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Analysis of grating scale copy machine based on ABAQUS

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ABSTRACT

Because the grating scale copying belongs to precision machining, so under the working status the requirement of flatness of the platform which grating ruler is putting on is high. Main structural deformation will happen when it is under the action of weight and compaction force, which affects the machining accuracy. A certain type of long grating precision lithography copy machine is considered as the research object. The finite element method is introduced to the structure improvement. Solidworks is used to establish the three dimensional model of objects and then ABAQUS is used to execute static analysis and modal analysis to existing structure so that weaknesses can be found. Structure improvement can be carried out based on the analysis result, so the stability of the whole structure and the uniformity in the flatness of the display platform can be improved.

KEYWORDS

Grating scale copy machine; ABAQUS; Static analysis; Modal analysis; Optimization design.

INTRODUCTION

Grating scale copy machine is mainly composed of base, support and platform which is used to support the grating scale. The three-dimensional model built by Solidworks is shown in Figure 1. Part 1 is the gland, part 2 is the platform, part 3 is the support, part 4 is the exposing lamp, part 5 is the base.

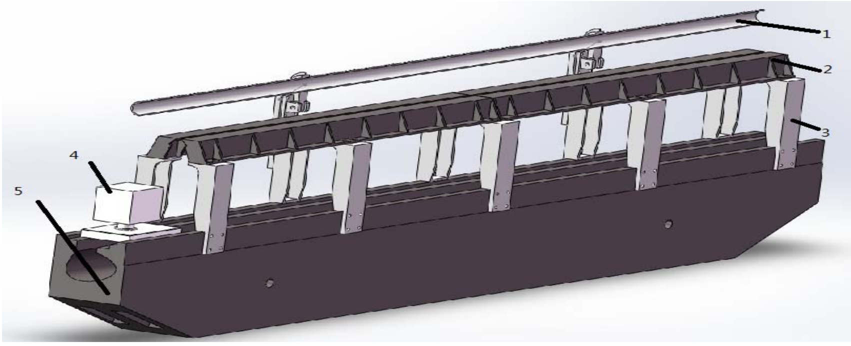


Figure 1 : Three-dimensional model of the grating scale copy machine

Exposure lamp pulled by wire rope slides circularly on the guide of base. Exposure lamp support is equipped with rolling bearing under the body surface to contact it with the guide of base. Grating scale copy machine is not only influenced by the static force but also affected by the dynamic force when it's under work conditions, which produce deformation and vibration on the platform. So a reasonable design of layout and structure of the bearing is very important thing in improving precision of grating scale copying.

ESTABLISH FINITE ELEMENT MODEL

The main structure factor which affects the machining accuracy of grating is the surface smoothness of the platform. Because the deformation and displacement of the base which is made of HT250 and fixed on the ground by the foundation screw is small, so the structure of 1, 4, 5 is ignored. And the analysis is focused on the assembly composed of the support and the platform. The length of the platform which is symmetrically arranged on the left and the right 3384 mm long and 100 mm high. Each side of it is divided into two sections, the length of each section is 1682 mm. The width of each support is 103 mm and the height is 300 mm. The number of the support arranged evenly on each side is 5.

A small number of sharp corners and other small features will increase the cost of finite element analysis and even lead to mesh failure. So model simplification is quite necessary in order to get a higher analysis economy under the premise of ensuring calculation accuracy. The model structure removed some small fillets, chamfers, installation bases that had little effect on the structural stiffness[1].

Import the simplified model into ABAQUS, use T-mm-s unit system. Define the platforms' material name HT200, with density of 7.28e-9T/mm^3, elastic modulus of 1.38e5Mpa, Poisson's ratio of 0.156. Define the supports' material name IRON45, with density of 7.89e-9T/mm^3, elastic modulus of 2.09e5Mpa, Poisson's ratio of 0.269. According to the actual working situation, the relationship between the contact surfaces is built: the supports' surfaces which should be contacted with the base is fixed, the platform is connected with the supports by bolts. Hexahedral meshes with high quality is created by using sweeping algorithms after the parts of the assembly have been separated suitably. Since the hourglass phenomenon and the Shear Locking hardly exist in the assembly, C3D8R (eight node hexahedral linear reduced integration element) is chosen as the mesh type. Statistics show that the finite element model shown in Figure 2 has a total number of 77874 nodes and 43364 elements.

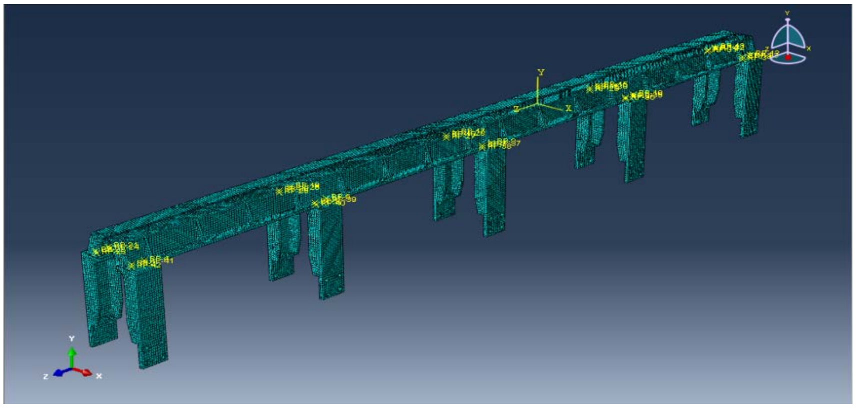


Figure 2 : Finite element model

STATIC ANALYSIS

The supports can be seen as a base. And a simply supported beam is composed of the supports and the platform components. The static deformation of structure is a result of the action of gravity and contact force, because not only there exit a static moment on the supports but also the platform is connected to support by bolts.

Analyse the deformation of the platform. Set the analysis step as general static step in ABAQUS. The gravity its own can be loaded automatically by defining the material density and the acceleration due to gravity. Submit analysis work, deformation mode and deformation is calculated by ABAQUS according to the definition of contact[2][3]. The post-processing shows that the main deformation is the subsidence of the platform surface, the maximum resultant displacement occurs at the inside edge of the platform is 1.192e-002mm in which the displacement along the direction of gravity is 5.925e-003mm. The resultant displacement nephogram is shown in Figure 3. The graph of resultant displacement along the inside edge of the platform is shown in Figure 4(c).

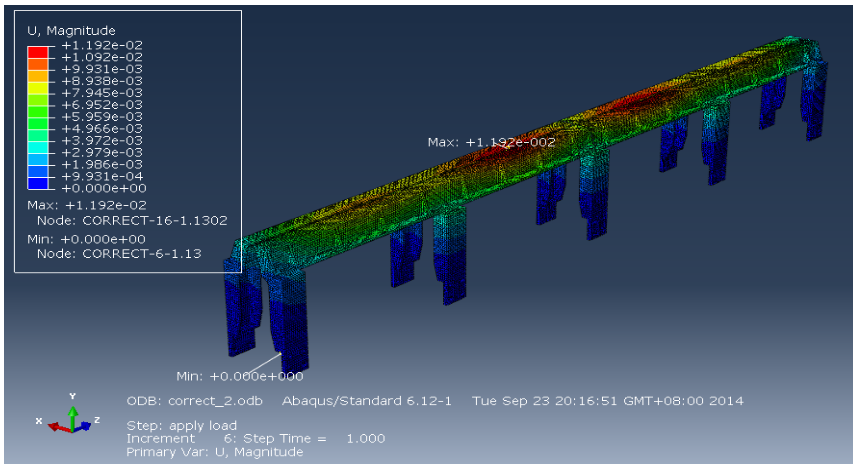


Figure 3 : The resultant displacement nephogram(original)

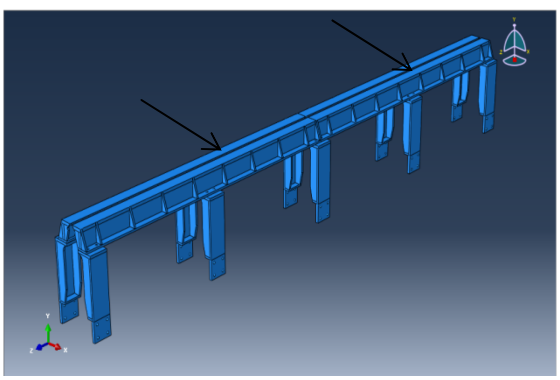


Figure 4(a) : The selection of displacement path

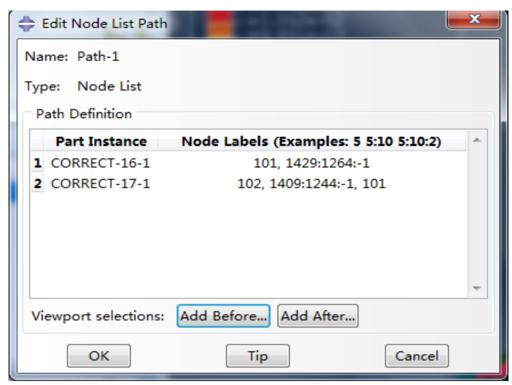


Figure 4(b) : The node number of path

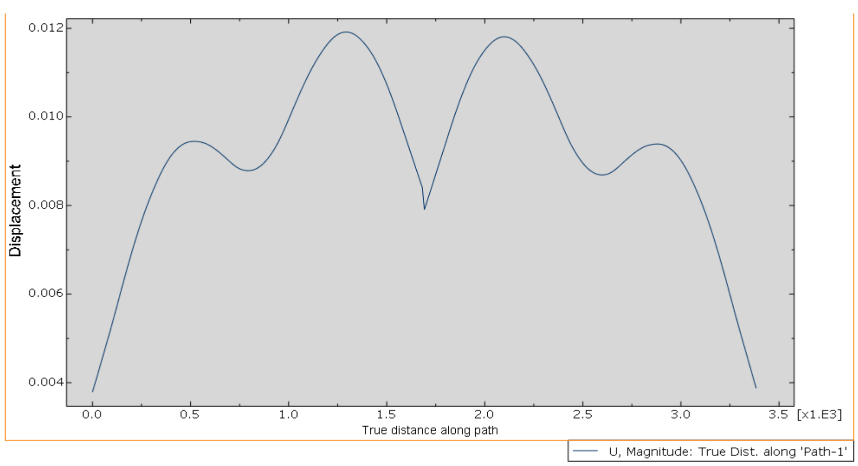


Figure 4(c) : The graph of resultant displacement along path(original)

MODAL ANALYSIS

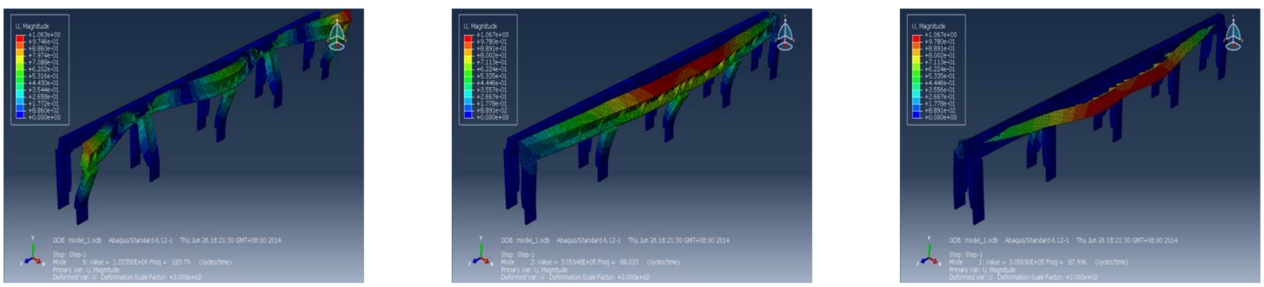
Modal analysis is the most basic content of dynamic analysis. It is used mainly to determine the natural frequencies and vibration mode, provide a theoretical basis for the structural optimization.

Grating scale copy machine is a multi-degree of freedom vibration system with multiple natural frequency. In the working status the vibrations created by the relative sliding between the exposure lamp and the guide sliding rail, the turning of cooling fans installed on the exposure lamp and drive motor have a direct or indirect influence on the platform. So it's important to avoid inherent frequency being too close to the he frequency of the above mentioned.

In modal analysis, for vibration is assumed to free vibration, only the boundary conditions play a role, other loads have no effect on the results of the analysis. Set the analysis step as the frequency extraction step in linear perturbation step. As the higher modes of the natural frequency is much higher than the actual situation of the excitation frequency can be achieved and generally can't resonate[4-6]. Only the preceding 30 orders natural frequencies are extracted, of which the preceding 10 orders natural frequencies is shown in TABLE 1. The vibration modes are shown in Figure 5. The vibration mode is mainly the bending deformation of the platform.

TABLE 1 : The preceding 10 orders natural frequencies

Order	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Frequency	87.99	88.003	96.595	96.622	111.88	111.90	132.47	132.47	183.79	183.83

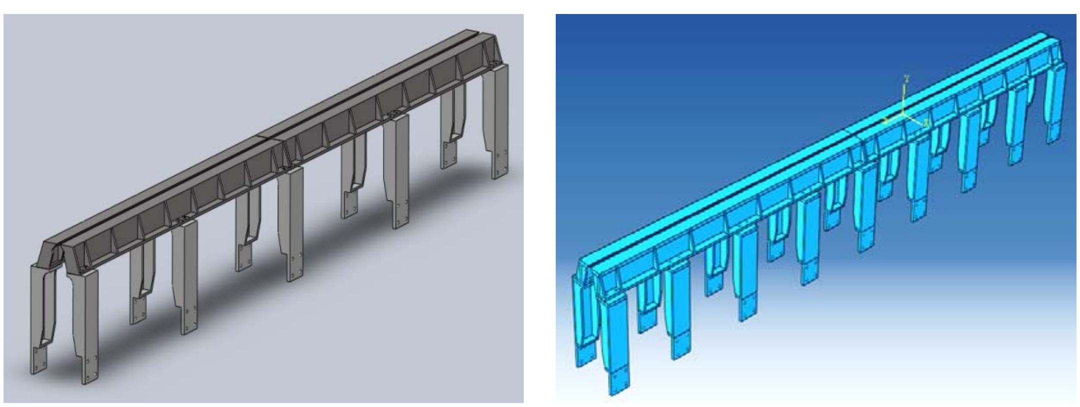


(a) **(b)** **(c)**

Figure 5 : The vibration modes, (a)-The first vibration mode, (b)-The second vibration mode, (c)-The ninth vibration mode

STRUCTURE OPTIMIZATION

Based on the above analysis, the distribution of displacement is uneven along the longitudinal direction on the surface of the platform. But the requirement of flatness is high when it is under the working condition. So in order to reduce the displacement amplitude and improve the flatness of the platform surface, another one is added between a pair of supports which is shown in Figure 6(b). The shapes and sizes of added supports is same as the supports before. The number of them is 8.



(a) **(b)**

Figure 6 : The main structure of grating scale copy machine, (a)-The original structure, (b)-The optimized structure

As shown in static analysis and modal analysis for optimized structure, the flatness of the platform is substantially improved. The maximum resultant deformation reduced from the original 1.192e-002mm to 4.949e-003mm, the resultant displacement nephogram is shown in Figure 7. The graph of resultant displacement along the inside edge of the platform of the optimized structure is shown in Figure 8. The contrast curve of resultant displacement along the inside edge of the platform surface is shown in Figure 9 in which the lower curve represent the optimized structure. The natural frequency has increased, the first 10 natural frequencies is shown in TABLE 2, the excitation(diver motor etc.) frequency should try to avoid these frequencies. The vibration modes are shown in Figure 10. The vibration mode is still mainly the bending deformation of the platform.

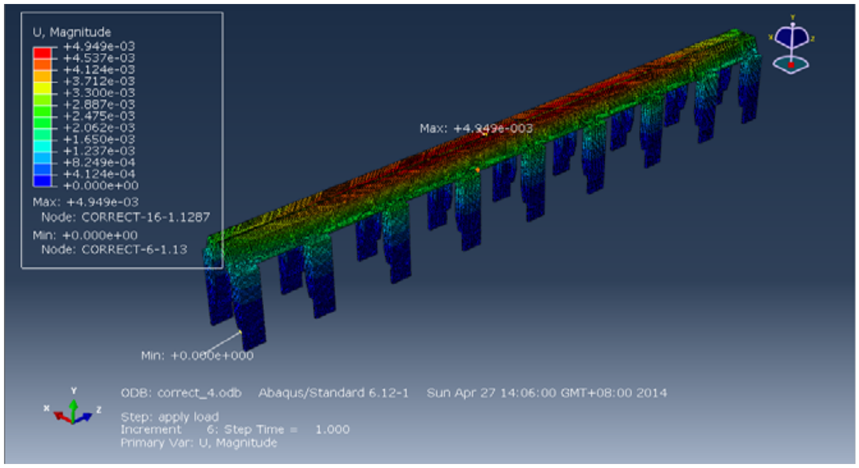


Figure 7 : The resultant displacement nephogram(optimized)

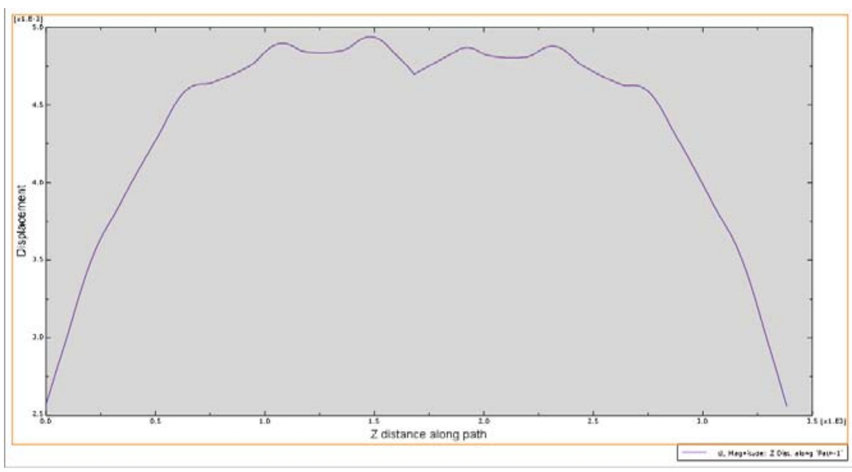


Figure 8 : The graph of resultant displacement along path (optimized)

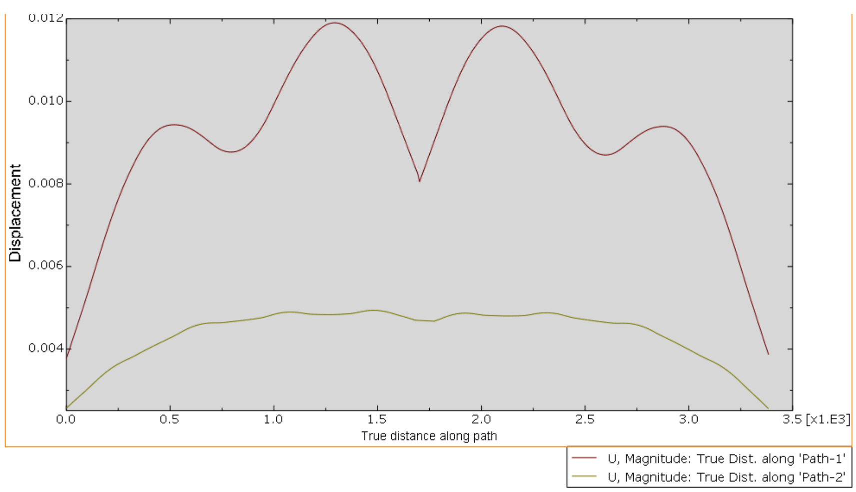
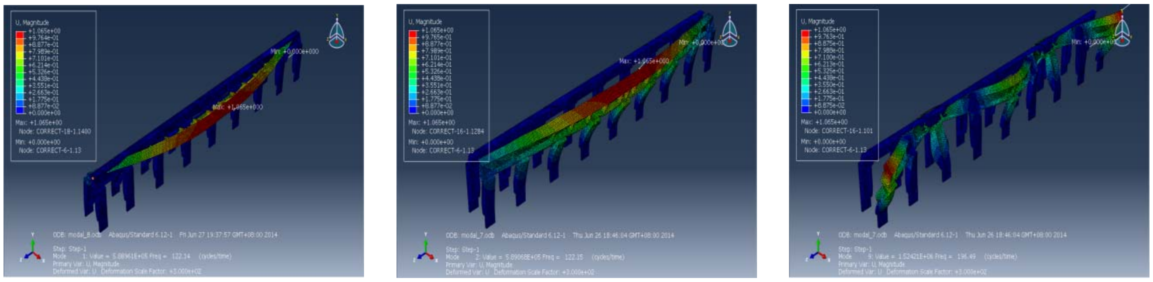


Figure 9 : The graph of resultant displacement along path(comparison)

TABLE 2 : The preceding 10 orders natural frequencies

Order	1	2	3	4	5	6	7	8	9	10
Frequency	122.14	122.15	130.03	130.04	144.69	144.72	164.60	164.62	196.49	196.53



(a) (b) (c)

Figure 10 : The vibration modes, (a)-The first vibration mode, (b)-The second vibration mode, (c)-The ninth vibration mode

CONCLUSIONS

The grating scale copy machine is regarded as the structure-reinforcement optimization object in this paper. After the static analysis and modal analysis of the support structure, the weakness has been found. And an improvement has been done to the original structure. The final scheme makes the maximum resultant deformation reduced by 58.5%, the flatness of the platform is substantially improved. After the pressure institutions added on the surface of the platform, the maximum resultant deformation and the flatness did not change obviously.

In order to improve the machining precision of the grating scale and avoid the influence of structural thermal deformation made by the light heat of the exposing lamp during the work, not only the structure optimization, but also the thermal analysis about exposing lamp and the arrangement of light path should be taken. The water cooling of exposing lamp and optimization of sliding mode also can be taken to reduce the influence of vibration which is created by the turning of cooling fans installed on the exposure lamp and relative sliding between the exposure lamp and the guide sliding rail on machining accuracy.

CONFLICT OF INTEREST

We declare that we do not have any commercial or associative interest that represents a conflict of interest in connection with the work submitted.

ACKNOWLEDGEMENT

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