a stable body, wheels with the road quickly to ease the impact of the state [4-5].

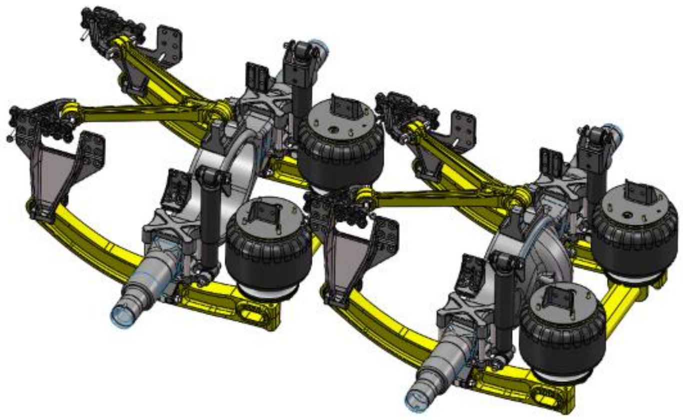

Figure 2: Double bridge and four air - bag suspension guide mechanism

Arrangement of active air suspension

ZZ4257V324HE1B heavy truck is selected and driven in the form of 6*4. Active air suspension design is carried out. See the following table for parameter configuration:

Table 1: Heavy duty vehicle configuration

Wheelbase	**3200+1400mm**	**Total quality**	**25t**
Front axle allows load	7000kg	The vehicle weight	8.8t
Rear axle allows load	/	Body length	6.985m
Front gauge	2041mm	Body width	2.496m
Track rear	1830/1830mm	Body height	3.85m

According to the design of the mid-rear axle suspension of this type of heavy truck, four air springs are respectively located at the top of the wheel, and the driving attitude is controlled independently by the double bridge. The shock absorber adopts the bidirectional acting cylinder shock absorber, which can improve the driving stability better by using the damping adjustment.

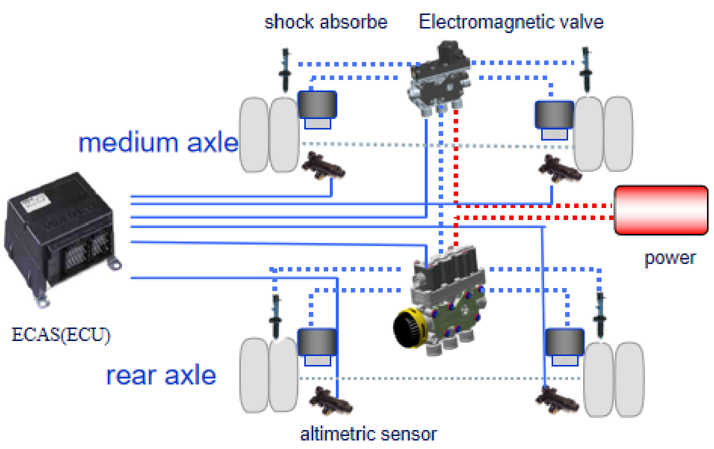

Figure 3: Double bridge four air bags active air suspension layout frame

Conclusions

1. A new type of air suspension structure with upper V and lower U guiding mechanism is proposed.
2. Design the frame of the active air suspension arrangement of the four airbags on the middle and rear axle according to a heavy truck model.

Acknowledgements

Thanks to the teachers and classmates who provided strong support during the writing of the paper.

References

[1]. Abe T, Isobe O, Yamada Y, et al. Development of Electronically Controlled Air Suspension System for Sight-seeing Buses "ESUS" [J]. Jsae Review, 1996, 17(4):444-56.

[2]. Zepeng G, Jinrui N, Lian L, et al. Research on Air Suspension Control System Based on Fuzzy Control [J]. Energy Procedia, 2017, 105:2653-2659.

[3]. Sun Shi lei. Study on the Control Strategy of electrically controlled active Air Suspension charging and discharging characteristics [D]. Taiyuan University of Technology,2019.

[4]. Taniguchi S, Yorifuji T, Hamada T, Analysis and optimization of front suspension characteristics based on ADAMS [J]. Modern Manufacturing Engineering 2013, 32(3): 43-47. Doi: 10.1111/j.1365-2230.1994.tb02689.x.

[5]. Cheng Chong. Study on mechanical Properties of air spring and Active Control Strategy of air Suspension [D]. Harbin: Northeast Forestry University, 2016.