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DEVELOPMENT OF THE BENT FOCUSING MIRROR IN HEPS FROM DESIGN TO TEST

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Abstract

The focusing mirrors are important for each beamline in the 4th generation photon source. One bent focusing face-down mirror in HEPS is taken for an example to be introduced from the design to the test. The effect of the gravity of the mirror is considered in the design. Moreover, for the sake of the compromise between the processing and the precision, the polygonal structure is adopted. Also, the iteration of the solution is improved to increase the design efficiency. The results reveal that the theoretical precision of the mirror after bending can reach less than 100 nrad RMS. In the aspect of the mechanics, the scheme of four roller bender comes out to avoid the parasitic moment, and the movable component in the bender are all coated with the MoS_2. As the type of the measurement is facing side which is different from the type of the actual condition, the effect of the gravity must be included in the metrology results. In the meantime, the stability and the repeatability are also measured. The result can be converged to around 200 nrad RMS, which is less than the required error. The stability, ΔR/R, can be constrained under the 0.6%, showing the outstanding performance.

INTRODUCTION

Since the small spot and the high brightness, people around the world engage in pursuing the 4th synchrotron radiation facility (SRF). Bent mirror is one of the most significant optical element in the SRF, which can not focus the light but also decrease the error induced by other elements in the beamline. High energy photon source (HEPS) is one of the establishing 4th SRF, of which the circumference is about 1360 m and the emittance is 34 pm·rad [1].

This paper is dedicated to illustrating one focusing bent mirror in the HEPS beamline from design to test, which is seldom explained in other articles. The method used in the design is one kind of new iteration algorithm to increase the efficiency [2]. And the outstanding performance of the whole system is shown in the off-line testing.

DESIGN METHOD

Since the bent mirror is vertical reflection, the influence of the gravity is nonnegligible in this design. In order to decrease the cost of the bent mirror, the gravity compensation is also considered, thus the polygonal profile is adopted. The width of the mirror can be described as

$$b(x)=\frac{M(x)+M_g(x)}{EI_0C(x)}b_0 , \quad (1)$$

where $b(x)$ is the width varying with the position of the mirror, $M(x)$ is the moment of the mirror, $M_g(x)$ is the moment caused by gravity, E is the elastic module, $C(x)$ is the curvature of the mirror shape, b_0 and I_0 are the width and the inertia moment at the mirror center, respectively.

The solution on mirror width is utilized by the method in this article [2], which can improve the efficiency of the calculation.

DESIGN RESULTS

The active area of the bent focusing mirror used in HEPS is 605×20 mm^2. The requirement for the total slope error is less than 0.3 μrad. The final width can be solved by the theory above, and the results of the performance of the mirror are also shown as following.

The mirror width is plotted in Fig. 1. For sake of the processing convenience, the mirror edge is divided into 5 segments. Due to its direction of reflection, the distribution of the width shows a concave polygon. This width shape can effectively reduce the influence of the gravity.

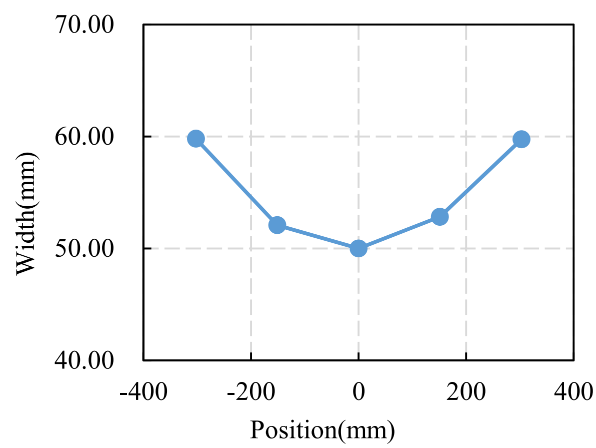

Figure 1: Mirror width along the position.

The design result of the slope error is shown in Fig. 2. The curve fluctuates between -0.03 μrad and 0.03 μrad, indicating the excellent performance of the mirror. The RMS (root mean square) of the slope error is about 14 nrad that is a very low value. Besides the design error, the material error, fabrication error and mechanical error are all included in this stage. The total error can be controlled around the 140 nrad RMS, which meets the requirement for less than 300 nrad RMS.

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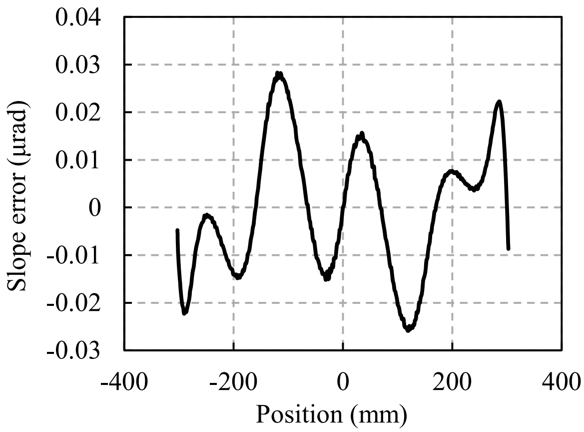

Figure 2: Slope error of the mirror in the design.

OFF-LINE TEST

Test Preparation

The inspection instrument we use in the off-line test is horizontal LTP (long trace profiler), while the direction of the reflection is face-down in the working condition. Therefore, the inspection result we obtain should be extra considered the influence of the gravity.

The drive force adjusting the shape of the bent focusing mirror comes from the four-cylinder benders that can avoid the parasitic moment. The most significant parts of the mechanism, even determine the performance of the adjustment, is the sleeve system which is shown in Fig. 3. The component is located in the front of the rotating motor, which is utilized to transfer the rotation to translation. Thus, all the sleeve systems are all coated with MoS_2 to improve the lubrication. In order to rotate the whole mirror system, the clamping is also fabricated.

Figure 3: Sleeve system with MoS_2 coating.

Test Results

The variation of the height error and the slope error with each iteration are presented in the Figs. 4 and 5, respectively. Because the error in the first iteration is too large, the curve in this step is eliminated. From the figure, one can find that the height error and the slope error both decrease as the iteration number increasing. Moreover, 4 or 5 iterations are enough to almost meet the requirement. The final slope error is converged to about 200 nrad RMS, which is also shown in Table 1. In the near future work, we intend to explore the limitation of the iteration or search for the better method on iteration to reduce the height error or the slope error.

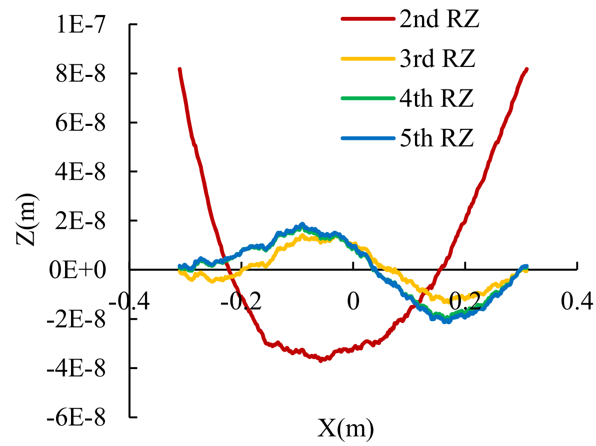

Figure 4: Height error curve for each iteration.

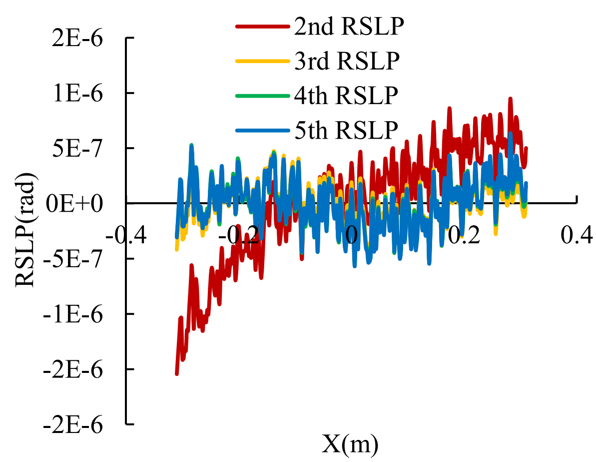

Figure 5: Slope error curve for each iteration.

Table 1: RMS of Residual Error for Each Iteration

Iteration number	Height error RMS [m]	Slope error RMS [rad]
1	3.31E-06	2.70E-05
2	4.77E-08	6.33E-07
3	1.32E-08	2.80E-07
4	1.44E-08	2.53E-07
5	1.21E-08	2.25E-07

After the adjustment of the mirror shape is accomplished, the stability of the system also should be cared about. The stable test is conducted. The period lasts about 3 days, and the evaluation index we used is the curvature radius that is shown in Fig. 6. The stable interval of the radius locate in about 5,320 m and the parameter $\triangle R/R$ corresponds to the 0.5%.

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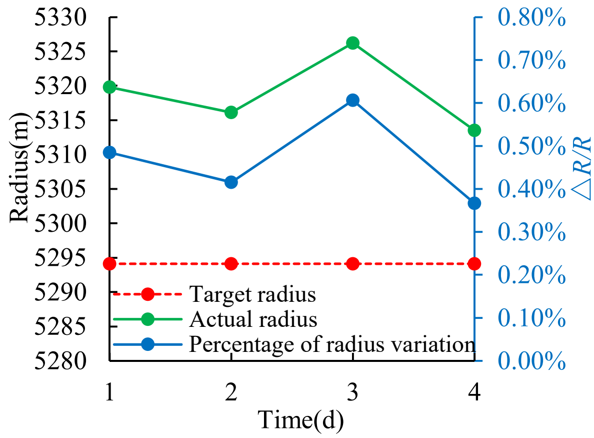

Figure 6: Variation of the curvature radius as the time.

CONCLUSION

This article states the development of one bent focusing mirror in HEPS from design to off-line test. The main topic is based on the performance of the mirror system. The results reveal that the theoretical precision of the mirror after bending can reach less than 100 nrad RMS. In the off-line test stage, the whole mirror system can be converged to around 200 nrad RMS, which is less than the required error. The stability, ΔR/R, can be constrained under the 0.6%, showing the outstanding performance.

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