# CALCULATION OF VERTICAL STIFFNESS OF AIR SPRING WITH FEM

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ABSTRACT –Finite element method (FEM) was introduced to analyze vertical stiffness of air spring because of traditional method's limitation. Taking a rubber air spring as an example, the preprocess work was done in the ANSA software and then solved in ABAQUS software. According to comparison of results between numerical simulation and experimental method, it shows that the numerical simulation method is feasible and effective for simulating the inflation process of rubber air spring, and calculating the vertical stiffness.

## 1 INTRODUCTION

Air spring was invented by John Lewis in 1847[1]. Due to the excellent feature of air spring in vibration control, the air spring has drawn a lot of attention. It was widely used in rail transport, aviation, machinery and other industry areas. The vertical stiffness of air spring is one of the core parameters in air spring design, theoretical calculations and experimental test are often used to obtain the vertical stiffness. Theoretical calculations mainly include analytical and graphic methods which are considered as a complicated process and lack precision [2]; on the other hand, to gain the vertical stiffness by experiment can achieve the exact value, however, it would be a long-time-consuming process. Fortunately, with the development of finite element method (FEM) and computer science the vertical stiffness of air spring can be obtained more feasibly and effectively.
Air spring is a kind of nonmetal spring, and it can be classified into three categories, such as pellicle, ballonet and others in China [3]. Air spring is widely being used in many domains in virtue of its excellent elastic characteristic. And the main features of air spring are as follows [4]:

1) Working altitude can be adjusted momentarily;
2) Due to the nonlinear characteristics, the Eigen curve can be designed feasibly;
3) Absorbing the high and lower frequency vibration and reducing the noise;
4) Damp parameters can be modified by amending some design.

In this study, the finite element analysis was introduced to research the vertical stiffness of rubber air spring, the preprocess work was done in the ANSA software and solved in ABAQUS software [5].

## 2 FINITE ELEMENT METHODS FOR AIR SPRING ANALYSIS

In the finite-element method, a distributed physical system to be analyzed is divided into a number (often large) of discrete elements. The complete system may be complex and irregularly shaped, but the individual elements are easy to analyze. Once the element matrices have been calculated, they are all combined together into one large matrix representing the whole complex system. By considering the boundary conditions and outside force, the equation KU=F can be solved using one of a variety of techniques, such as Gauss-Jordan elimination.
For the air spring analysis, the core techniques mainly focus on the following two points, which lie in the simulation of the air or air boundary and the complex preprocess especially the meshing design. Luckily, by using the commercial FEA code ABAQUS the simulation of air boundary in air bag can be done feasibly, and many powerful preprocess methods were supplied by another commercial software ANSA where the design ideal grids can be obtained.

## 3 Example

The axisymmetric model of air spring was shown in fig.1 where the different color means different materials, and the parameters of material were shown in table 1. In the partial enlargement the air bag lines also can be seen.

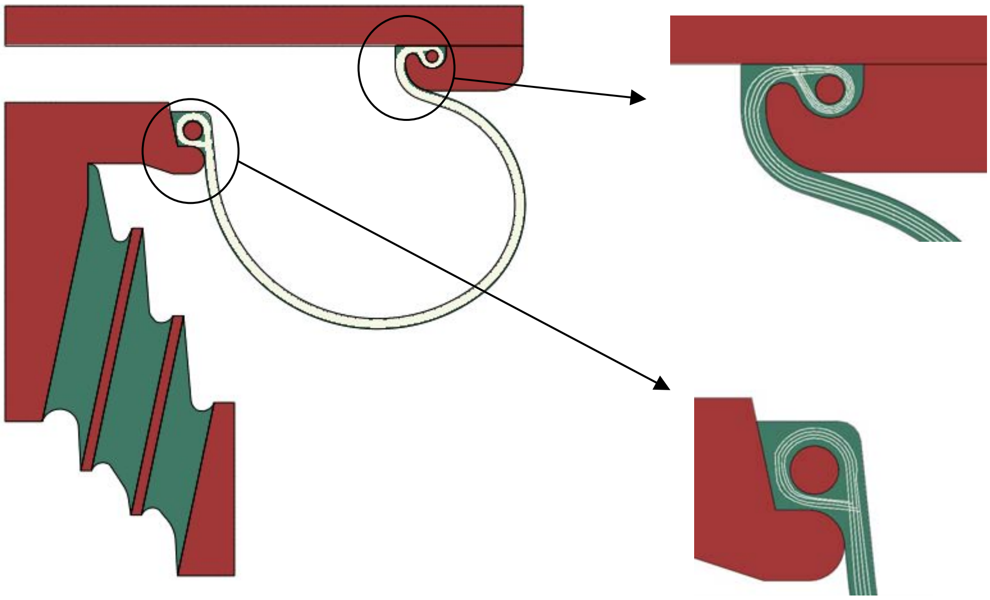

Fig.1 Axisymmetric model of air

Table 1 Material parameters

| Material | E (MPa) | V | $C_{01}$ | $C_{10}$ | D |
|---|---|---|---|---|---|
| Steel | 210000 | 0.3 | - | - | - |
| Line | 1500 | 0.4 | - | - | - |
| Rubber | - | - | 0.07 | 0.33 | 0.1 |

The operating condition mainly includes three steps as following:

1) Fixing the bottom of air spring;
2) Inflating little gas, and moving down the head plate 40mm;
3) Inflating gas until the reaction of head plate achieve 64KN;
4) Calculating the stiffness of model, when the head plate move down 10mm.

To simulate the gas in air bag, the share-nodes-technology was introduced in this study, which the solid element would share the boundary nodes with air boundary, as in Fig.2, the symmetry model of air boundary was shown. And in ABAQUS software the element type FAX 2 was elected which supply an additional degree 8 to evaluate the internal pressure of air bag. Besides, during the deformation of air bag, especially the rubber material deformed heavily, in order to calculate a correct and convergent result, the meshing work was done in the ANSA software which is a very powerful tool in preprocess.

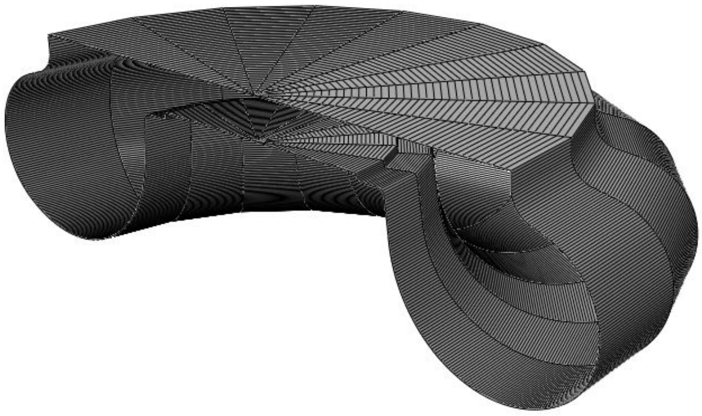

Fig.2 The symmetry model of air

The rubber deformed heavily while the head plate moving down, and the Von Mises stress of symmetry model was shown in Fig.3, the maximum stress is 74MPa.

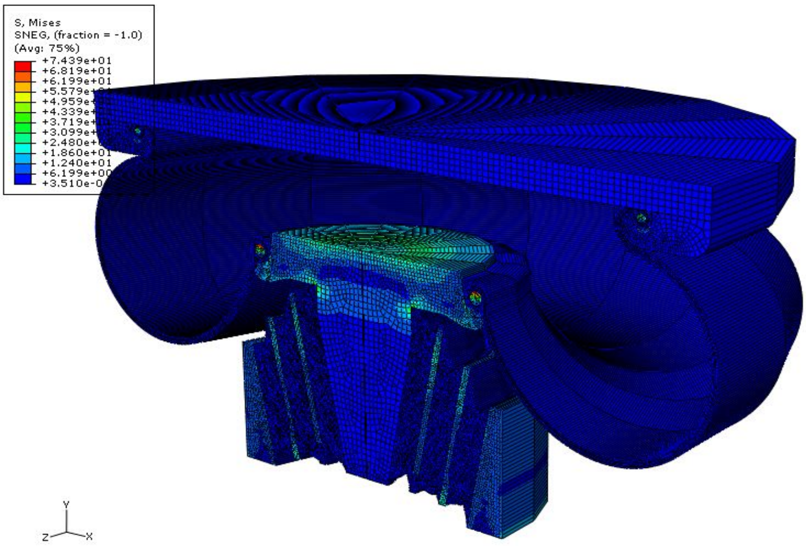


Fig.3 The Von Mises stress of symmetry

The displacement-reaction force relationship was shown in fig.4 (minus denotes reaction force), also the experiment result was included, by comparing the results between numerical simulation and experimental method, it shows that the vertical stiffness calculated by finite element method appears a little greater, which caused by the model idealization and the friction coefficient effluence.

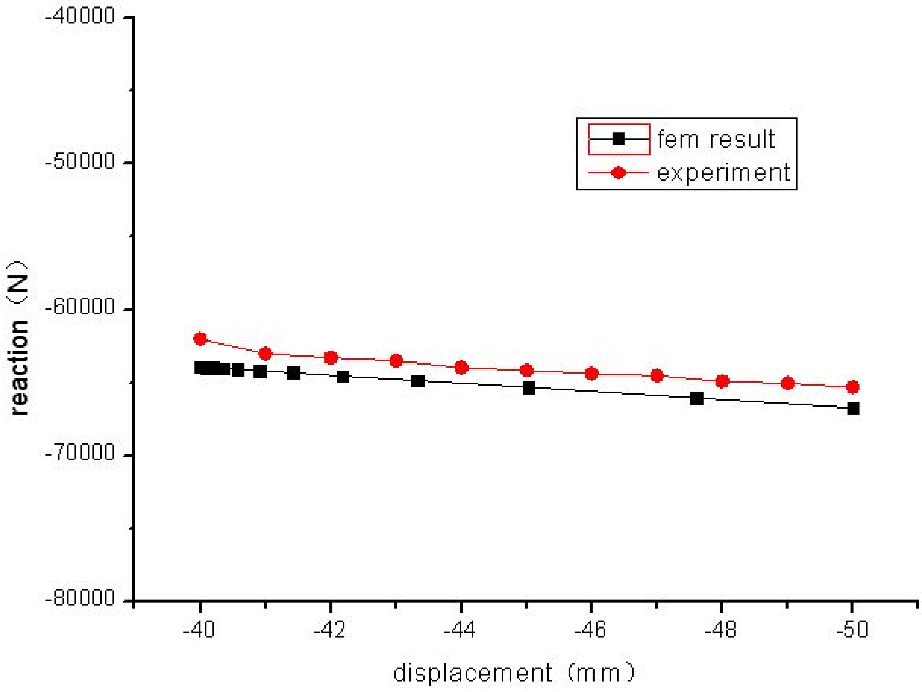


Fig.4 Displacement-reaction force relationship

## 4 CONCLUSIONS

Both finite element method and experimental test method were used for vertical stiffness calculation of air spring. According to comparison of results between those two methods, it shows that the test results and numerical simulation results are very similar, and the numerical simulation method is feasible and effective for simulating the inflation process of rubber air spring, and calculating the vertical stiffness.

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