Analysis Nonlinear mechanical characteristics analysis of a UAV landing gear shock absorber

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Abstract. Shock absorber of landing gear can reduce landing overload and vibration. Under different working conditions, the shock absorber structure is easy to produce stress and strain changes. This paper takes a kind of spring shock absorber as the research object. The single factor method is used to analyze the mechanical characteristics of the shock absorber under different compression stroke and landing deflection angle. The simulation calculation is carried out by ANSYS Workbench software. The simulation results show that: with the increase of the compression stroke of the shock absorber, the contact pressure and stress between the piston and the outer cylinder as well as between the piston rod and the lower cover will also increase. With the increase of the land deflection angle, the contact pressure between the structures will also increase. When the contact pressure is too high, the shock absorber will be stuck. It is easy to cause shock absorber failure. The results of this study can provide guidance for structural optimization design of shock absorber.

1. Introduction

The Landing gear is mainly used for aircraft parking and taxiing process as a supporting component of the aircraft \cite{1}. The shock absorber is the main buffer mechanism in the landing gear. It can reduce landing overload. When it runs into an uneven runway, it can quickly absorb and consume the impact kinetic energy of the aircraft hitting the runway. So as to reduce the vibration damage of the ground surface to the fuselage \cite{2,3}.

The compression stroke of shock absorber of UAV (Unmanned aerial vehicle) will change under different landing overload conditions. This will result in a different compression stroke of the shock absorber \cite{4}; When the landing angle is different, the force direction of the piston rod and the axial direction of the outer cylinder will produce different deflection angles \cite{5}. These two situations will lead to different compression stroke, force magnitude and direction of shock absorber. As a result, the friction force and stress of the contact parts of the piston assembly, the outer cylinder and the lower cover are changed accordingly \cite{6}.

In this paper, two factors of different compression stroke and landing deflection angle of shock absorber are simulated and analyzed. ANSYS Workbench software is used in simulation analysis. The change characteristics of stress and strain of shock absorber under different compression stroke are
simulated and analyzed; At different landing angles, the interaction characteristics between the piston assembly and various parts of the shock absorber are also discussed. The change law of interaction force between piston assembly and other structures under different landing deflection angle is calculated by simulation. It can prevent the shock absorber from sticking due to excessive friction. So as to avoid shock absorber failure. The failure of the shock absorber will cause the fuselage overload and damage the fuselage structure [7,8].

2. Model establishment and force analysis

2.1. Model establishment
The main landing gear of UAV is composed of wheel, wheel shaft, upper and lower torque link, torque link support, piston, piston rod, strut outer cylinder, diagonal strut, fixed bracket, etc. The geometric parameters of the shock absorber model are shown in Table 1. The three-dimensional model of landing gear components is established by CATIA software. Then the corresponding assembly is carried out according to the assembly relationship between the components. In the assembly process, in order to ensure the accuracy of the relative position of each component, the assembly of each component is constrained accurately. Because only nonlinear analysis and calculation are carried out on the shock absorber part. The influence of wheel and other components is not considered. So other parts are simplified during modeling. The landing gear model is shown in Figure 1.

Table 1. Geometric parameters of shock absorber

| Parameter                             | value /mm |
|---------------------------------------|-----------|
| Outside diameter of outer cylinder D₁ | 30        |
| Inner diameter of outer cylinder D₂   | 24        |
| Piston outer diameter d₁              | 24        |
| Piston rod diameter d₂                | 16        |
| Length of outer cylinder l₁           | 150       |
| Piston rod length l₂                  | 85        |

Figure 1. Strut type main landing gear structure diagram

2.2. Force analysis of shock absorber
In this paper, the nonlinear force characteristics of the spring shock absorber structure in the strut type main landing gear are studied. Landing gear buffer system is generally composed of shock absorber and wheel. The outer cylinder, spring, piston and piston rod are the main components of spring shock absorber. When the UAV lands, the ground transmits the force to the piston rod through the wheels, which makes the shock absorber compress and stretch. In the compression and extension stage of shock absorber. Due to the overload of landing gear and landing deflection angle is not fixed. This will change the contact pressure and friction between the piston assembly and the outer cylinder. The stress diagram of strut landing gear is shown in Figure 2.
The lower end of the shock absorber piston rod is subjected to the following two forces:

\[ F_t = m \ddot{Z}_m + F_Z - mg \]  
\[ N_t = F_x - m \ddot{X}_m \]  

The force analysis of the shock absorber structure is obtained:

\[ F_t L \sin \theta + N_1 (L_u + S) = N_t (L_r + L_u \cos \theta) \]  
\[ N_1 = \frac{[N_t (L_r + L_u \cos \theta) - F_t L \sin \theta]}{L_u + S} \]  
\[ N_2 = -(N_t \sin \theta + F_t \cos \theta) + N_t \]  

Because the friction force between the piston assembly and the inner wall of the outer cylinder and the lower cover is \( \mu_1 = \mu_2 \). So the internal friction of the shock absorber is as follows:

\[ F_f = \mu_t \left[ \frac{[N_t (L_r + L_u \cos \theta) - F_t L \sin \theta]}{L_u + S} \times 2 - (N_t \sin \theta + F_t \cos \theta) + N_t \right] \]

3. Simulation results and analysis of shock absorber

The three-dimensional model of shock absorber is imported into ANSYS Workbench software. Then set the material of shock absorber outer cylinder and piston assembly to structural steel. Its elastic modulus is 210GPa, density is 7837 kg/m³ and Poisson's ratio is 0.283. The tolerance value of the contact pair is 0.65. The contact mode between the piston and the outer cylinder, the piston rod and the lower cover is friction contact. The friction coefficient is 0.1.

3.1. Mesh division

In ANSYS Workbench finite element analysis, the mesh division of geometric model has a direct impact on the numerical results. Generally, increasing the number of grids is an important method to improve the accuracy and accuracy of calculation. According to the geometric characteristics of the landing gear, the following division method is adopted: The fixed bracket was divided automatically; The hexahedron dominant method is used in outer cylinder, lower cover, piston and piston rod; The smaller grid size is used to divide the contact position of piston assembly with outer cylinder and lower cover. Good mesh quality can be obtained by mesh encryption of contact position. The result of meshing is shown in Figure 3.

3.2. Simulation results of different compression stroke

The main purpose of this simulation is to study and analyze the various changes caused by the interaction between the piston assembly, the outer cylinder and the lower cover. When the compression stroke of shock absorber is 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, 30 mm. The main part is to do the following simulation analysis of the shock absorber structure.

(1) The stress and strain caused by the interaction between the piston assembly, the outer cylinder and the lower cover are simulated and analyzed. The equivalent stress of the inner wall of the outer
cylinder and the lower cover is shown in Figure 4.

![Equivalent stress diagram of inner wall of outer cylinder with different compression stroke](image1)

It can be seen from Figure 4 that during the axial compression of the shock absorber, because there is friction between the piston and the outer cylinder. Therefore, when the piston moves to different positions, there will be greater stress at the contact position. As the piston moves upward, the deformation of the inner wall of the outer cylinder and the piston will accumulate. This will lead to the friction between the two will also increase. So that the stress on the inner wall of the outer cylinder will continue to increase.

2) There is friction contact between the piston rod and the cylinder surface in the lower cover. In the initial state, the maximum stress is concentrated at the lower end of the contact surface. As the piston rod moves upward, the maximum stress gradually changes to the upper end of the contact surface. With the increase of piston rod moving distance, the stress also increases. Its stress variation is shown in Figure 5.

![Nephogram of stress variation of lower sleeve](image2)
(3) When the shock absorber is in different compression stroke. The axial deformation of the inner wall of the outer cylinder is shown in Figure 6. The figure shows the deformation of the shock absorber when the compression stroke is 10 mm, 20 mm and 30 mm. In the compression stage, with the piston sliding upward, the deformation of the inner wall of the outer cylinder contacted by the piston is the largest. From the bottom to the top, the deformation of the inner wall of the outer cylinder decreases gradually.

![Figure 6. Axial deformation diagram of inner wall of outer cylinder with different compression stroke](image)

(4) With the increase of the shock absorber's compression stroke. The contact surface between the piston and the inner wall of the outer cylinder will deform. This is caused by friction between the piston and the inner wall of the outer cylinder. The deformation increases with the increase of compression stroke. This will cause the stress in the contact position to increase. The stress change of shock absorber at different stroke is shown in Figure 7.

![Figure 7. Stress diagram of shock absorber with different compression stroke](image)

3.3. Mechanical characteristics of shock absorber under different landing deflection angles

Due to the irregularity of runway, crosswind and landing conditions, shock absorption can be affected. During the landing process of UAV, the landing gear will have different landing angles. This will make the direction of the ground reaction force on the piston rod deviate from the axial direction of the outer cylinder. At this time, friction and contact pressure of different sizes will be produced between the piston assembly, the inner wall of the outer cylinder and the lower cover. The simulation analysis is carried
out by applying a force of 100 N with different deflection angles on the piston rod. The deflection angles between the force direction and the piston rod axis direction are 3°, 6°, 9°, 12° and 15° respectively. When the landing deflection angle is 3°, 9° and 15°, the stress change of shock absorber is shown in Figure 8.

![Figure 8. Stress variation of shock absorber under different landing deflection angles](image)

It can be seen from Figure 8 that under the action of a certain force. When the landing deflection angle is 3°, the stress change on the left side of the shock absorber is larger than that on the right side; However, when the landing deflection angle is larger than 9° and 15° the stress changes greatly on the left and right sides of the shock absorber. And the stress on the right side of the outer cylinder decreases gradually from top to bottom.

It can be seen from figure 9 that with the increase of UAV landing angle, the contact pressure between piston assembly, outer cylinder and lower cover will also increase. And the contact stress also increases. When the contact pressure is too high, the shock absorber will be stuck during compression. The shock absorber will fail and the aircraft body will be damaged easily during landing.

### 4 conclusions
Through the simulation and analysis of the spring shock absorber in the landing gear of UAV, the following conclusions are drawn:

1. With the increase of the compression stroke, the shear stress and strain of the shock absorber will change. The reason for this change is that the friction force between the piston assembly, the outer cylinder and the lower cover changes. In addition, the deformation increases continuously during the compression stroke. Which makes the contact pressure between them increasing. This will eventually increase the stress on the shock absorber.

2. In the process of UAV landing, landing gear tends to have different landing angles. Under a certain landing load, with the increase of landing deflection angle. The contact pressure of each component in
the shock absorber will also increase. This will lead to the increase of contact stress. When the contact pressure reaches a certain value, the shock absorber will be stuck. This is because higher contact pressure will lead to increased friction between piston assembly, outer cylinder and lower cover. When the friction force is too high. It can not slide relative to each other. This will cause the shock absorber to fail. As a result, the structure of the aircraft was damaged during landing. The research results can provide a reference method for shock absorber seizure-preventing and structure optimization.

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