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Analysis of Landing Buffer Characteristics of Unmanned Airdrop Rescue Vehicle

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Abstract: Taking an unmanned airdrop rescue vehicle as the research object, in order to reduce the impact overload of the airdrop landing, the exhaust type airbag buffer mode suitable for the airdrop vehicle is determined. Firstly, the scheme of the airdrop system is designed. According to the basic assumption of the airdrop process, the thermodynamic analysis model of the buffer bag is derived and the parameters are designed. Secondly, the finite element model of airdrop system with airbag buffer is established based on the airbag finite element algorithm (CV method). Finally, the buffering effect is evaluated by analyzing the change of tire force. The calculation results show that the system overload is reduced from 35g to 22g by using airbag buffer, and the buffer effect is obvious.

Keywords: Aerial vehicle; Airbag buffer; The finite element method.

1. Introduction

Unmanned airdrop rescue vehicle has the characteristics of high tactical mobility. With the advent of various large and high-performance transport aircraft, the development process of airdrop rescue vehicle has been accelerated, making it play an increasingly important role in rescue and disaster relief [1].

In terms of the overall scheme design of the airdrop system, He Qing[2] carried out the overall scheme design of the whole gun for the airborne rocket launcher. In the study of the working process of the parachute. Shang Jianhua[3] drop the truck-mounted gun system dynamics are studied, mainly through the method of finite element of fluid-solid coupling analyses the working process of the parachute, in view of the main umbrella straight, the main umbrella aeration, the main umbrella does systemic research on the stability and the buffering phase, eventually by airdrops example for the whole process simulation in the system, The corresponding analysis results of each stage are given. Wu lei[4]on process of the parachute drop, inflatable, stable down three stages, using the method of combining the theory and experience, the parachute at all stages of loading, the trajectory and the overload situation is analyzed, the method based on fem ALE fluid-structure interaction for parachute aeration process simulation, get umbrella landing process change and overload conditions.

2. Design of Airbag Cushion Scheme for Airbag Impact Meter

2.1. Statistical airdrop system design

An airdrop rescue vehicle with a chassis mass of about 7t [5]. The 3D model is shown in Figure 1. The rescue vehicle meets the load and size requirements of the delivery platform. The airbag buffer device has the characteristics of simple structure, good buffering effect, folding installation, less space occupation and reusable, and has been widely used in the fields of soft landing of spacecraft and precise airdrop protection of materials. In this paper, the buffer air bag is used as the buffer mode of airdropped rescue vehicle.

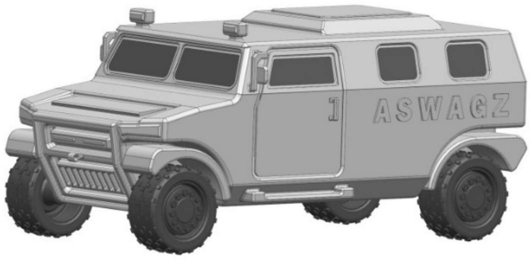

Figure 1. Airdrop rescue vehicle model

The shape of a cargo platform is shown in Figure 2. There are several reserved holes on the cargo platform to install fixed rings, and the equipment is bound and fixed with the cargo platform through the binding rope and fixed rings; The left and right sides have one arm to prevent the equipment from disconnecting during landing, and the arm structure is not considered during modeling; There are slipways on both sides of the bottom of the cargo platform to match the raceway on both sides of the engine room to reduce the friction when the cargo platform slides out of the engine room; Buffer air bags can be installed inside the cargo platform, and folding air bags with about diameter are arranged and fixed inside the cargo platform through the bottom bracket and slide; The slipway and pallet are fixed on the main body of the cargo platform through the locking mechanism, which is connected with the traction rope, and the other end of the traction rope is connected with the parachute. During the process of falling under the cargo platform, when the parachute is fully opened and the parachute rope is pulled tight, the locking mechanism will be released under the action of tensile force, and the bottom pallet and pallet will be separated from the main body of the cargo platform and accelerated to fall under the action of gravity. Thus, the folded airbag is pulled up at the same time. At this time, negative pressure is formed in the airbag, and the air flow is charged into the airbag through the air inlet at the bottom of the airbag. The use of the support plate can not only ensure that each air bag is inflated at the same time, but also avoid direct contact between the air bag and the ground, and prevent the air bag from being punctured or worn during landing.

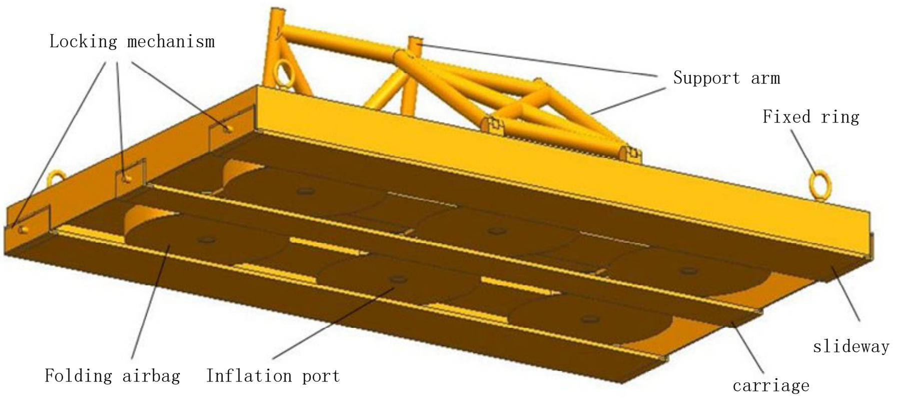

Figure 2. Cargo platform model

2.2. Basic Assumptions

In order to establish the analytical model of airbag cushioning process, the following assumptions are introduced: airbag fabric is not stretchable, ignoring the energy absorption and cushioning effect of the material itself. In the process of buffer compression, the changes of airbag section shape and touchdown area are ignored. The influence of air resistance is ignored in the buffer system. It is assumed that there is no temperature change in the buffer process, that is, there is no heat exchange. The inflation gas is an ideal gas, and the exhaust process only flows out of the exhaust hole, and the fabric has no air leakage. Regardless of the mass of the gas in the airbag and the airbag itself.

2.3. Establishment of analytical model of cystic vertical airbag

In the process of equipment airdrop landing, if the influence of air resistance is not considered, the equipment is only affected by gravity and gas pressure in the capsule in the direction perpendicular to the ground, and the force equation is [6],

$$Ma = (p - p_a)A - Mg \tag{1}$$

Where, M is the equipment quality. a is the falling acceleration of equipment. P is the gas pressure in the capsule. P_a is atmospheric pressure. A is the contact area between the airbag and the equipment ground, which is also equal to the contact area of the airbag. g is the acceleration of gravity 9.8m/s^2.

Heat exchange is ignored in the exhaust process, and the flow rate of gas in the exhaust hole is

$$v_a = \sqrt{\gamma R T_0 (\frac{p_a}{p_0})^{\frac{\gamma-1}{\gamma}}} \tag{2}$$

Where, P is the gas pressure in the capsule. P_a is the pressure of extracapsular gas. r is the air insulation index. R is the thermodynamic gas constant. T_0 is the initial thermodynamic temperature of the gas in the capsule. P_0 is the initial pressure of gas in the capsule.

In the dynamic equation and gas flow equation of airdrop equipment, the parameters are transformed dimensionless, where, $y = x/l$ represents the ratio of the height of the airbag at any time to the initial height during the falling process. $T = v_0 t/l$ represents the time parameter. $P_b = P/P_a$ represents the ratio of gas pressure inside the capsule to gas pressure outside the capsule. $H = lg/v_0^2$ represents the airbag height parameter. $Z = AP_a/Mg$ Represents the load parameter. $B = A_n v_a / A v_0 \sqrt{\gamma}$represents the vent parameter.

The first mock exam is to establish a dimensionless unified model of the airbag buffer system,

$$\frac{d^2 y}{dT^2} = H(Z(p_b - 1) - 1) \tag{3}$$

$$\frac{dp_b}{dt} = \frac{B\delta + \varepsilon \frac{dx}{dt}}{l\eta} \tag{4}$$

2.4. Data meter parameter design

It is assumed that the total weight of the airdrop system is 9t and the floor area of the cargo platform is 10m^2. Since the top of the airbag is fixed together with the bottom of the cargo platform, in order to ensure reliability, the maximum area of the airbag design should be the same as the floor area of the cargo platform as much as possible to ensure the maximum coverage size of the bottom of the cargo platform. Through literature review [7] and investigation, it can be seen that under normal circumstances, the initial velocity of airdrop landing should range from 6 to 7m/s, and the final velocity after buffering is 3 to 4m/s. For safety considerations, the maximum initial velocity is 7m/s and the minimum final velocity is 3m/s are taken as the design conditions. Generally, the landing impact overload that the airdrop equipment should be able to withstand is about 30g, and 30g is used as the overload design requirement.

According to the analysis of the design requirements, the energy efficiency calculated according to the initial and final landing velocity is 81.6%, which meets the requirements. For the airbag combination composed of 6 airbags, the dimensionless mass parameter Z is calculated as 17.4, and the corresponding relationship between Z, B and H in the airbag parameter matching diagram [8] selected according to the design requirements is interpolated to obtain the values of B and H when Z is 17.4. The height is calculated as 1.2m by the calculation formula of dimensionless height parameter H and dimensionless exhaust hole parameter B. The vent area is 0.1m^2, and the ratio of height to diameter is 1.2, which meets the requirements.

3. Simulation Calculation

3.1. Finite element modeling

Model constraints and boundary conditions were introduced in bottom-up order: 7m/s initial velocity was applied to the airdrop equipment (including air bags), the ground translational rotation freedom was constrained, and a simplified model of the cargo platform was established according to the cargo platform size. The finite element model of the airdrop system was shown in Figure 3.

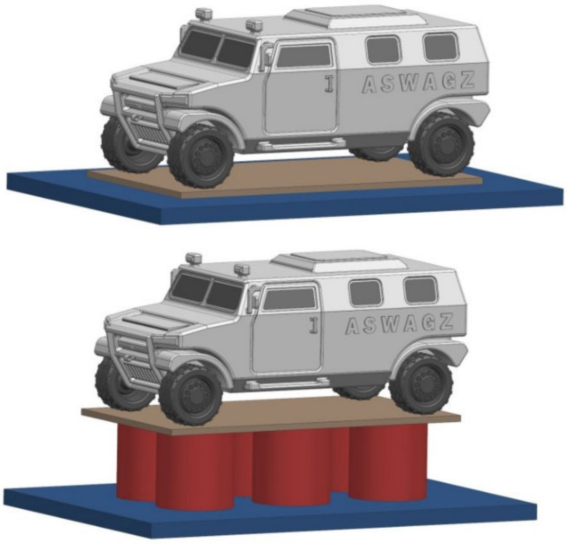

Figure 3. Finite element model of a rescue vehicle airdrop

3.2. Constraints and boundaries

The finite element algorithm of airbag is defined by "AIRBAG WANG NEFSKE".The atmospheric pressure is 100KPa and the air density is 1.169kg/m^3, the gas temperature is 293K, the gravity conversion constant is 1, and the exhaust hole area is 0.1m^2, since it is a self inflating air bag, it has been inflated and opened during landing. It is defined that the filling gas flow rate curve is 0, and the initial pressure in the bag is consistent with the atmospheric pressure. In order to prevent penetration of the ground, air bag and cargo platform, contact is set between the two. During the actual airdrop, the combat vehicle is fixed on the cargo platform through the binding rope. During the modeling, the contact is set between the combat vehicle and the cargo platform, and the cable unit is used to simulate the binding rope effect to prevent the launch box from separating from the cargo platform during the impact process. The body is modeled by rigid body, and the body mass is coupled at the tire axis through mass points. The tire is made of elastic rubber.

3.3. Calculation results

The stress curves of the four tires for airbag free buffer landing are shown in Figure 4. ABCD is the stress curves of the left front, right front, left rear and right rear wheels respectively. The maximum stress of each wheel is about 60t, and the position of the center of mass is backward to the right, so the maximum stress of the right rear wheel is 68t, and the total stress of the tire is 248.5t, the overload of airdrop equipment is about 35g. Maximum stress of pallet 420Mpa, The stress cloud diagram is shown in Figure 5.

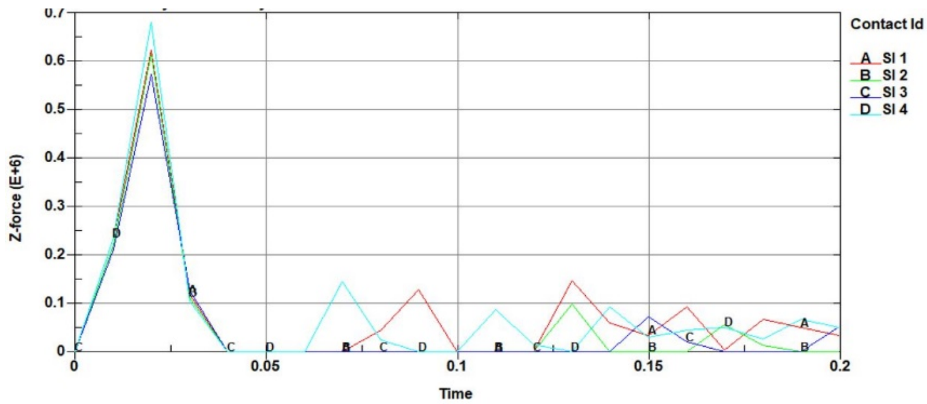

Figure 4. Uncushioned tire forces

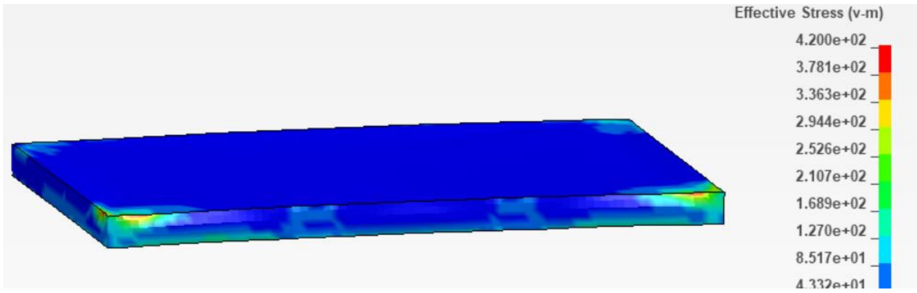

Figure 5. Maximum stress of unbuffered platform

The stress curves of the four tires with airbag buffer landing are shown in Figure 6. ABCD is the stress curves of the left front wheel, right front wheel, left rear wheel and right rear wheel respectively. The maximum stress of each wheel is about 40t, and the position of the center of mass is behind the right. The maximum stress of the cargo platform is 230.1Mpa, and the stress decreases by 45.2%. The stress cloud diagram of the cargo platform is shown in Figure 7, and the process of airbag buffering is shown in Figure 8.

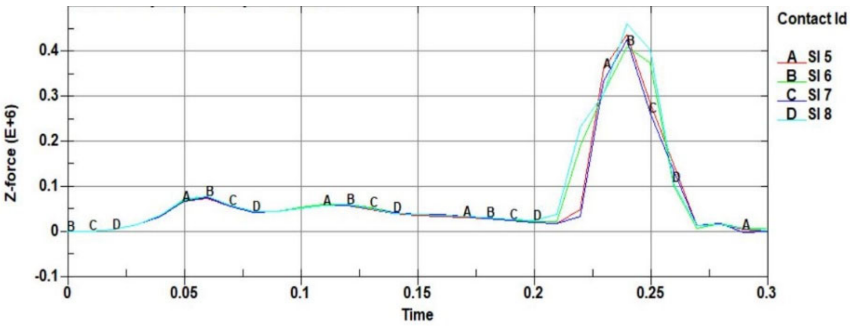

Figure 6. The air bag cushioned the tire

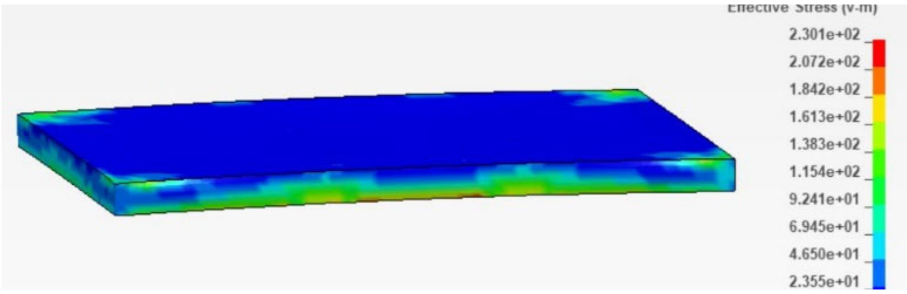

Figure 7. Cushioning the maximum stress of the cargo platform with air bag

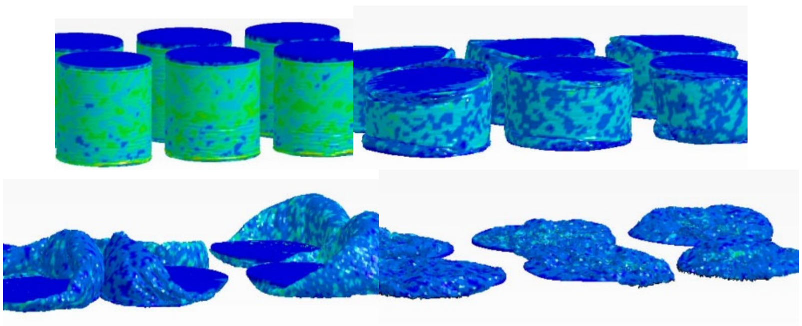

Figure 8. Balloon compression process

4. Conclusion

The simulation analysis of an airdrop system before and after airbag buffer is carried out, and the following conclusions are drawn:

(1) Compared with no buffering state, after airbag buffering, the maximum overload of the system decreases by 37.1%, and the maximum stress of the cargo platform decreases by 45.2%.

(2) The parameters of the airbag can be further optimized to ensure that the oblique landing can also have a good cushioning effect, maximize the cushioning effect of the airbag and reduce the impact of landing.

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