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Research on Deformation Control Technology of Back Plate Based on Vibration Aging

Zhongyuan Guo[a], Yan Feng[b], Changgang Nai[c], Lan Ding[d]

Beijing Aerospace Ginseng Machinery Equipment Co., Ltd, Beijing 100050, China

[a]guozhongyuan@live.com, [b]1834069586@qq.com, [c]569526060@qq.com, [d]840181397@qq.com

Abstract. This paper takes the back plate as the research object, uses finite element simulation and vibration aging to predict and control the deformation of back plate. First, analyze the deformation characteristics of the back plate combined with processing practice, and detect the residual stress before the vibration aging. Second, determine the vibration aging parameters by finite element method. Last, verify the simulation results by trial machining. This study shows that the finite element analysis method is feasible to determine the vibration aging parameters, and provides a reference for the deformation control of plate parts.

1. Introduction

With the rapid development of modern technology, weapons are becoming increasingly sophisticated, lightweight and highly reinforced. In order to meet the requirements of high level weaponry, research needs to be further conducted in terms of material selection, structural design and deformation control. As the installation of precision parts in some key model, the dimension accuracy of back plate directly determines the positioning accuracy of the weapon equipment, so to predict and control the deformation of the back plate has practical engineering value.

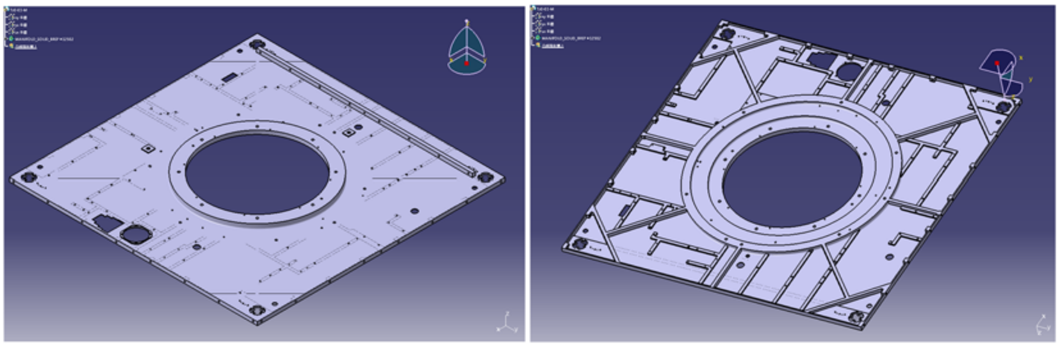
This paper intends to use vibration aging to control the residual stress of the back plate, and through the method of finite element analysis to predicte the parameter design of vibration aging, so as to guide the implementation process of vibration aging.

2. Deformation and analysis

2.1. Introduction of back plate

The back plate is a typical flat plate type thin-wall part, it is mainly composed of middle step whole, back reinforcement bar, rectangular table and convex platform. Its 3d model is shown in figure. 1.

In the design, in order to ensure the bearing strength of the back plate and meet the requirements of lightweight weapons, it select aluminum forgings as blank for the back plate, with the brand number of 2A12, T4 status.



a) Front view b) Back view

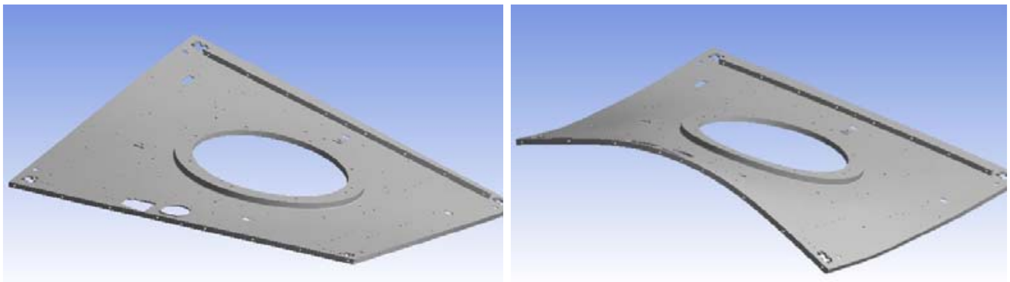
Figure 1. Back plate 3d model

2.2. *Deformation characteristics*

In view of the deformation of the back plate, several trial-manufacture processes were carried out. According to the detection statistics, there are two main deformation modes of the back floor. The deformation is shown in figure 2.

a) Torsional deformation. Clockwise or counterclockwise torsional deformation occurs on the side parallel to and away from the convex platform.

b) Bending deformation. Convex or concave bending deformation occurs on the side parallel and away from the side of the convex platform.



a) Torsional deformation b) Bending deformation

Figure 2. Deformation characteristics

2.3. *Deformation analysis*

According to the processing experience and literature review, the internal residual stress is the main cause of part deformation, and rough machining has a great impact on the residual stress [1]. So in this paper, in order to solve the above two deformation problems, selecting X ray method to detect the residual stress of parts.

In this paper, we design 22 measuring points at the deformation position of the back plate. The measuring point positions are shown in figure 3. Each measuring point position measures stress in three directions. Parallel to the convex platform specific length direction as a measure of 0° stress direction, vertical convex platform specific length direction as 90° stress direction, the specific measurement data shown in figure 4.

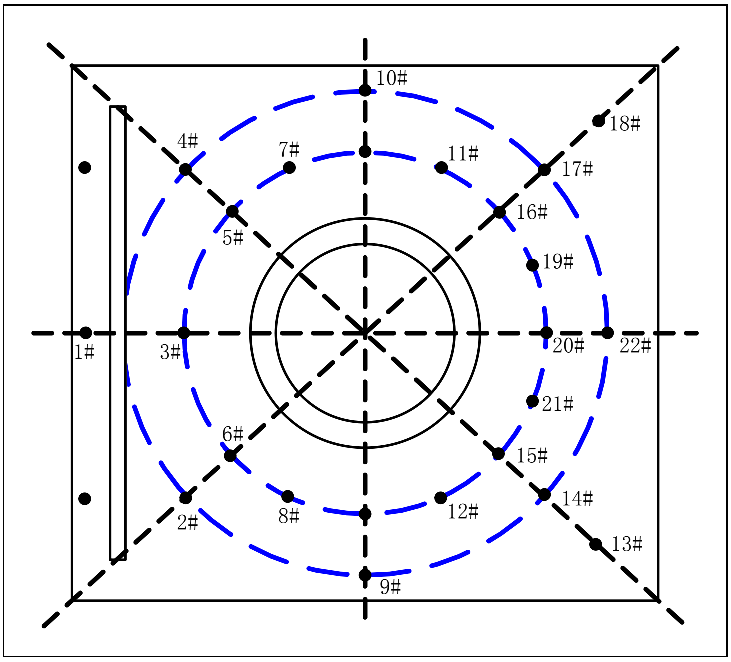


Figure 3. Measuring point positions

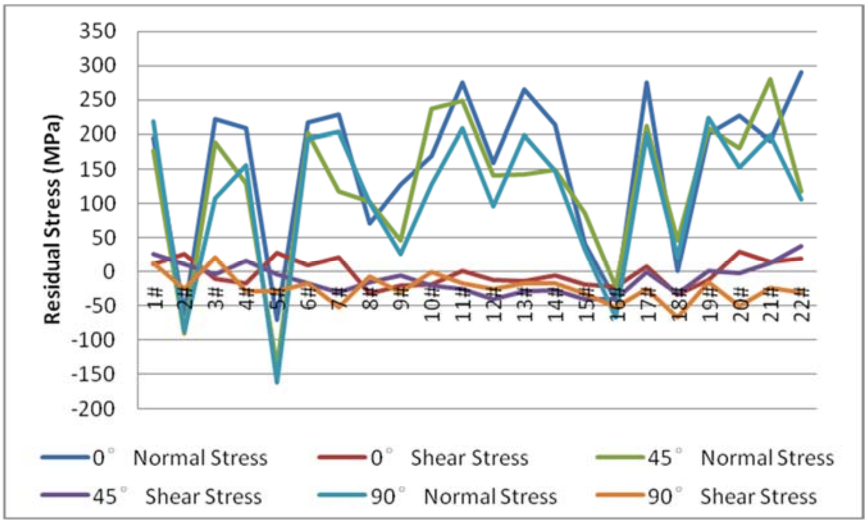


Figure 4. Measurement data before vibration aging

3. Determination of vibration aging parameters

3.1. Establish the finite element simulation model

Establish the 3d structure model according to the rough machining state of the back plate, as shown in figure 5. In addition, select hexahedral grids with good accuracy and high efficiency to grid division, the number of grids divided is 66206, as shown in figure 6.

In this paper, according to the processing environment, selecting physical parameters and mechanical properties parameters as calculation data in 20°C, the specific parameters are shown in table 1.

IOP Conf. Series: Earth and Environmental Science **252** (2019) 022118 doi:10.1088/1755-1315/252/2/022118

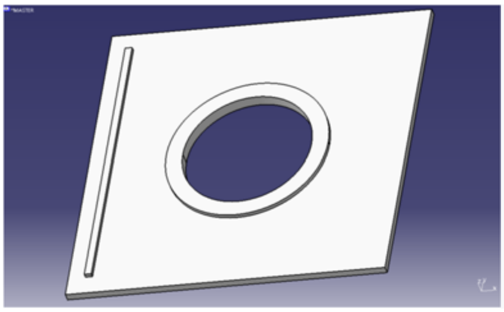


Figure 5. The rough machining model

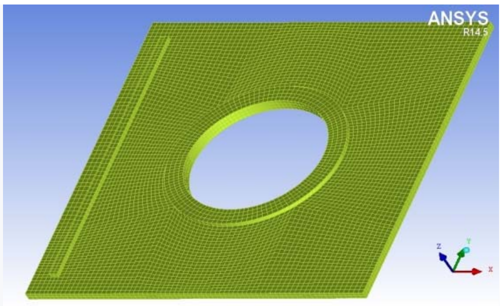


Figure 6. Computational grid

Table 1. Materials calculating parameter

Density	Thermal Conductivity	Specific Heat Capacity	Thermal Expansion Coefficient	Yield Strength	Elasticity Modulus	Poisson Ratio
2.81 kg/m^3	$210 W/m^3$℃	$868 Jkg/$℃	2.27	366MPa	73Gpa	0.32

3.2. The modal analysis

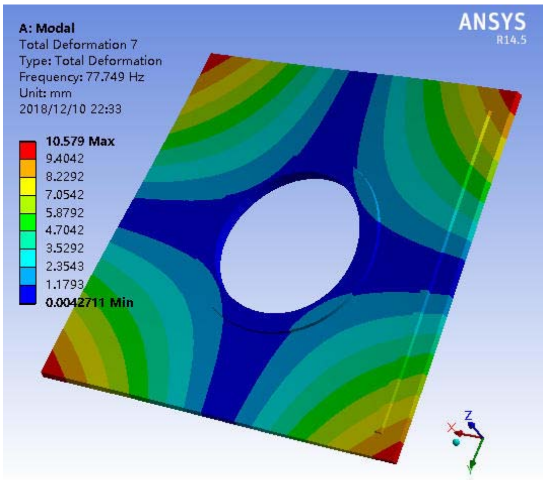
Modal analysis of the back plate is carried out in this paper, and the natural frequency and mode diagram are obtained through the modal analysis. According to modal analysis, the excitation frequency of vibration aging process parameters is determined.

According to the principle of vibration aging, when the part is in resonance state, the minimum vibration energy can be used to generate the maximum amplitude of the part, and the maximum dynamic stress and energy can be obtained, so that the residual stress in the part can be eliminated to the maximum extent [2]. In addition, according to the engineering practice, the selected vibration frequency is generally lower. Combined with the actual vibration process, it is shown that the lower order frequency has a greater impact on the mode, so when conducting modal analysis, the first six modes can be analyzed to save computation [3]. The first six natural frequencies of the back plate are shown in table 2. The first four modes are shown in figure 7.

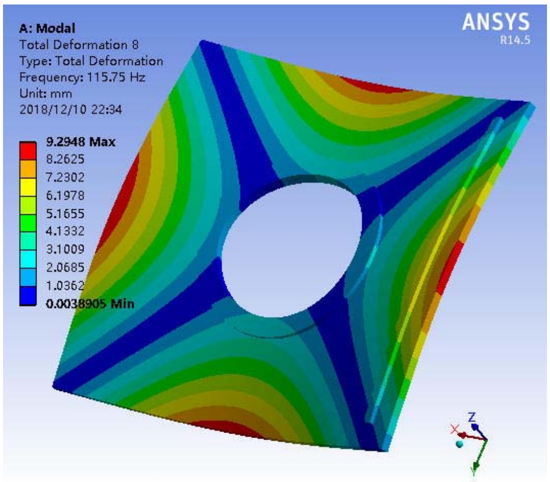
Table 2. Natural frequencies (Units: Hz)

Order	1	2	3	4	5	6
Frequency	77.7	115.8	157.2	205.2	209.95	351.95

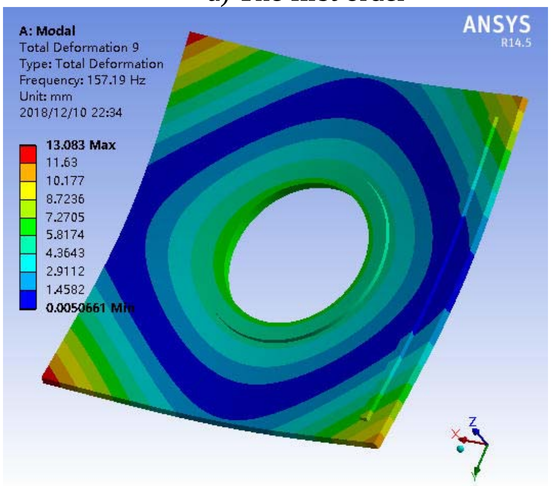
IOP Conf. Series: Earth and Environmental Science **252** (2019) 022118 doi:10.1088/1755-1315/252/2/022118



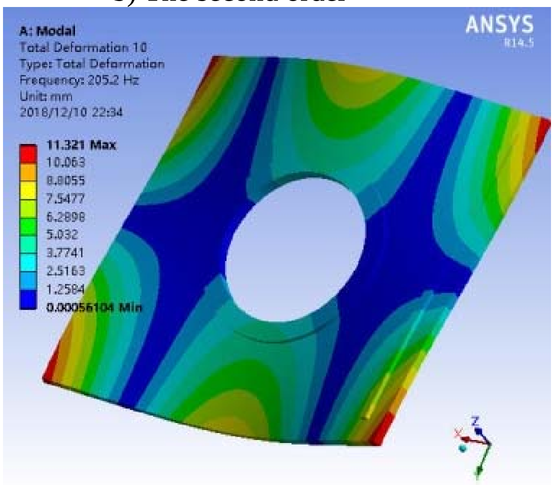
a) The first order



b) The second order



c) The third order



d) The fourth order

Figure 7. The first fourth modes

At present, the first or second order natural frequency of part is usually selected as the excitation frequency of vibration aging in engineering applications. In addition, in the process of vibration aging, the natural frequency of the part will decline, and the vibration excitation of the part under the natural frequency is unstable, so it is difficult to get the best effect. Therefore, the frequency in the subresonance region is selected as the excitation frequency in the engineering vibration aging. The range of subresonance region is usually calculated by formula.

$$w_1 + (1/3)(w_0 - w_1) \sim w_1 + (2/3)(w_0 - w_1) \quad (1)$$

In the formula, $w_1 - w_0 = \xi w_1$, ξ is the damping ratio of material, w_1 is the natural frequency [4].

Combined with the deformation characteristics of the back plate, it can be seen that the deformation mode is similar to the vibration pattern diagram of the first mode and the second mode respectively. so the natural frequencies of the first and second order are substituted into formula (1), ξ=0.046. After solving, the numerical range of the sub resonance region is 75Hz~77Hz and 112Hz~114Hz. So select 76Hz and 113Hz as excitation frequencies respectively.

3.3. Harmonic response analysis

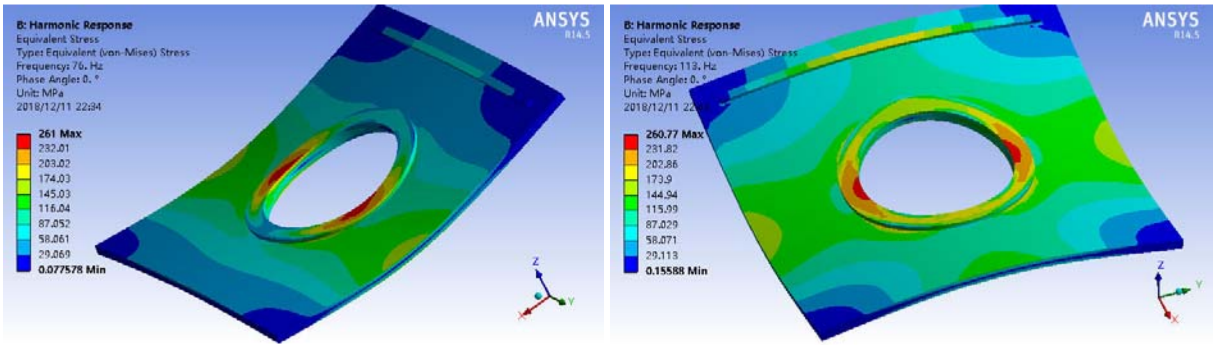
Based on harmonic response analysis, the vibration response of the back plate is calculated within a certain frequency range and under a certain excitation. Determine the excitation response amplitude of parts in the vibration aging process to obtain the optimal excitation force.

In this paper, the mode superposition method is adopted, and the interval is 0~200Hz with an increment of 10Hz. In addition, according to the principle of vibration aging, the sum of dynamic stress and residual stress in the part during vibration aging should be greater than the yield strength of the part material [5].

$$\sigma_d + \sigma_r > \sigma_s \tag{2}$$

According to the measurement data of residual stress, the calculation shows that the minimum equivalent residual stress of the back floor is 105.3MPa, that is σ_r =105.3 MPa. The yield strength of the material is 366MPa, so σ_d > 260.7 MPa.

According to the harmonic response simulation analysis, when the vibration frequency of the back floor is 76Hz, the excitation force is 46.4kn. At this time, the maximum equivalent dynamic stress is 261MPa, so the minimum excitation force is 46.4kn.When the vibration frequency of the back floor is 113Hz, the excitation force is 6.68kn. At this time, the maximum equivalent dynamic stress is 260.77mpa, so the minimum excitation force is 6.68kn.The results of harmonic response analysis are shown in figure 8.



a) f=76Hz b) f=113Hz

Figure 8. Results of harmonic response analysis

According to the harmonic response analysis, considering the economy and operability comprehensively, two vibration timings were selected. The excitation frequency and excitation force parameters were set as shown in table 3.

Table 3. The excitation frequency and excitation force

The first vibration aging		The second vibration aging	
excitation frequency	excitation force	excitation frequency	excitation force
76Hz	46.4Kn	113Hz	6.68Kn

4. Stress measurement and machining verification

The vibration parameters obtained by finite element analysis are used for vibration aging, and the residual stress after vibration is detected, the specific measurement data shown in figure 9. Combined with the detection data before vibration aging, the equivalent stress was compared and analyzed, as shown in figure 10.

It can be clearly seen from the comparison diagram of residual stress that the residual stress of the back floor before vibration aging has been more obviously homogenized and reduced, which proves that the method of obtaining vibration parameters by finite element analysis in this paper is correct and feasible.

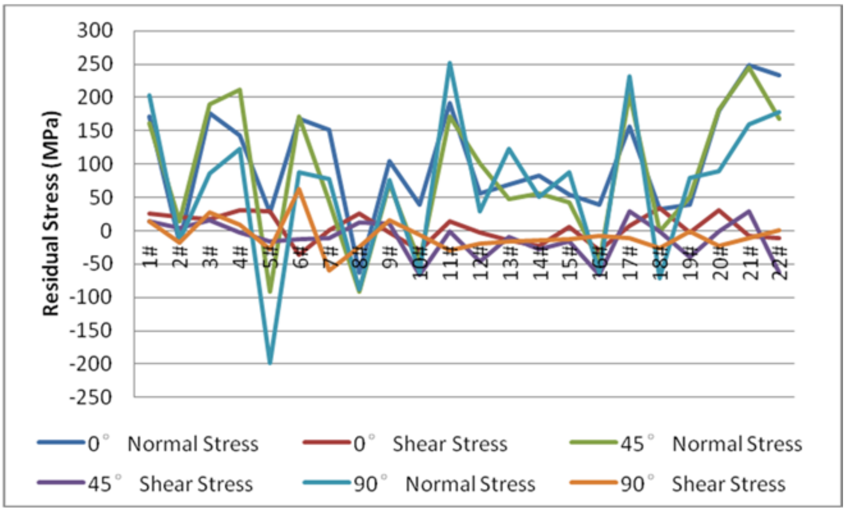


Figure 9. Measurement data after vibration aging

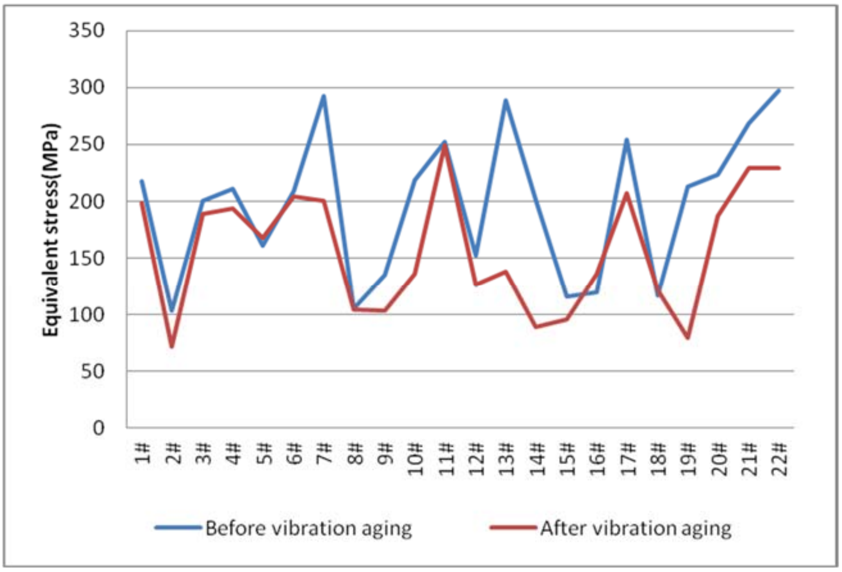


Figure 10. The comparison of equivalent stress

Through the comparison, it can be seen that the residual stress after vibration aging has been significantly reduced and homogenized. However, whether this method can solve the deformation problem of the back plate still needs to be further verified. Therefore, this paper conducted a trial machining after vibration aging to test the effect of vibration aging. Back plate test products have passed the precision test, met the design requirements and reached the acceptance standard. It can be proved that the vibration aging method can solve the back plate deformation problem

5. Conclusion

In this paper, the parameters of vibration aging are simulated and predicted by finite element method, and the deformation of back plate is controlled by vibration aging. This study not only realizes the

IOP Conf. Series: Earth and Environmental Science **252** (2019) 022118 doi:10.1088/1755-1315/252/2/022118

control of vibration aging on residual stress, explores the feasibility of finite element method in the prediction of vibration aging parameters, but also forms a set of simulation prediction method of vibration aging parameters, which can provide reference for the deformation prediction and control of other plate parts.

Acknowledgments
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