# 3D modeling design and engineering analysis of automotive suspension beam

Zhi Lan JU[a], Fu Bao ZHANG , Guo Ran HUA ,Hua ZHANG

*School of Mechanical Engineering, NanTong University, Nantong 226019, P.R.China*

**ABSTRACT:** Automotive suspension is an important device for transmission and torque. The main parameters and dimensions of 40 tons of heavy duty truck spring suspension system are designed in the paper. According to the data, the 3D modeling and virtual assembly of the leaf spring suspension are carried out by using parametric design. Structural stress of spring suspension is analyzed which can provide a guide and basis for the design of the leaf spring suspension.
***Keywords:*** Leaf Spring Suspension, Parametric Modeling, Finite Element Analysis

## 1 Introduction

Vehicle suspension system is a generic terms for all transmission gear and coupling arrangement between body-chassis units or frame construction and wheels or axle. The main function is to deliver the bearing force, lateral reaction force, vertical reaction force as well as the movements generated by those forces above to the body-chassis units or frame, which ensures the normal vehicle running [1]. The optimization design and static analysis of the suspension is one of the important contents of the vehicle movement. Currently for heavy duty automobile, the simple structure, low cost, mature and reliable technology of leaf spring suspension is the best choice, which is still worthy of study focus, in the design stage of the automotive suspension of stress field, temperature field and deformation analysis, and understanding automobile plate spring suspension thermal load state and comprehensive stress distribution situation and the suspension system improved, reducing the heat load, improve the thermal stress distribution, it is of great significance to improve the reliability.

Passive leaf-spring suspension has more advantages than active air suspension. The 40 tons of heavy truck suspension leaf-spring system was studied in this paper. Using parametric technology and finite element analysis to construct three-dimensional modeling and assemble suspension system virtually, according to the design requirements. Then the suspension system static analysis was carried out on the basis of the model.

## 2 The design of main structural parameter

### 2.1 suspension load

According to the leaf-spring placement, the designing of the leaf-spring is placed on the axle, the spring load distribution parameters as seen in the ***Tab .1.***

Tab.1. the arrangement of spring load

| | Front suspension | Rear suspension |
|---|---|---|
| xial load mass | 15 ton | 25 ton |
| **unsprung mass** | 1 ton | 1.5 ton |
| Spring load | 14 ton | 23.5 ton |

### 2.2 Determination of basic parameters of leaf-spring

In consideration of the overall layout of the car, the steel leaf-spring should be designed as long as possible. Because of the longer steel sheet can reduce the stiffness of the leaf-spring, and then can improve the ride comfort of the vehicle [2]. On the other hand, the long spring plate also can reduce the working stress, so it can improve the service life of the leaf spring. Comprehensive consideration of various factors, the length of the front suspension spring was calculated about 1570mm.

The total moment of inertia of the U type bolt can be cited to express as follow [3]:

$$J_0 = \frac{\delta(L-KS)^3 C}{48E} \qquad (1)$$

$\delta$ is the deflection coefficient and the deflection coefficient formula is calculated using ***Eq.(2).***

$$\delta = \frac{1.5}{1.04\times(1+\frac{n_1}{n_0})} \qquad (2)$$

Which $n_1$ is the number of overlapping slices with equal length, $n_1 = 2$ and $n_2$ is the valuation of the total number of springs, take $n_2 = 16$ [4], so $\delta = 1.357$ was calculated.

[a] **Corresponding author:ju.zl@ntu.edu.cn**

Where L is the spring stretched length, $L = 1570mm$. $K$ is invalid length coefficient, generally $K = 0.5$, while s is the center of the U-shaped bolt distance, $s = 95mm$; C is the spring stiffness, $C=5.6\times10^5 N gm^{-1}$, $E$ is the elastic modulus, $60Si_2Mn$ is chose as the spring material, then $E = 210GPa$.Therefore $J_0$ can be obtained ,so the value is $2.66\times10^{-7} m^4$.

As seen from previous considerations, the depth of steel plate can be cited to express as ***Eq. (3).***

$$h \le \frac{8Jo}{Fw(L-kS)}[\sigma_C] \quad (3)$$

$\sigma_c$ is the material allowable bending stress, $\sigma_c = 450N\cdot mm^{-2}$, $h$ can be obtained $\le 17.97mm$. So the spring thickness was selected 12mm.

The spring load is determined according to the 40 tons of heavy vehicle performance, followed by calculation of the basic parameters: static deflection, deflection, full of arc height and leaf spring sheet size parameters. It provides the necessary data and foundation for the three-dimensional modeling of the leaf spring. The dimension parameters of the rigid spring suspension system are shown in ***Tab.2.***

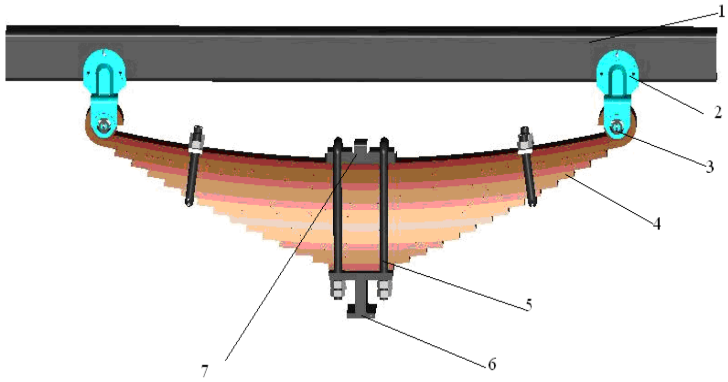
Tab.2. Size parameter of rigid spring suspension system

| The Name of Part | Materials | Elastic Modulus *GPa* | Poisson's ratio μ |
|---|---|---|---|
| Leaf spring plate | $60Si_2Mn$ | 206 | 0.29 |
| Leaf spring | Gray cast iron | 145 | 0.25 |
| U bolt | 35 | 212 | 0.31 |
| Upper cover plate | Gray cast iron | 145 | 0.25 |
| Spring pin | 20 | 206 | 0.30 |
| Spacer | 35 | 212 | 0.31 |
| ut | 45 | 209 | 0.3 |
| Washer | Q215 | 210 | 0.26 |

# 3 Simulation and analysis of vehicle suspension beam

## 3.1 Three Dimension model

Based on the design parameters presented in ***Table.2***, the three-dimensional model of rigid spring suspension system was established, as shown in ***Fig.1***.




1-beam 2-bracket 3-eye axis 4-beam spring 5-U stud
6- the base of spring 7- Upper cover plate

Fig.1. the structure diagram of automobile suspension system

## 3.2 Engineering analysis of suspension beam

The performance of suspension system can be seen in ***Tab.3***

**Tab.3.**Material properties of suspension parts

| The name of parameters | Selected or calculated values |
|---|---|
| Extended length | 1570 mm |
| Static disturbance | 625 mm |
| Dynamic disturbance | 675 mm |
| Rigidity | $5.6\times10^5$ $Nm^{-1}$ |
| Moment of Inertia $J_0$ | $2.66\times10^{-7}$ $m^4$ |
| Thickness | 12 mm |
| Width | 120 mm |
| Number of tablets | 16 |

## 3.3 FEM Analysis

The finite element modeling of leaf-spring suspension has been built in Para.2.1, then to solve it by loading in FEM software. The total deformation of suspension system results as shown in ***Fig.2*** and the equivalent elastic deformation are shown in ***Fig.3***, and so on.

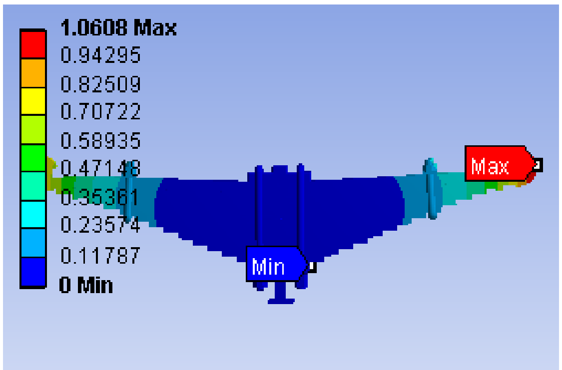



Fig.2. The total deformation

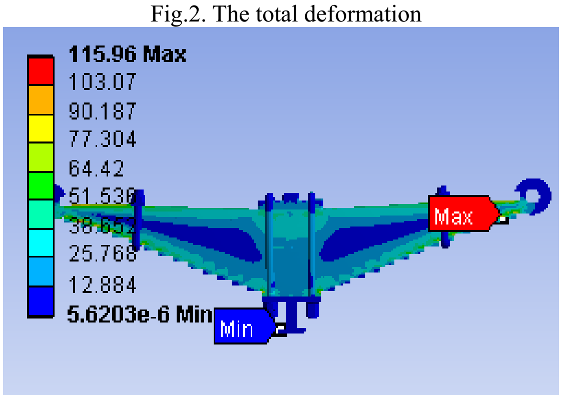



Fig.3. Equivalent elastic deformation

### 3. 4 The result analysis

The result shows that the maximum value of equivalent stress of the leaf spring suspension is 115.96 $MPa$. And the stress mainly concentrated on the vicinity of the leaf spring suspension at both ends of the mouse ear chickweed. The yield strength of 60Si2Mn spring steel was 800 $MPa$, and the tensile strength was 1000 $MPa$ [5]. So the results of strain-stress of the vehicle suspension can meet the design requirements.

In consideration of the steel plate spring suspension, the $Z_{max}$ load can be given by ***Eq. (4)***.

$$Z_{max} = kG = 35000 \times 3 = 105000N \quad \textbf{(4)}$$

$k$ and $G$ are dynamic load coefficient and vehicle suspension spring static load, respectively. The safety factor K is also need to consider in addition to the safe of automobile driving process. The safety factor of the project is n=1.2. When the vehicle runs on rough road, the strength of the steel plate spring is satisfied with the design requirement that can be seen in ***Eq.5.***

$$\sigma_{max} = \sigma_1 \times k \times n = 115.96 \times 3 \times 1.2 = 417.46MPa$$
$$< [\sigma] = 800MPa \quad \textbf{(5)}$$

The maximum deformation value is 1.06mm. The zero of the maximum deformation zero of leaf spring suspension is appeared near the ends of the mouse ear chickweed, which can be seen from Fig.3. According to the finite element analysis, near both ends of the spring eye can be surface strengthened to improve the whole performance of the leaf-spring suspension system.

### 4 Conclusion

Based on the given parameter value, the suspension system was built through the parametric design software in this paper. Then the suspension is simulated and the stress analysis is obtained by FEM. The results show that the optimization was done correctly and effectively on improving the kinematic characteristics of the suspension system, which can provide the theoretical guidance for the following optimization design.

### Acknowledgements

The authors express their deep gratitude to Natural Science Fund of China under Grant No.51205212, Natural Science Fund of Jiangsu Province of China under Grant No.BK2012233 and Nantong Municipal Science and Technology Bureau under Grant No.K2014037.

### References

[1] Zhao Conglin.*Hebei University of Technology,* 2010.
[2] Xu Pingtao. *Changan University,* 2012.

[3]Wang Qinwu.*Kunming University of Science and Technology*, 2003

[4] Min peng, Zhao Jincheng. *Building Science.*29 (2013).
[5] Zhao Yuanyuan.Harbin Institute of Technology, 2009.