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Vibration Modal Analysis of Landing Gear Based on ANSYS

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Abstract **Modal analysis is used to determine the vibration characteristics of the structure or machine part in the design, ie the natural frequency and mode. Modal analysis is a linearanalysis, which can be modal analysis of pre-stressed structures and modal analysis of cyclic symmetry structures. It is the starting point of harmonic analysis, transient dynamics analysis and harmonic analysis. Using ANSYS finite element analysis software, the A-10 attack aircraft air-craft landing gear as the research object, using the commonly used Block Lanczos method to calculate the landing gear fixed boundary conditions of the first four natural frequency and vibration mode are about 48Hz, Thus providing a reliable basis for the design and improvement of the landing gear.**

Keywords: A10 attack aircraft landing gear; Finite element method; Block Lanczos method; Modal analysis.

I. INTRODUCTION

The aircraft landing gear is the key force of the aircraft takeoff and landing, it not only bear the load when the aircraft takeoff and landing, but also to complete the aircraft running and steering, so landing gear is essential to the aircraft, to protect the aircraft landing Safety is necessary to protect the landing gear of the mechanical performance and service life[1-5], With the improvement of aircraft performance, the design of the landing gear also put forward higher requirements, not only requires sufficient strength and reasonable force, But also to try to be lightweight, in the cyclical changes in the dynamic load, the main components of the landing gear may be a strong resonance, The resulting dynamic stress and dynamic displacement will be several times under static load, or even ten times, seriously affecting the reliability of landing gear work [6]. Vibrating the worsening of a dynamic fatigue crack, which in turn causes the landing gear to break, causing a malfunction or crash [7]. Therefore, the modal analysis of the aircraft landing gear, get the natural frequency and mode of the landing gear, according to the analysis results to take measures to reduce the probability of landing gear resonance, thereby extending the life of landing gear to ensure flight safety. The modal analysis of the landing gear is related to the safety, comfort and reliability of the aircraft [8].

In this paper, the landing gear of the A-10 attack aircraft is used as the model. The finite element model of the landing gear is established by CATIA software. The ANSYS finite element analysis software has carried on the reasonable meshing and the modal analysis to the landing gear [10].

II. MATRIX ORTHOGONAL SOLUTION METHOD

In the theoretical modal analysis, the choice of a good solution method will improve the calculation speed and accuracy. Block Lanczos method eigenvalue solver is the provincial solver, which uses Block Lanczos algorithm, is a set of vectors to real block Lanczos recursive calculation. This method is as accurate as the subspace method, but is faster. Thus, for the same problem, the computational speed of the comparable subspace iterative method is nearly 10 times higher, and the eigenvalue eigenvector has higher accuracy and is a higher computational efficiency method [11].

$$P\psi_{n\times m} = N\psi_{n\times m}\Lambda_{m\times m} \quad (1)$$

Where: matrix $\psi_{m\times n}$ by m n-dimensional vectors; K is $n\times n$ order real symmetric positive definite matrix; N is a symmetrical array; Diagonal array

$$\Lambda_{m\times m} = dig(\omega^2_{11},\ \omega^2_{22},\cdots,\ \omega^2_{mm})$$

Called the spectral matrix, each of its diagonal elements corresponds to the square of the natural frequencies of the structural steps.

order $B = K^{-1}P$, $\lambda = 1/\Lambda_{m\times m}$,then equation (1) can be changed to:

$$B\psi_{n\times m} = \lambda\psi_{n\times m} \quad (2)$$

The basic idea of the Block Lanczos method for solving the B eigenvalue problem of order symmetric matrices is as follows: Determine an arbitrary unit vector q_1, A set of orthogonalization sequences is constructed through the Block Lanczos process $q_1,\ q_2,\cdots,\ q_n$. Order $Q = [q_1,\ q_2,\cdots,\ q_n]$, then $QBQ = L$, L For a symmetric three diagonal matrix. In the transformation

process , a series of symmetric three diagonal matrices are generated L.

Their lower order eigenvalues are getting closer to the lower order eigenvalues of the matrix B, the eigenvalue problem of such large-scale matrix B is transformed into the eigenvalue problem of small scale symmetric three diagonal matrices L.

Select the initial iteration vector q_1, And so $[q_1]^T q_1 = 1$, then: $Bq_1 = \alpha_1 q_1 + \beta_1 q_2$ Deformation available:

$$\beta_1 q_2 = Bq_1 - \alpha_1 q_1 \quad (3)$$

Where Are coefficients: α_1 , β_1 Coefficient.

use q_1 Dot product(3) Both sides, utilize $(q_1,\ q_2) = 0$ (That is $q_1,\ q_2$ orthogonal) can be obtained:

$$\alpha_1 = q^T_1 Bq_1 \quad (4)$$

record $r_1 = Bq_1 - \alpha_1 q_1$, and assume $r_1 \neq 0$, order $\beta_1 = \| r_1 \|_2$, into the type（3）available q_2 act as:

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$q_2 = r_1 / \| r_1 \|_2$

obviously q_2 unit vector.

The recursive process from above will produce q_i , α_i , β_i . The concrete calculation process is as follows:

$r_i = Bq_i - \alpha_i q_i - \beta_{i-1} q_{i-1}$ $\beta_0 q_0 = 0$

$\beta_i = \| r_i \|_2$

$q_{i+1} = r_i / \beta_i$ $(\beta_i \neq 0)$

$\alpha_{i+1} = q^T_{i+1} B q_{i+1}$ $(i = 1,2,\cdots,$ n-1)

from α_i and β_i the composition of the triangular matrix L is:

$$1)\quad L = \begin{bmatrix} \alpha_1 & \beta_1 & & & & \\ \beta_1 & \alpha_2 & \ddots & & & \\ & \ddots & \ddots & \ddots & & \\ & & \ddots & \ddots & \ddots & \\ & & & \ddots & \alpha_{n-1} & \beta_{n-1} \\ & & & & \beta_{n-1} & \alpha_n \end{bmatrix} \quad (5)$$

(6) Is the famous Block Lanczos iterative method where q_i is called the Block Lanczos vector, L is the Block Lanczos matrix.

Therefore from $Q^T BQ = L$ and Q the orthogonality is available

$BQ = QL$ （6）

Joint type（2）、（6）available:

$L(Q^T \psi_{n\times m}) = \lambda(Q^T \psi_{n\times m})$

order $Q^T \psi_{n\times m} = \phi_{n\times m}$, Then we can get the standard eigenvalue formula of the three diagonal matrix L in the Block Lanczos vector, $L\phi_{n\times m} = \lambda\phi_{n\times m}$, thus determining the eigenvalues and eigenvectors. The actual calculation shows that the Block Lanczos method has higher computational accuracy and efficiency than the subspace iterative method. The computational workload is greatly reduced, especially when calculating the dynamic response of the structure, there is often a higher convergence rate [7]. Therefore, the finite element modal calculation is carried out by Block Lanczos method.

III. LANDING GEAR FINITE ELEMENT MODEL ESTABLISHMENT

A-10 attack aircraft landing gear finite element model of the establishment of rocker landing gear mainly by the shock absorber, retractable rod, cylinder, upper and lower shear arm, wheel and brake devices and other components. A-10 attack aircraft before and after landing gear see Figure 1. Abbreviations and Acronyms

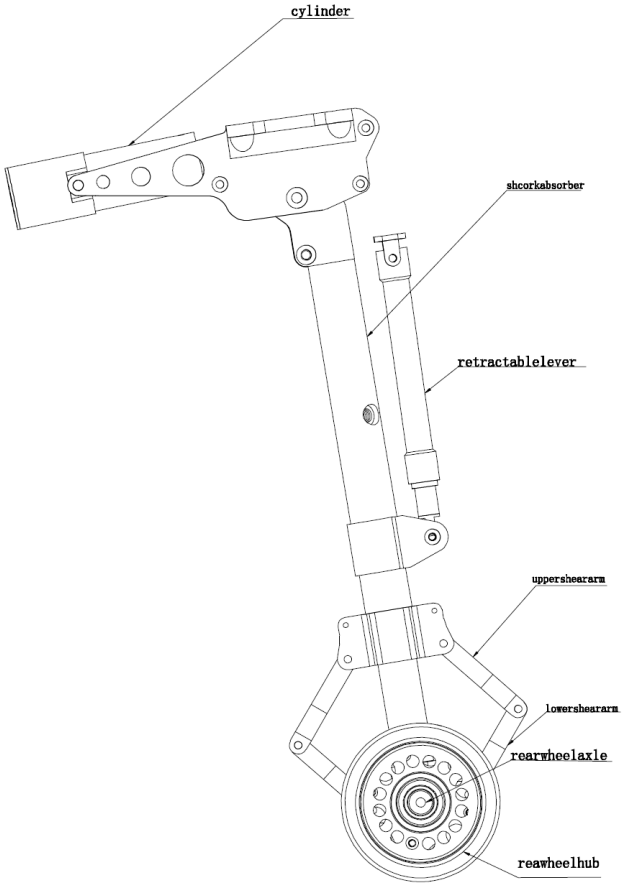

Figure 1 landing gear

The three-dimensional solid model of landing gear is established in CATIA environment and then imported into ANSYS finite element software. As the landing gear structure is complex, the various parts of the distribution of many small chamfer, rounded corners and a variety of bolt link holes, according to the characteristics of finite element analysis so do not have to simplify the manage. In the definition of material properties to pay special attention to the physical unit of the same, because CATIA modeling using mm units, import the ANSYS model of the length of the unit is mm, that is, the $^{ela}_{sti}$ $E = 2\times10^5 MPa$, Poisson's ratio $\mu = 0.3$, density $\rho = 7850kg / m^3$.

Because CATIA and ANSYS have good compatibility, the landing gear CATIA model into ANSYS after the various components will maintain the original assembly relationship, the assembly is relatively easy to generate. According to the relationship between the components and the association

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between the use of split geometric elements in the operation of the various methods of the various components of the division, the process of segmentation in strict accordance with the size of the measurement data, and set the tie command constraints, helps to eliminate rigid body displacement, and greatly reduces the need to calculate the contact state of the iteration; set the boundary conditions, the front brackets, brackets and front bracket is fully fixed.

When dividing a grid, use the smallest unit and the Relevance Center to Fine. First, the element are divided into more regular parts, when the partition to set the global seed size, and in the key parts of the definition of local seeds in order to refine the grid, and finally get the total number of nodes 222971, the total number of 119552 units. The results are shown in Figure 2

Figure 2 Grid results

IV. CALCULATE THE RESULTS AND ANALYSIS

According to past experience, when the structure resonates under dynamic load excitation, there are generally only a few low-order (2 000 Hz)resonance conditions , so it is often necessary to know several natural frequencies and formation when performing vibration analysis, without having to find out all the natural frequency and formation. Therefore, the Lanczos method can be used to extract the first four order modes when the analysis step is set, and the first four natural frequencies obtained are shown in table 1.

Table 1

modal	natural frequency Hz	shape description
1	21.140	bending vibration
2	52.311	twist and swing
3	57.647	torsional vibration
4	69.095	bending and twisting

Landing gears before the fourth-order natural frequency modes natural frequency / Hz Mode description Bending and twisting 69.05Hz, bending vibration 43.72Hz, torsion and swing Hz 52.30Torsional vibration 57.64Hz By bending and twisting the extraction of the order includes low order,middle Order and the highest step mode shown in Figure 3to Figure 5 shows.

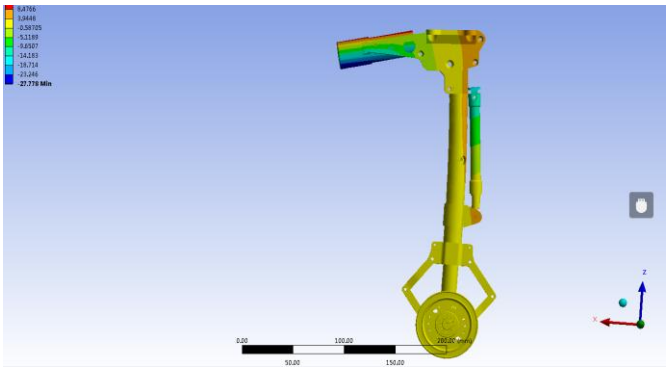

Figure 3 bending vibration

The first stage vibration mode (21.140Hz) mainly manifests as the bending vibration of the whole of the landing gear, the amplitude of the buffer, the pillar and so on, the vibration of the wheel part is the largest, and the back of the bracket is asymmetrical bending vibration.

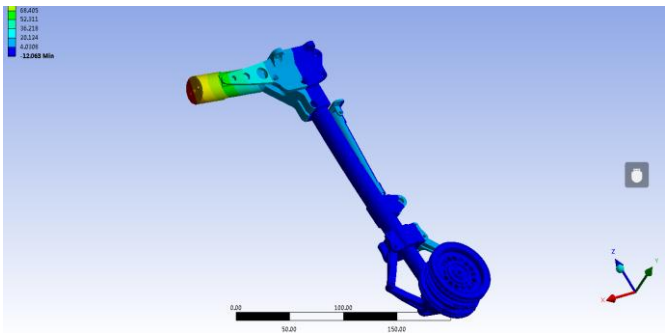

Figure 4 torsion and swing

The second-order mode (52.311Hz) mainly shows the vibration of the landing gear torsion and swing (along the Z direction), the amplitude of the rocker and the wheel is larger, the front pole and the bracket do the bending vibration, the amplitude of the front bracket vibration small.

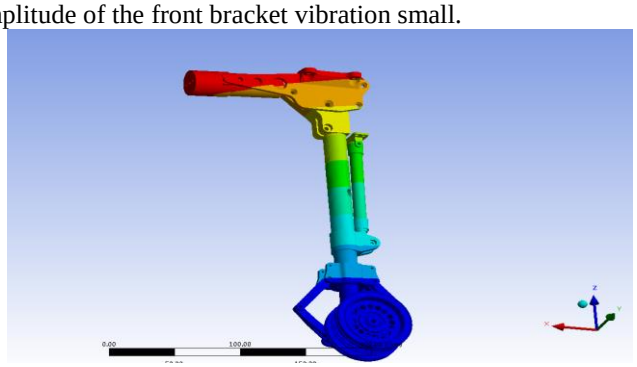

Figure 5 bend and twist

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The fourth stage vibration mode (69.095Hz) mainly shows the coupling vibration of the landing gear as a whole and the bending vibration of the crankshaft and the crankshaft. The torsional movement, the buffer and the rocker joint near the top of the pillar The largest amplitude.

V. CONCLUSION

In this paper, ANSYS finite element modal analysis is carried out on the aircraft landing gear. The first four natural frequencies and modes are obtained and compared with the brake vibration test. The following conclusions are obtained. 1) The whole landing gear system is more complex, the performance of the pillars, brackets and rocker parts such as complex bending, twisting and swing, and the direction, amplitude, etc. are different.

2) The dynamic characteristics of the landing gear can be seen through the vibration pattern of the landing gear, which provides a theoretical basis for the further improvement of the landing gear structure.

3) The inherent frequency of the landing gear is about 48Hz, so the excitation frequency should be kept away from the natural frequency of the landing gear, so as to prevent the resonance phenomenon from occurring and ensure the safe and smooth operation of the landing gear.

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