Application In Communication Equipments  Antiseismic 
Time History Analysis Based on Advanced Mass Scaling

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Abstract: RADIOSS is a powerful and stable explicit non-linear finite element analysis (FEA) solver in Altair HyperWorks. In this paper, the seismic time history analysis of communication equipment based on RADIOSS solver was taken as the research object. In the numerical simulation, three methods were applied in the computational efficiency enhancement: the non-timestep control method, the traditional mass scaling technology, and the advanced mass scaling technology (AMS). Calculations prove that the AMS technology in RADIOSS can not only improve the solution efficiency, but also garantue the calculation accuracy in antiseismic time history analysis.

Key words: communication equipiments, antiseismic analysis, RADIOSS, AMS

1. Overview
Computers, the Internet, cloud computing, the Internet of Things, big data and other new information technologies provide strong support for the current booming economy. However, unpredictable and highly destructive earthquake disasters greatly threaten data security. Once communication is interrupted, data loss will have inestimable consequences. The high-stability, high-reliability, and high-economical data storage capabilities are receiving more and more attention from designers, operators, and customers [1]. At this stage, earthquake prediction is still in the research stage with few results. In order to resist and mitigate earthquake disasters and reduce the economic loss caused by communication interruption, it is necessary to carry out structural seismic analysis of communication equipment.

When the communication equipment structure is subjected to seismic load, the nonlinear problem of structural damage is prominent. At present, the response spectrum analysis method commonly used in the world is limited to linear elastic structures. The time-history analysis method used in this
analysis can obtain each instantaneous Internal force and displacement response, in order to observe the change of internal force of the structure from elastic to inelastic under the action of earthquake, and the whole process of cracking and damage of the component to the collapse of the structure[2]. The time-history analysis method considers the effect of ground motion as a vibration process, which takes into account both the intensity of the ground motion and the frequency spectrum characteristics and duration, so that the structural seismic response analysis is in the dynamic analysis stage, so that the analysis process and results are more Appropriate to the actual situation.

The technical bottleneck that restricts the application of explicit non-linear time-history analysis technology in the seismic analysis of communication equipment structures lies in its analysis time and the time spent on it based on this. Different from other typical fields of application of explicit non-linear time-history analysis technology (such as car collision, penetration and detonation, etc.), the load acceleration time characterizing the input of acceleration signals of seismic waves is usually about 20-30 seconds. Longer load durations, the existence of critical time steps, and the more complex geometry of communication equipment often lead to computational hardware resource consumption and time consumption exceeding the limit, which results in the failure of analysis. Therefore, there is an urgent need to find practical and effective technical means to greatly improve the efficiency of the seismic analysis of communication equipment on the premise of ensuring that the calculation accuracy is accurate and reliable[3]. In this paper, the anti-seismic time history analysis of communication equipment based on the RADIOSS solver is taken as the research object. The non-accelerated solution technology, the traditional forced time-step accelerated solution technology, and the advanced mass scaling solution technology (Advanced Mass Scaling (AMS)) to improve computing performance and its impact on computing accuracy. Numerical simulation results show that the calculation model constructed using advanced mass scaling solution technology maintains a high degree of consistency with the original model without the addition of time step control, and its calculation efficiency has been greatly improved.

2. Seismic time-history analysis of gantry

2.1 Mesh of gantry structure
The analysis of this paper is carried out by using hanging gantry for a communication equipment (hereinafter referred to as gantry) as the carrier. The structure of the gantry see Figure.1. The equipment consists of upright, base and beam. And it is installed to the C shape channel by using 4 M12 bolts. The C shape channel is installed to the shaker table by using 4 M16 bolts.
Figure 1. The structure of the gantry

According to the test sample, in Altair HyperMesh 2017, a large-scale general finite element preprocessing software, a finite element model for seismic time-history analysis of gantry was constructed based on RADIOSS 2017 solver. The upright, base, beam and the fixture channel steel were subdivided with an average unit size of 5mm, see Figure.2. The two-dimensional element P1 SHELL was used for discretization, and 5 integration points were set in the thickness direction to ensure the calculation accuracy[4]. Connection bolt is simulated by P3 BEAM unit and the effect of preload is considered. Potential contact positions exist between the column and the base, and the contact pair is established based on the contact model of RADIOSS Type 7, and the influence of friction is taken into account. A total of 35,774 elements were obtained through mesh generation.

Figure 2. Two-dimensional element P1 SHELL was used for discretization

2.2 Material and property
The gantry is made of steel and simulated by the /MAT/LAW2 constitutive model in RADIOSS. Relevant parameters of the model are shown in table1.
Table 1. Johnson-Cook constitutive model parameters

| No. | Parameter         | Item                  | Numerical value   |
|-----|-------------------|-----------------------|-------------------|
| 1   | [Rho\_Initial]   | Density               | 7.85e-6 Kg/mm³    |
| 2   | [E]               | Modulus of Elasticity | 210 GPa           |
| 3   | [nu]              | Poisson's ratio       | 0.33              |
| 4   | [a]               | Yield strength        | 0.206 GPa         |
| 5   | [b]               | Hardening parameter   | 0.450 GPa         |
| 6   | [n]               | Hardening exponent    | 0.5               |

2.3 Load and boundary conditions
The standard seismic wave acceleration time-history load is applied to the gantry bolt holes connected to the shaking table at the bottom of the channel steel along the z-axis of the global coordinate system[5]. And the translational degrees of freedom of the bolt holes along the X-axis and Y-axis of the global coordinate system are constrained. The seismic wave curve see Figure 3. Take its first 20 seconds as input. The maximum of the peak acceleration along the z-axis of the global coordinate system is 0.664g in the positive direction, and 0.736g in the negative direction along the z-axis of the global coordinate system.

2.4 Postprocessing of animation result
In Altair HyperView 2017, the animation results of the gantry structure were processed. In the previous solution, the output interval of the animation result was set in RADIOSS Engine File to 0.5 seconds (/ANIM/DT). The RADIOSS animation result post-processing file (A0n) comes to 41 frames. As shown in Figure 4, the displacement cloud diagram of the gantry structure at 5 seconds, 10 seconds, 15 seconds and 20 seconds is given[6]. Under the action of seismic wave load, the motion form of the structure can be described as reciprocating vibration around its original position. The relevant time history results will be discussed in detail in section 3.
Figure 4. The displacement cloud diagram of the gantry structure

3. Application of AMS technique in seismic time-history analysis of gantry structure

3.1 Explicit analysis time step control technique

In explicit nonlinear time history analysis, the central difference method is usually used to discretize the time domain, and the differential equation is transformed into a difference equation. Velocity and acceleration are obtained by using finite difference instead of displacement derivative with respect to time. This method avoids solving simultaneous equations by diagonalizing the mass matrix, thus occupies less memory space and has no convergence problem. However, in order to ensure the stability of numerical solution, the time step of model calculation should be less than or equal to the critical time step of model.

The critical time step of the model is determined by the element corresponding to the characteristic side length of the minimum element in the model and its corresponding material properties. As shown in formula 3-1 and 3-2, where \( l \) is the characteristic side length of the element, \( c \) is wave velocity, \( E \) is modulus of elasticity, \( \rho \) is density.

\[
\Delta t = \frac{l}{c} \tag{1}
\]

\[
c = \sqrt{\frac{E}{\rho}} \tag{2}
\]
In the modeling process of communication gantry, due to the inherent limitations of finite element modeling technology, it is obviously impossible to control the characteristic edge length of all elements to the same value. In order to ensure the stability of numerical calculation, the current time step is required to be determined according to the minimum time step of all the current elements. If we want to improve the efficiency of model calculation, we need to modify the critical time step of the system. After the modeling work is completed, the shape and connection relationship of the element are determined, so we cannot effectively modify the characteristic edge length of the element. The modification of elastic modulus can affect the critical time step of a certain element, but this modification will bring the instability of numerical calculation, so we usually choose to modify the density of a single element to achieve the amplification of time step. As mentioned above, the critical time step is proportional to the square root of the element density, that is, under the condition of fixing other parameters, the calculated time step of the element increases by two times for each four times of the density of the corresponding element.

3.2 Results verification comparison
The T01 file of the gantry structure is processed in the post-processing tool Altair Hyper Graph 2017. The relative deformation of the top relative to the bottom is the most concerned performance index of the communication cabinet equipment with the longmen frame as the typical representative. As shown in Figure 5, the calculation results of without time step correction technology, 2.5E-07 fixed time step (mm-ton-s-mpa system of units is adopted in the model system) and 5.0E-06 time step based on AMS technology are given.

![Figure 5](image)

**Figure 5.** The T01 file of the gantry structure is processed in the post-processing tool Altair Hyper Graph 2017.

3.3 Comparison of solution error and calculated resource
The model uses Intel(R) Core(TM) i7-7700hq CPU @2.80ghz, 32g physical memory and 1T hard disk storage space workstation for calculation. Table 2 shows the comparison of the calculation results of the three acceleration schemes.

| Scheme | Maximum Relative Deformation (mm) |
|--------|-----------------------------------|
| AMS    | 2.5E-07                           |
| CST    | 5.0E-06                           |
| No time step correction | 1.0E-06 |

**Table 2.** The calculation results of the three acceleration schemes
| Model occupation and calculated resource consumption | No time step control | CST | AMS |
|----------------------------------------------------|----------------------|-----|-----|
| Time step(second)                                  | 2.24E-07             | 2.5E-07 | 5E-06 |
| Model mass gain                                    | -                    | 0.07% | 0.00% |
| Calculation time(hour)                             | 313.5                | 302.6 | 17.0 |
| Solution error compared with no time step control  | -                    | 3.37% | 0.26% |

4. Analysis and conclusion

The technical bottleneck of seismic time-history analysis of communication equipment lies in its extremely long computing time and the huge consumption of hardware resources. Different from other typical applications of explicit nonlinear time-history analysis (such as vehicle collision simulation, on the millisecond to second scale and simulation of penetration and detonation in milliseconds), the seismic time-history analysis of communication equipment is located in a segment of the order of 10 seconds (typical seismic wave load: 20s~30s). The traditional mass scaling technique can improve the computational efficiency of seismic analysis to some extent, however, the additional mass gain it introduces, in seismic analysis, a special analysis occasion, in the calculation time of 20 seconds or longer, will bring a lot of accumulated errors, and even cause the divergence of calculation results, ultimately leading to solution failure. The explicit nonlinear time history analysis calculation step length can be greatly improved on the premise of not introducing additional quality gain because of the explicit nonlinear solver RADIOSS unique technology AMS. Reasonable setting of AMS parameters can improve the computing efficiency by 5 to 20 times on the premise of ensuring the calculation accuracy. It has a very broad application prospect in the field of seismic time-history analysis of communication equipment.

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