Simulation of Cushion Characteristic of Airbags Based on Corpuscular Particle Method

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Abstract. In this paper, cushion process of the cylinder airbag in airdrop equipment landing system has been simulated. Based on the finite element theory, the finite element model of the airbag cushioning system is modeled by using the dynamic analysis software LS-DYNA in ANSYS, and the air bag cushion process is simulated by the corpuscular particle method. The simulated variation of airbag cushion height, cargo table acceleration meet the requirements of equipment airdrop overload. Compared with the traditional control volume method, the corpuscular particle method simulation is verified. The research results can provide reference for the engineering staff in the airbag design or reliability.

1. Introduction

Airbag cushion can effectively reduce the overload of impact. Therefore, it is widely used in large-sized equipment airdrop. Cushion airbags mainly rely on their own compression or discharge gas to absorb impact energy during landing process [1]. In this paper, the simulation technology has been used in an exhaust type cylindrical airbag to analysis its cushion characteristics.

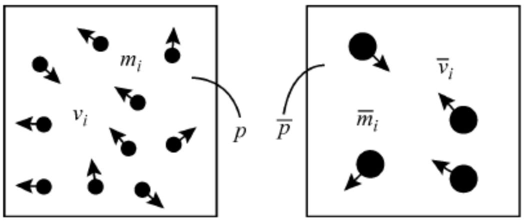
In landing process of equipment airdrop, airbag need to ensure that the overload and landing speed is less than the specified index, so the verification of the airbag is needed. However, airdrop test is hardly to do comprehensive and accurate test to every kind of condition. With the development of computer technology, modeling and Simulation of airbag is mature gradually, it provides a flexible and convenient way for the engineering staff in research of airbag cushion characteristics. At present, the control volume method (CV) is used widely in the airbag simulation field, this paper attempts to use the recently developed corpuscular particle method (CPM) to model the airbag, analysis its cushion characteristics and compare it with traditional method.

2. Theory of Corpuscular Particle Method

The static gas pressure in a volume V is a direct function of the total translational kinetic energy of the molecules in the gas. The pressure p is built up by molecules colliding with the boundary of the volume. There are typically 10^{23}-10^{24} molecules in an inflated airbag and one can not treat each and every one of them individually in a numerical model.

The corpuscular particle method (CPM) in LS-DYNA for airbag simulations is unique in that it stays with a corpuscular modeling of the gas flow. That is, the gas is modeled as a set of individual particles. This has been made possible by letting each particle represent many molecules. The expected pressure is matched by ensuring that the total translational kinetic energy of the particles is correct [2].

In Fig.1, m_i is the quality of specific volume of any gas molecules i; v_i is the specific volume of any gas molecule speed of i; W_k is the total average kinetic energy of gas molecule in specific volume; N_m is the total number of gas molecule in specific volume; p is a gas pressure for molecular form in specific volume; $\overline{m}_i$ is the quality of any gas particle i in specific volume; $\overline{v}_i$ is the velocity of any gas particle i in specific volume; $\overline{W}_k$ is the total average kinetic energy of gas particle in specific volume; N_p is the total number of gas particle in specific volume; $\overline{p}$ is a gas pressure for particle form in specific volume.



$$W_k = \frac{1}{2}\sum_{i=1}^{N_m} m_i v_i^2 \qquad \overline{W}_k = \frac{1}{2}\sum_{i=1}^{N_p} \overline{m}_i \overline{v}_i^2$$

$$\overline{W}_k = W_k \Rightarrow \overline{p} = p$$

Fig. 1 Corpuscular particle method

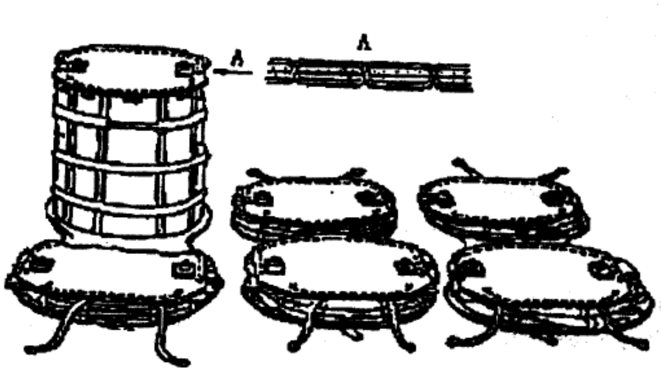


Fig. 2 Air shock absorber

3. Model of Cushion System

The cushioning system includes a cargo table and the air shock absorber. as shown in Fig.2. The airbag is composed of two layers of silk cotton canvas and only has one air chamber. Air inlet is at the bottom, it can automatically inflate during the airdrop process, when the airbag contact land, inlet is closed down. The vent hole is positioned on the upper part of the side wall of the airbag, attached by a velcro, When the inner and outer pressure difference of the airbag is higher than the combining force, the vent hole is opened. The pressure difference is set to 0.5atm. The model of the cushion system is established in the dynamic analysis software LS-DYNA. LS-DYNA has excellent performance in solving the problem of large deformation and large displacement.

3.1 Structural parameters of the model of the cushion system.

For the purpose of saving computing time, a single airbag is modeled according to the symmetry principle, simplify the goods and the table to a rigid mass (SOLID 164), fully constrained rigid surface (SHELL 163) is used in the ground, and the RIGID material is used in all of them.

Airbag element type select the SHELL 163 element, defined as the three node Belytschko-Tsay fully integrated film element [3], a three-dimensional model of air bag and vent holes is established. Since the SHELL 163 element can only be given to face, so remove the entity, keep the surface of the model. The mesh is divided, for the airbag, the tetrahedral free grid is adopted in the form of the mesh. The whole cushion system model is divided into 4270 elements, as shown in Fig.3.

Gravity environment, initial speed and constraints are imposed to the model. Contact between the equipment and the airbag, airbag and the ground is selected as the Surface to Surface_Automatic (ASTS). The control calculation time is 0.3s, the time step is 0.005s, the hourglass is controlled to 10%, and the final completion of the model is written in K file format.

3.2 Airbag model keyword parameter setting.

Keyword definition is required for the detailed parameter settings for the airbag, This step is finished in the LS-PrePost which is the pre and post processing software of LS-DYNA. Air bag material is defined as 34 orthotropic fabric material (*MAT_FABRIC), and the density is 876 kg/m^3. The key word *CONSTRAINED_EXTRA_NODES_SET is used to complete the connection of the equipment and the surface of the air bag [4].

The *AIRBAG_PARTICLE keyword is used to define the airbag when CPM is used to simulate. Among them, considering the volume of the air bag, the number of particles is set to 1e5, Unit is set to the SI-units, molar mass of gas is 0.029kg, constant heat capacity parameter is 29.04J/mol·K, The internal and outer pressure difference of the exhaust gas (*AIRBAG_PARTICLE_PPOP) is 5e4 Pa. *AIRBAG_PARTICLE_IAIR is set to 2, that is, the initial gas bag using particle method for calculation, if set to 1, it is still using the traditional control volume method (CV) [5].

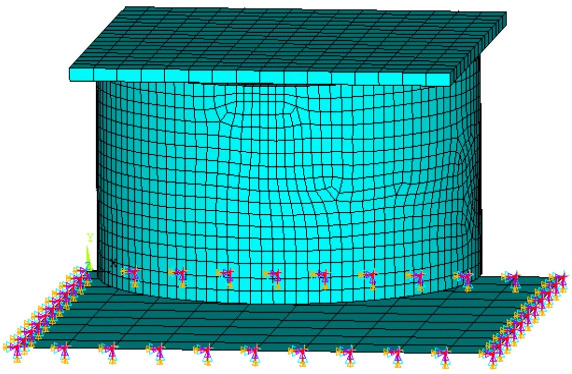


Fig. 3 Corpuscular particle method

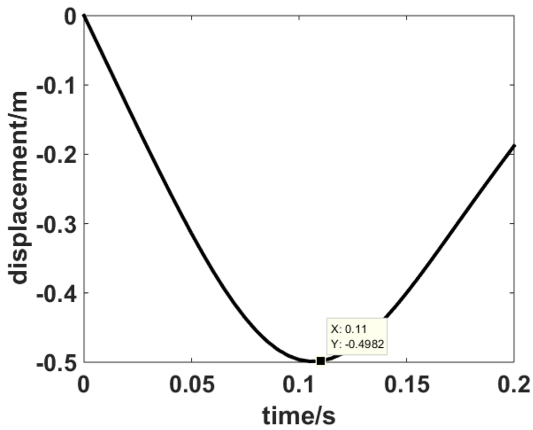


Fig. 4 Displacement of equipment

4. Analysis of Simulation Result

The K file is solved by LS-DYNA Solver, time consuming 1h45min, the calculation process of the solver gives the time for the opening of the airbag vent hole is 63.4ms. The characteristic curves of the equipment during the landing process were extracted and shown in Fig.4-6.

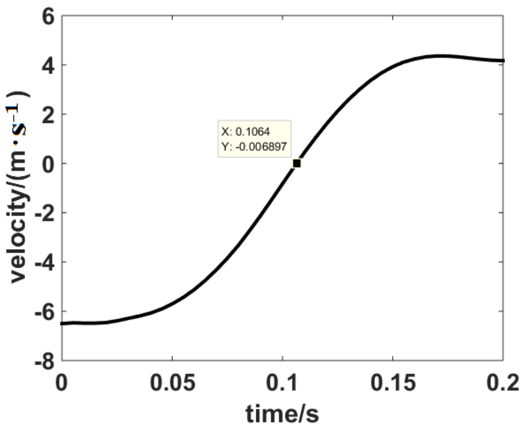


Fig. 5 Velocity of equipment

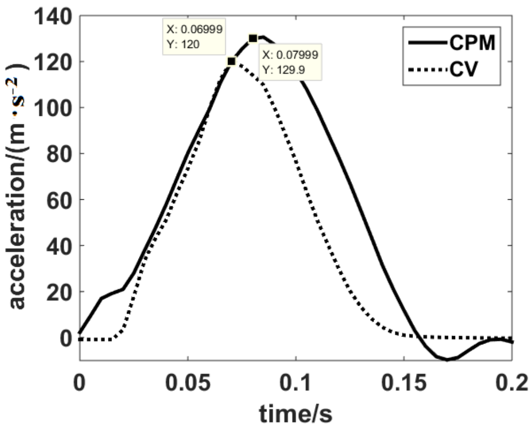


Fig. 6 Acceleration of equipment with two methods

As can be seen from the calculation results, the landing cushion time is about 0.2s. Airbag began to buffer when it contact the ground, at this time the compressed airbag pressure is slightly higher than atmospheric pressure, lower than the exhaust pressure. As the air bag is compressed, the internal pressure is getting higher and higher, and the equipment is falling more slowly. In 63.4ms, internal pressure is 0.5atm higher than the atmospheric pressure, the vent hole has open and start the exhaust. In 110ms, the remaining height of the airbag is compressed to 0.5m, and the equipment speed is reduced to 0m/s, which starts to rebound, and in the whole cushioning process, equipment and airbag has a significant rebound. The acceleration curve given in Fig.6 show that the equipment has a maximum overload 13g in 80ms with CPM, satisfies the technical requirements of equipment airdrop overload (20g).

The CPM is compared with the traditional CV method. The landing impact acceleration curve of two methods is given in Fig.6, two simulation results at three different time are compared in Table 1. By comparing the results we can know that the two methods of impact acceleration curve of the trend of the consistency is good, all the time simulation results also have a high degree of consistency. Table 2 lists two methods of the vent hole open time and the maximum overload calculation results, the error is 10.7% and 8.3%, therefore, using CPM method to simulate the cushion airbag meet the needs of Engineering analysis.

Table 1 Compare of two methods

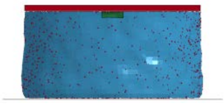
Time/s	CV	CPM
0.03		
0.07		
0.12		

Table 2 error analysis

	Time to open the hole/ms	maximum overload/m·s^{-2}
CV	70.97	120.0
CPM	63.40	129.9
error	10.7%	8.3%

5. Conclusions

In this paper, a finite element model of exhaust air cushion airbag is established, and the numerical simulation is made by using the corpuscular particle method, the curves of displacement, velocity and acceleration in the landing process are calculated. The corpuscular particle method is compared with the traditional control volume method, the error of the two main parameters of the maximum overload and the open time of the vent hole are obtained, the corpuscular particle method is proved to meet the needs of engineering analysis. Research on the acceleration of the equipment landing impact by the corpuscular particle method indicated that the maximum overload in the process of landing by the cylinder type exhaust type airbag is 13g, satisfies the technical requirements of equipment airdrop overload.

6. References

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