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# DEVELOPMENT AND IMPROVEMENT OF HEPS MOVER*

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*Abstract*

High Energy Photon Source (HEPS) has been constructed after decade of research. As the first diffraction-limited storage ring light source, many advanced devices are applied in this project, including the Beam Based Alignment Mover (Mover), which support and adjust the position of the Sextupole Magnet. It undertakes to remotely online adjust the position of Sextupole to meet the Physical requirement to correct the optics coefficient of Electron beam current. The positioning accuracy, attitude angle, and coupled error of Mover with 450 kg load strictly proposed and tested during the development of Mover. There are three main types of Mover, including Four-layer with sliding guide, Three-layer with rolling guide, and Three-layer with sliding guide. This paper introduces the development and improvement of Mover.

## INTRODUCTION

The High Energy Photon Source (HEPS) has been designed and constructed to be the first high energy diffraction-limited storage ring (DLSR) light source whose electron beam energy reach to 6GeV and emittance is less than 60pm·rad [1].

Movers are designed to accurately adjust the position of Sextupoles to eliminate a strong feed-down effect and so formed dominating contribution to the optics distortion [1-2]. In LCLS, EXFEL, SXFEL, and DCLS, Mover is applied to carry relative lightweight quadrupoles [3-5]. HEPS firstly apply Mover to accurately adjust the position of 450kg Sextupoles.The specific requirements are shown in Table 1.

Table 1: The physical Requirements for Mover

| Content | Requirement |
|---|---|
| Positioning Accuracy | ± 5 μm |
| Yaw | 3″ |
| Roll | 3″ |
| Pitch | 2″ |
| Coupled Error | 15 μm |
| Natural Frequency of support system | 54 Hz |

Three kinds of of prototype, including four-layer with sliding guide, three-layer with rolling guide, and three-layer prototype with sliding guide are studied.

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The method and result of measuring process of motion performance of batch production of Mover is described in this paper.

## STRUCTURE & MANUFACTURE

The structure of Mover should be elaborately designed to possess the properties such as high precision, low velocity, good stability, resistance to radiation, long service life, and compact size.

The model of four-layer with sliding guide is firstly designed based on previous research [6]. It is basically consisted of five parts (see Fig. 1), including horizontal plate, lateral constraint guide, upper wedge plate, lower wedge plate and base plate. Three-layer with rolling guide which is driven by piezoelectric ceramic motor is designed then (see Fig. 2). It mainly consists of upper wedge plate, lower plate, base plate, and high rigidity linear guide. The structure is further simplified to three-layer prototype with sliding guide (see Fig. 3). It mainly consists of upper wedge plate, lower plate, and base plate.

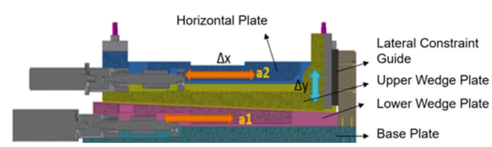


Figure 1: Four-layer with sliding guide Mover.

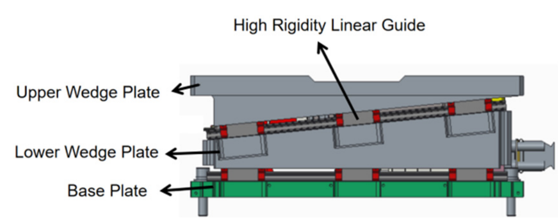


Figure 2: Three-layer with rolling guide Mover.

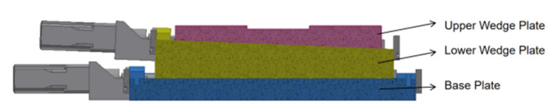


Figure 3: Three-layer with sliding guide Mover.

Cast iron is chose to be the material of Mover body since its properties of good resistance to vibration, stable performance and good accuracy retention, and easy to shape.

One of an important manufacture process should be scraping and grinding of sliding guide (see Fig. 4). It is helpful to decrease the residual stress in the plate so that accuracy and rigidity are enhanced. The lubricant could be reserved at series of uniform pit after scraping and grinding to form an oil film to improve friction performance and service life as a result.

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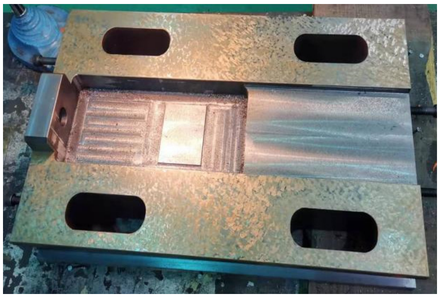

Figure 4: Surface after scraping and grinding.

At the end of processing, the upper layer of Mover would be ground after assembling (see Fig. 5) to improve the flatness and parallelism. This process can eliminate error both in machining and assembling. It is pivotal for alignment of magnet during the installation of HEPS.

Figure 5: Assemble grinding.

## MOTION PERFORMANCE

Each Mover will be tested before its applied installing, including Attitude Angle, Positioning Accuracy and Coupled Error. And the Attitude angle includes Roll, Yaw, and Pitch. Figure 6 shows the coordinate system of Mover.

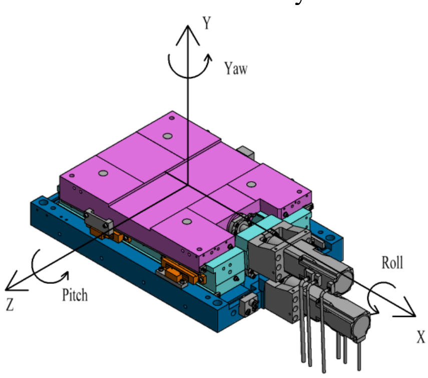


Figure 6: Coordinate system of Mover.

### Attitude Angle

Three attitude angles, including pitch, roll and yaw, are measured by the CCD dual-axis autocollimator and the electronic level meter (see Fig. 7). During pratical moving range of ± 0.3 mm, yaw and roll should be less than 3″ while pitch should be less than 2″. This index mainly represents the quality of manufacturing.

Figure 7: Measurement of attitude angle.

### Positioning Accuracy

The position of Mover is determined by two absolute grating rulers. The installed position of grating ruler is crucial to ensure the positioning accuracy. The basic position is fixed by the machining process.

Positioning accuracy both in horizontal and vertical direction is measured by Renishaw XL-80 laser interferometer (see Fig. 8). The measured point is higher than the center of sextupole magnet where the magnified positioning error that amplified more by the attitude angle than the error at the center.

Figure 8: Measurement of positioning accuracy.

### Coupled Error

The vertical motion of Mover should be finished by cooperating axis A1 and axis A2 to eliminate the horizontal shift. This horizontal shift is called coupled error, which should be less than 15 μm.

Coupled error is measured by Attocube laser interferometer at the starting moment (See Fig. 9). It monitors the horizontal shift during the whole moving process. Mover is set to vertically moves and stop for 5 seconds at each 0.3 mm. Then the coupled error can be obtained at the starting moment.

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Table 2: Comparison of Three Kinds of Mover

| **Margin** | | **Four-layer with sliding guide** | | **Three-layer with rolling guide** | | **Three-layer with sliding guide** | |
|---|---|---|---|---|---|---|---|
| | | Horizontal | Vertical | Horizontal | Vertical | Horizontal | Vertical |
| Positioning Accuracy | | 1.9 µm | 1.3 µm | 0.5 µm | 2.7 µm | 1.8 µm | 1.5 µm |
| Attitude Angle | Yaw | 2″ | 3″ | 0.4″ | 3″ | 0.4″ | 1.7″ |
| | Roll | 1.2″ | 2.6″ | 0.2″ | 1.5″ | 1.2″ | 0.9″ |
| | Pitch | 1.8″ | 1.2″ | 0.4″ | 1.8″ | 0.3″ | 2″ |
| Coupled Error | | 13 µm | | 1.5 µm | | 15 µm | |
| Natural Frequency of support system | | 58 Hz | | 25 Hz | | 74 Hz | |

Figure 9: Measurement of coupled error.

### *Natural Frequency*

The process of natural frequency measurement has been studied in previous work [6-7]. Vibration sensors are attached to the support system model (See Fig. 10). The natural frequency of mover is mainly decided by its material and structure. This test proves the rationality of design and machining craft.

Figure 10: Measurement of natural frequency of support system model.

## RESULT

Table 2 shows the detailed information of three kinds of Mover. All of them satisfy the requirements of positioning accuracy and attitude angle. However, the coupled error of the four-layer prototype with sliding guide cannot be easily maintained. The efficiency of production is low. The natural frequency of support system which three-layer prototype with rolling guide is installed is just 25 Hz. The three-layer prototype with sliding guide can both satisfy the moving requirement and the stability of support system.

## CONCLUSION

Three layer Mover with sliding guide is successful to satisfy the requirement. This batch of Mover is qualified to be applied in HEPS. There is still room for improvement. The coupled error could be decrease more by enhancing the quality of contact surface. This research will be continued.

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