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Fatigue Life Analysis and Optimum Design of Suspension Spring

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Abstract: Automotive suspension springs is one of the important components of the automotive vibration system, which determines the comfort, stability, ride comfort and reliability of the car in the course of travel. Therefore, it is necessary to calculate and evaluate the stress and strain of the suspension springs. In this paper, the 3D model of a suspension spring is established by UG software, the stress and strain are calculated and analyzed by using ANSYS-workbench finite element software. Through the analysis ,the weak region of spring fatigue deeterminted, which can provides the theoretical basis and technical support for the spring optimization design and analysis.

Keywords: Suspension spring, finite element ,stress ,strain

I. INTRODUCTION

With the rapid development of the automobile industry and the increasing demand of the automobile market, people have put forward higher standards for the quality and long-term use of the automobile. In order to improve the service life of the automobile as a whole, the parts of fatigue and fracture failure analysis of become the important subject. Suspension spring is one of the main components of a vehicle suspension system, will directly affect the service life and damping capability of the suspension system. Because of the cyclic alternating load during the whole working process, the analysis of the stress and strain of the spring can be transformed into the fatigue life of the spring. In order to improve the service life of the spring and improve the design of the spring, this paper carries on the finite element analysis of the suspension spring and so on.

Firstly according to the spring of parametric design data of spring of 3D modeling (the experimental modeling in UG software to, and then import ANSYS-Workbench , defining the material properties, meshing, adding loads and constraints. The stress, strain and other statics analysis and calculation will be applied to the analysis of the data results of different loads, and provide a reliable basis for the optimization design of the spring.

1 3D Model establishment in UG

According to the existing data parameters, spring diameter, the diameter of the material, convoluted ratio and other parameters, calculated the spring, diameter, curvature coefficient and effective work load, and spring 3D model construction. The calculation formula is as follows.

Coefficient of curvature $$K=\frac{4C-1}{4C-4}+\frac{0.615}{C} \quad (1)$$

The curvature coefficient is stress coefficient of spiral spring, is mainly the calculation accuracy of stress correction.

Parameter K

C	4	6	8	10	12	14	16
K	1.40	1.253	1.184	1.145	1.119	1.102	1.088

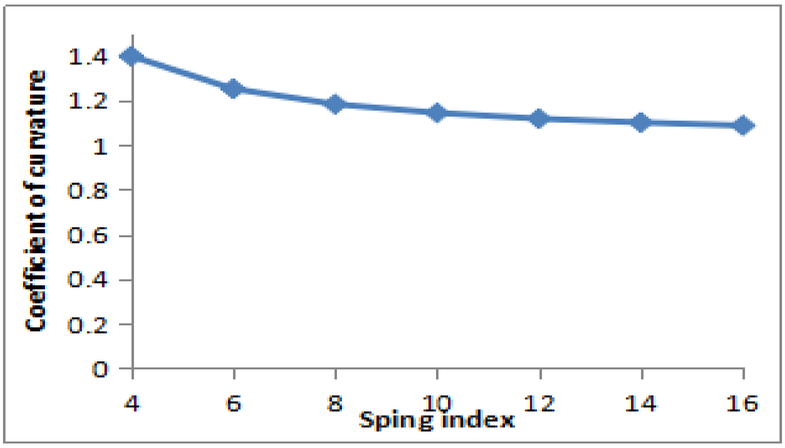


Fig. Change curve of K

This chart is the curvature coefficient with the winding ratio change diagram. From the figure, with the increase of winding ratio, curvature ratio showed a downward trend. Especially, it adequate choice is K=5～8.

Working load $$P = \frac{\pi d^3}{8KD_2}[\tau] \qquad (2)$$

Spring load under normal operating conditions. This load must be within the limit load range of the spring lock.

Outside diameter of spring $$D_1 = D_2 + d \qquad (3)$$

It mainly to control the transverse size of the spring, the size is not only related to the diameter of the material, but also with the spring in the relevant.

Mid-diameter of spring $$D_2 = \frac{D + D_1}{2} = Cd \qquad (4)$$

This is an effective control parameter for design calculation and modeling.

Inner diameter of spring $$D_1 = D_2 - d \qquad (5)$$

Used to control the size of the inner ring of the spring, to ensure the normal compression spring in the limited space.

Spring stiffness $$P^1 = \frac{Gd^4}{8D^3{}_2 n} = \frac{P_n - P_1}{h} \qquad (6)$$

Spring stiffness is the ratio of the load increment dP and the increment of deformation DH, that is, the load required to produce the unit deformation, the spring stiffness calculation formula is P^1=dP/dh. Characteristic line for increasing the spring, stiffness with the increase of the load increases; and decreasing of spring, stiffness decreases with the increase of load. As for the linear spring, the stiffness does not change with the change of the load, that is, the P^1=dP/dh=P/h= constant. Thus, for a spring having a linear characteristic line, the stiffness of the spring is also constant.

Spring index $C = \frac{D_2}{d}$ (7)

Spring index(C) can be used is that to maintain the stability of the spring. In order to make the spring not quiver or too soft (generally C=4～16).

in which, $[\tau]$ — Allowable stress （MPa）；

G — shear modulus （MPa）；

d — spring diameter （mm）；

n — Number of working cycles；

h — Working stroke （mm）；

P_n — Maximum working load(N); P_1 — Minimum working load(N);

Gotten data has a free length of the spring h=344.3mm, the material diameter d=14.5mm, Spring stiffness P1=204.7±25 , Effective number of turns 7.5 circles(Second circles D21=124.5mm, Maximum circle D21=136.5mm) Number of supporting rings1circles（In diameter of spring D2=65mm），For different pitch springs, the gap between the adjacent ring of the spring is also required. The load and stiffness of the spring at different heights can be obtained by defining the pitch and rise angle of each cycle.

According to the calculation results, in the UG software, the 3D model of the suspension spring can be constructed by sweeping the baseline, As shown in Fig.1

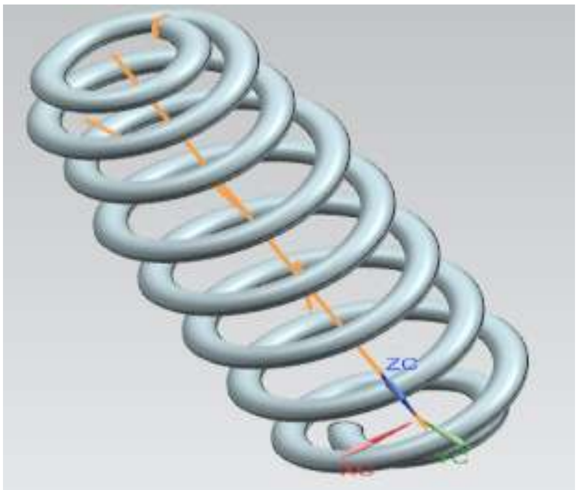


Fig1 suspension model

II.FINITE ELEMENT STRESS AND STRAIN CALCULATION

Finite element method is a powerful tool to solve practical engineering problems. This is a mathematical method for the practical application of specific issue, Analysis of the suspension spring is mainly on the static analysis. The fatigue life of the spring is evaluated by the analysis and study of the nonlinear problems such as the large variation, stress tempering, contact and so on.

It is an important step to establish an accurate and reliable calculation model by using finite element method for finite element analysis. The CAD software built spring model is imported into ANSYS Workbench, first of all to spring were the definition of material properties, and then to the grid, generally preferred hexahedron and impose constraints, finally carries on the computation, because the analysis of the static analysis, so we do not consider the calculation process, only on the results were analyzed.

2.1 Analysis assumptions

For close representing the real spring in FEM software, following assumptions are introduced. First, the material is homogeneous and isotropic, in which linear elastic rules can be used. Second, the speed of the load is ignored. The change of velocity, acceleration and displacement in the course of motion is not considered, and the analysis is carried out under the condition of static force. Third, the state of the object is thought as a non-stress state, that is, before the force of the object, the internal stress is zero. Because the compression of the suspension spring is a large deformation problem, it is necessary to consider the factors of large deformation in the analysis process.

2.2 Definigition of material properties

After the model is imported into ANSYS Workbench, the material of the model needs to be defined. A material library is built in the software. The material properties of the parts can be either selected, or customized according to the actual material properties. Because the suspension spring is a linear static analysis, it is not necessary to consider the influence of heat, so it is only necessary to define its young's modulus (E=196500 ~ 198500MP), shear modulus (G=78600 ~ 80670MP) and Poisson's ratio （$\mu = \frac{E}{2G} - 1$）. In general, we assume that the spring is equal to the stiffness of the production.

The selection of the material has an important influence on the life of the spring and the fracture resistance of the spring. Suspension spring requires the material must have high yield strength, strong toughness, heat resistance, heat resistance, fatigue resistance and high life expectancy, so the 55Si2M alloy is selected for the spring, with young’s modulus E=203700MP, poisson’s ratioμ=0.3, shear modulus G=78400MP.

2.3 Meshing

Grid in the pre-processing plays an important role, is the finite element analysis of the key work. The quality of the mesh will on the calculation result of considerable influence, also different types of mesh, the calculation results also corresponding impact. In general, the first choice of quadrilateral or hexahedral mesh generation, mesh number also not easy too much, otherwise it will make calculation time is too long, too long calculation time, data utilization rate of decline. Because the spring parts are relatively simple, and in order to improve the quality of the grid, the tetrahedral mesh should be used, and the unit size is 2.8mm.

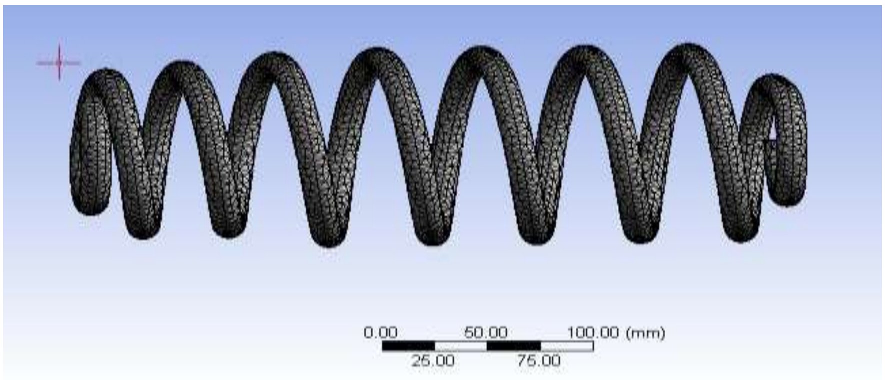


Fig2 mesh

2.4 Imposing boundary conditions

In order to ensure the upper end of the spring swing and lateral displacement does not occur, pre constrains the spring seat X, Y axis direction of the translations and rotations about the X, Y axis of rotation degrees of freedom, and retain only the Z direction of the translational and around the z-axis rotational degrees of freedom. Only in this way can prevent spring seat compression process, the spring has large lateral displacement, resulting in instability of spring. So the spring on the lower end surface of the installation base, end the fixed support constraint, the lower end face of the base and the spring applied frictional contact, the end surface of the release along the Z axis vertically down the degrees of freedom and other five degrees of freedom constraints. The spring is compressed to three working positions, the height is: 304.3mm, 240.3mm, 154.3mm. The free height of the spring is 344.3mm, the compression stroke is 40mm, 104mm, 190mm, respectively.

2.4.1 Contact constraint

ASNSYS workbench has four kinds of contact type and contact bound, which are non-separation contact, no-friction contact, asperity contact. Especially, the contact bound and no separation contact is a linear operation behavior, solving process only one iteration. Otherwise, no friction and rough contact is a non-linear computational behavior, solving process requires many iterations. In addition to considering the deformation. The finite element model of the spring is used to simulate the actual working conditions by the spring compression . The spring base is bound by the vertical displacement of the spring seat. So the transfer of the spring seat and the spring is a contact problem. Because the spring seat in the stress process of deformation is very small, mainly in the spring compression deformation. And the contact point of a rigid body and flexible body to simulate his yellow in the compression process, definition of two contacts. Respectively, for the lower spring seat with the spring and the spring seat and a spring, spring seat is a target body, spring is a contact body. According to the spring rationality, spring deformation large, which analyze must open the large deformation. The upper base(Fig2-3) and the lower base(Fig2-2) are respectively carried out with the spring for the friction constraint (the friction coefficient is 0.1).Taking into account the process of spring row ring, and may spring itself is self -contact (Figure 2-4).

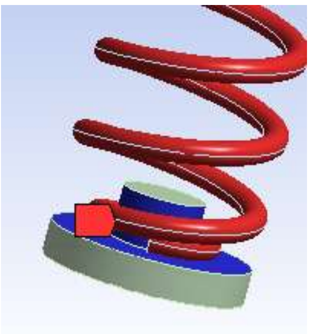


Fig3: end friction constraint

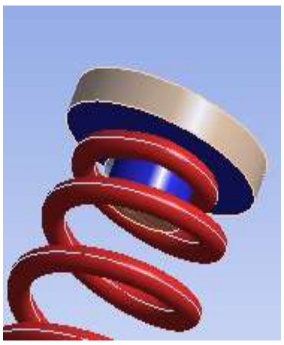


Fig4: Upper friction constraint

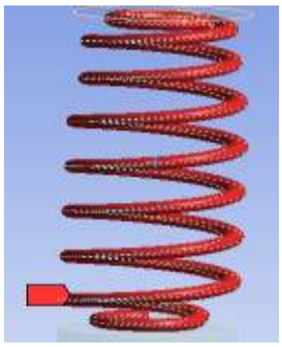


Fig5: self –contact

Contact	2 Faces
Target	2 Faces
Contact Bodies	lunwen--spring_stp
Target Bodies	lunwen--spring_stp
Definition	
Type	Frictional
Friction Coefficient	0.1

Fig6: Frictional

2.4.2Imposed displacement constraint

According to the actual working condition of the spring, the lower base of the spring is completely restrained, that is, all six degrees of freedom are fixed, and the upper end face is released along the Z axis. As the spring in the work of the force is unknown, the general use of displacement to replace the analysis. The simulation test of the three trips were analyzed, respectively, 40mm initial compression stage, 104mm middle stroke stage and 190mm pressure and circle stage.

III. STATIC ANALYSIS

3.1 Displacement stroke 40mm solution results

As figures are spring along the Z axis compression 40mm of cloud results, Figure 3-1 for the equivalent stress, from the figure it can be seen that the spring in the compression process of equivalent stress maximum value appeared in the inner spring, the inner ring should stress and strain in the spring compression stroke are generally higher. From Figure 3-2, we can see that the maximum deformation of the spring appears on the top, the minimum deformation at the lower end, which is in full compliance with the spring compression deformation theory.

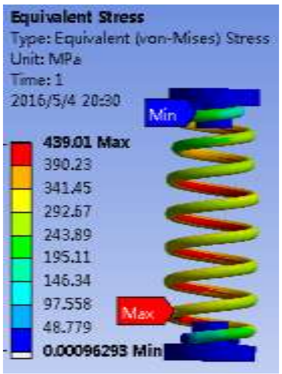


Fig7Equivalent stress

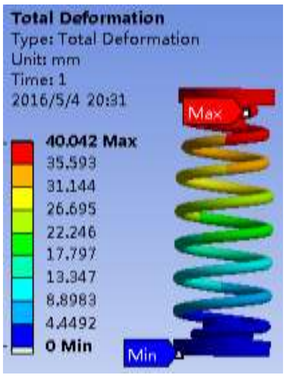


Fig8Total deformation

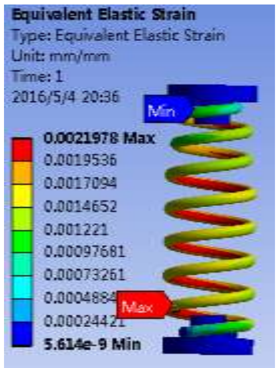


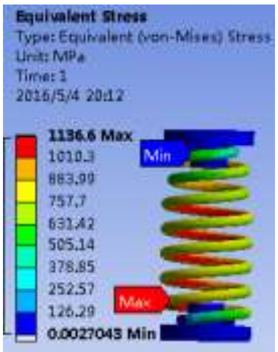
Fig9 Equivalent elastic strain

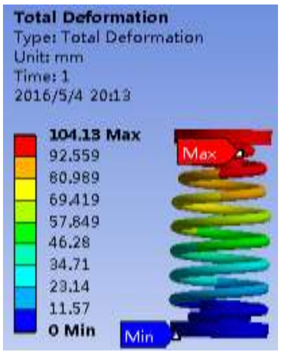
Compression volume is 40mm

Result	**Minimum**	**Maximum**	**Units**	**Time(s)**
Equivalent stress	9.6293e-004	439.01	MPa	1
Total deformation	0	40.042	mm	1
Equivalent strain	5.614e-009	2.1978e-003	mm/mm	1

3.2 Displacement stroke 104mm solution results

As figures are the spring along the Z axis compression 104mm results of the cloud, the Figure 10and Figure 12 also shows that the same strain and stress maximum value appears in the spring inner ring, the minimum value in the spring on the lower end of the circle. Figure 11shows the total deformation at the upper end of the circle.





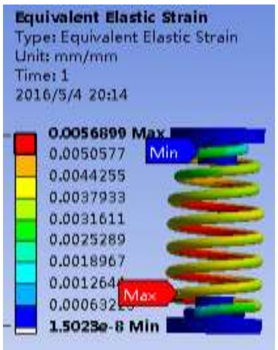


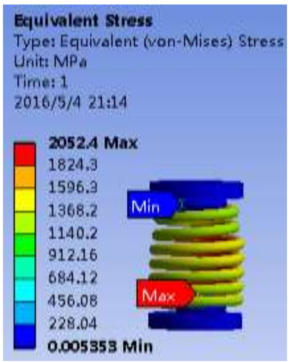
Fig10 Equivalent stress Fig11Total deformation Fig12 Equivalent elastic strain

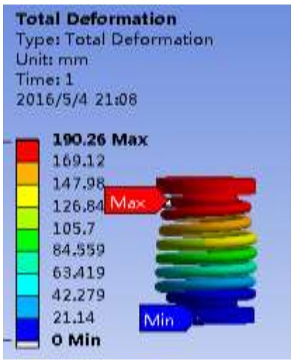
Compression volume is 104mm

Result	**Minimum**	**Maximum**	**Units**	**Time(s)**
Equivalent stress	2.7043e-003	1136.6	MPa	1
Total deformation	0	104.13	mm	1
Equivalent strain	1.5023e-008	5.6899e-003	mm/mm	1

3.3 Displacement stroke 190mm solution results

As figures are the results of the spring compressed 190mm along the Z axis. This stage is the spring pressure and ring state, but also the limit position of the spring displacement travel. The maximum deformation of the spring when the spring is effective, as shown in Figure 14, the maximum deformation is 190.26mm.





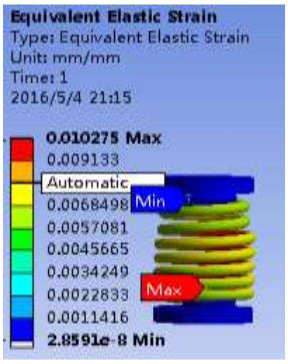


Fig13: Equivalent stress **Fig14:** Total deformation **Fig15:** Equivalent elastic strain

Compression volume is 190mm

Result	**Minimum**	**Maximum**	**Units**	**Time(s)**
Equivalent stress	2.7043e-003	1136.6	MPa	1
Total deformation	0	104.13	mm	1
Equivalent strain	1.5023e-008	5.6899e-003	mm/mm	1

Through the analysis of the above three stages of displacement is found that in the spring effective travel range, that is, to meet the allowable stress, the stress, strain and deformation of the value position basically unchanged, that spring in the compression process by stress and strain of the position should generally do not change with the load change. The life of the spring is determined by the position of the maximum stress. Therefore, it is necessary to optimize the position of the maximum stress and strain to improve the strength and prolong the service life of the spring. So as to improve the spring's ability to resist fatigue and fracture.

.4 Reaction force

Along with the increase of load, the supporting force of the base is also increased. The nonlinear relation between the supporting force and the load is seen from the point of discrete point in Figure 13.

Displacement and Reaction force

Displacement	10	40	70	100	130	160	190
Reaction force	506	2124.9	3668.5	4200.4	4802.6	5425.9	5802.2

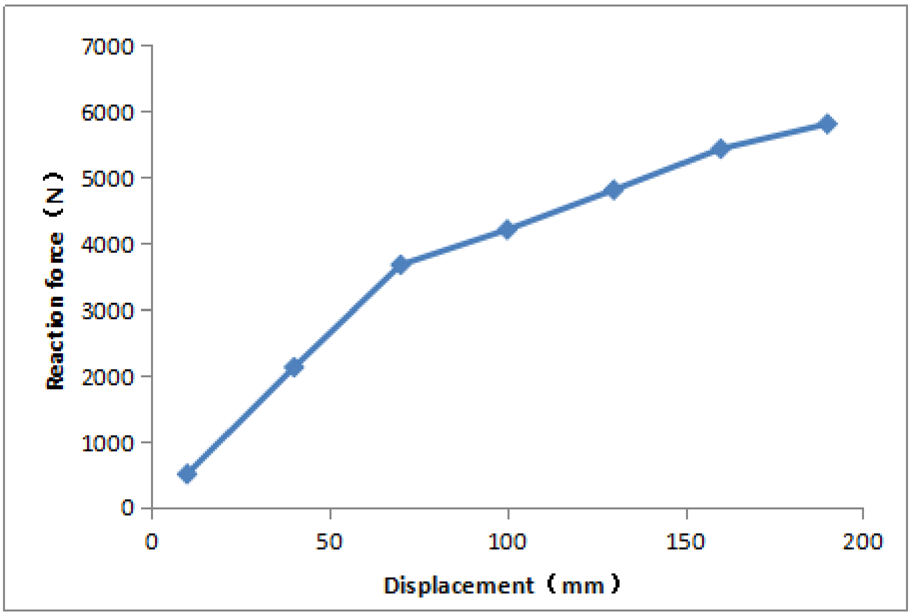


Fig16 : Displacement diagram

From the graph we can see that, with the increase of the displacement, the reaction force is on the upward trend, the displacement is between 50 to 70, and the reaction force increases rapidly. Between 70 to 190 the trend is slowly.

IV. CONCLUSION

In the finite element analysis of the suspension spring, the mechanical model is solved by finite element simulation, the equivalent stress, equivalent strain and total deformation of the model are compared. It is concluded that the effective limit load of the spring in the assembly position and compression is affected by the position of the ring. To provide a strong basis for the optimal design of the spring, the maximum stress and the strain position of the spring are calibrated.

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REFERENCES

[1]. ANSYS Workbench based Pu generalized tutorial with detailed examples [M]. 2 edition. Beijing: Chinese water conservancy and Hydropower Press, 2013.

[2]. Ceng Pan. Finite element analysis [M]. Tsinghua University press, 2004 (6).

[3]. Hu Min. Finite element analysis and application [J]. Shanghai automobile, 2007 (7).

[4]. Fang Fang. Elastic mechanics [J]. auto parts, 2009 (28).

[5]. Zhang Ying, Liu Hai hang, Wang De cheng. Spring manual [M]. Beijing: Mechanical Industry Press, 1997.

[6]. Cheng Da xian. Handbook of mechanical design [M]. Chemical Industry Press, 2004.

[7]. Ding Yufeng.ANSYS12.0 finite element analysis complete handbook [M]. Publishing House of electronics industry, 2011

[8]. Chen Yanxia, Chen Lei Workbench.ANSYS engineering application case proficient in [M]. Electronics Industry Publishing House, 2012

[9]. Lu Shuang, Sun Ming li, Ding Jin fu, Hu Ren xi Worbench13.AYSYS finite element analysis fromentry to the proficient [M]. Machinery Industry Press, 2012

[10]. Li Bing, He Zheng jia, Chen Xue feng ANSYS Worbench. design, simulation and optimization [M]. Tsinghua University press, 2011

[11]. Wang Mengfu, Zhao Junhai. Spring mechanics and finite element [M]. Wuhan University of Technology press, 2003