Development and improvement of HEPS Mover

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Abstract

The High Energy Photon Source (HEPS), a diffraction-limited storage ring light source, has been constructed after a decade of research. This project employs many advanced devices, including the Beam Based Alignment Mover (Mover). The Mover supports and adjusts the position of the Sextupole Magnet and is responsible for remote online adjustments to meet the physical requirements for correcting the optics coefficient of the electron beam current.

During the development of the Mover, strict standards were applied and tested for positioning accuracy, attitude angle, and coupled error with a 450kg load. There are three prototypes of Movers: Four-layer with a sliding guide, Three-layer with a rolling guide, and Three-layer with a sliding guide. This paper outlines the development and improvement of the Mover.

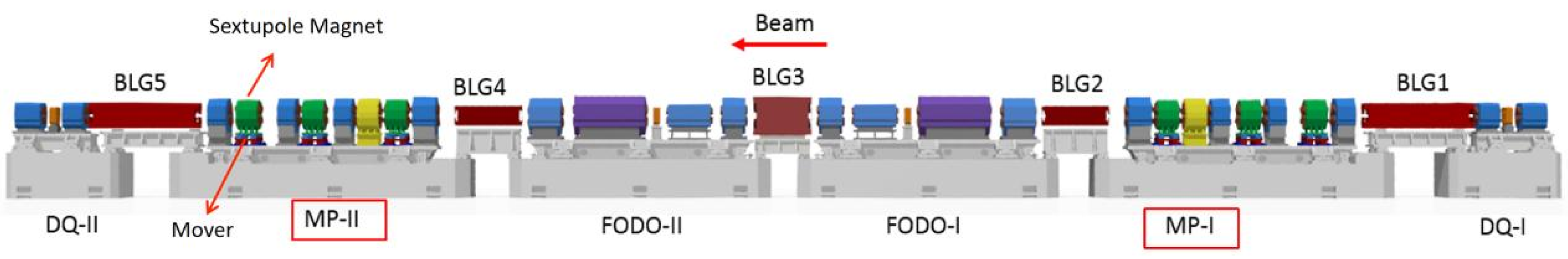

Figure 1. Installing position of Mover in one 7BA cell.

Introduction

The Storage Ring, the primary component of HEPS, has a circumference of 1360.4m. It is comprised of 48 cells of 7BA (seven-bend acrobat) structure. Each cell contains two MP units, each containing three sextupole magnets. This results in 288 Movers periodically arranged along the Storage Ring.

Main technical requirements:

- Positioning Accuracy: The error between actual position and ideal position;
- Attitude Angle: The angles of rotation around the 3 axes of motion;
- Coupled Error: The horizontal displacement during vertical movement;
- Natural frequency: The natural frequency of the whole support system, including Mover.

Table 1. Requirements of Mover.

Content		Requirement
Positioning Accuracy		±5μm
Attitude Angle	Yaw	3″
	Roll	3″
	Pitch	2″
Coupled Error		15μm
Natural Frequency		54Hz

Structures of Prototypes

Three types of Mover:

- Four-layer with sliding guide Mover;
- Three-layer with rolling guide Mover;
- Three-layer with sliding guide Mover

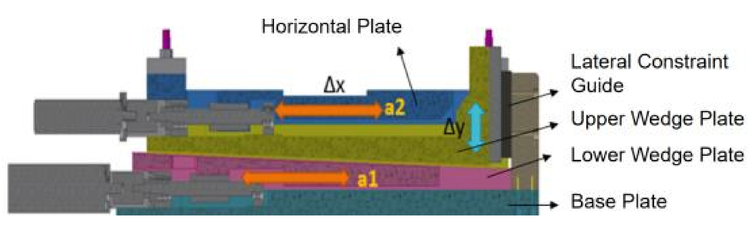

Figure 2. Structure of Four-layer with sliding guide.

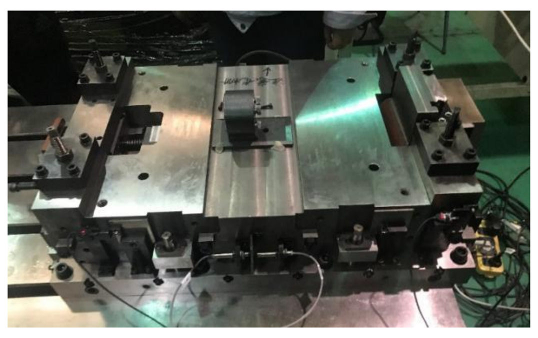

Figure 3. Four-layer with sliding guide.

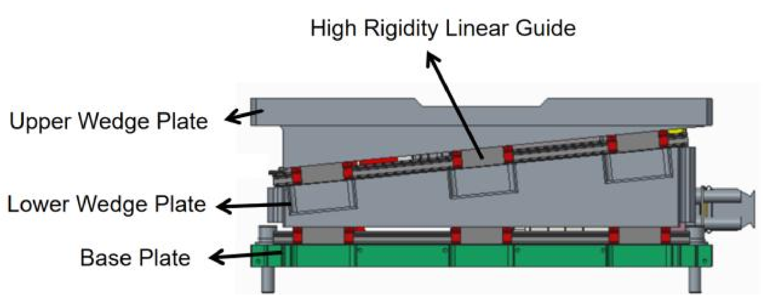

Figure 4. Structure of Three-layer with rolling guide.

Figure 5. Three-layer with rolling guide.

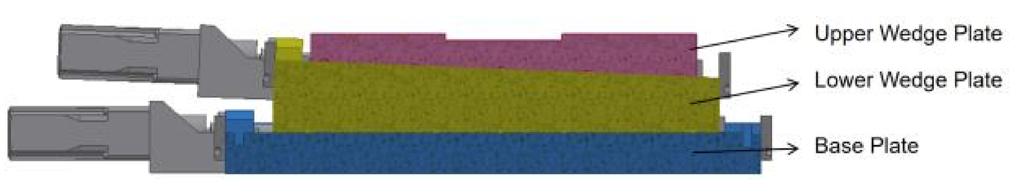

Figure 6. Structure of Three-layer with sliding guide.

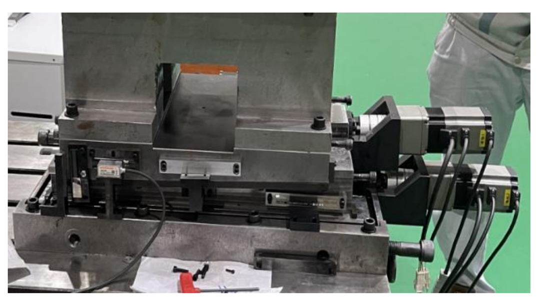

Figure 7. Three-layer with sliding guide.

Manufacture

The cast iron is used as the material of Mover. Special and key machining and assembling processes is applied to sliding guide prototypes.

Key processing:

- Heat treatment to eliminate stress and ensure the size.
- The scraping and grinding of sliding guide is exerted to achieve flatness as high as 0.5μm.
- Grind at the upper layer after assembling to improve flatness and parallelism.

Figure 8. Surface after scraping and grinding.

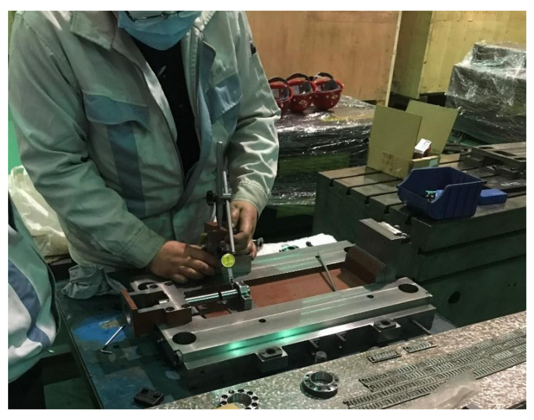

Figure 9. Installing test of ball screw.

Figure 10. Assemble grinding.

Performance Test

- **Content**: Attitude Angle, Positioning Accuracy, Coupled Error, and Natural Frequency;
- **Instrument**: Renishaw XL-80 laser interferometer, CCD dual-axis autocollimator, electronic level meter, Attocube laser interferometer, IEPE voltage electric accelerometer;
- **Load**: 450kg.

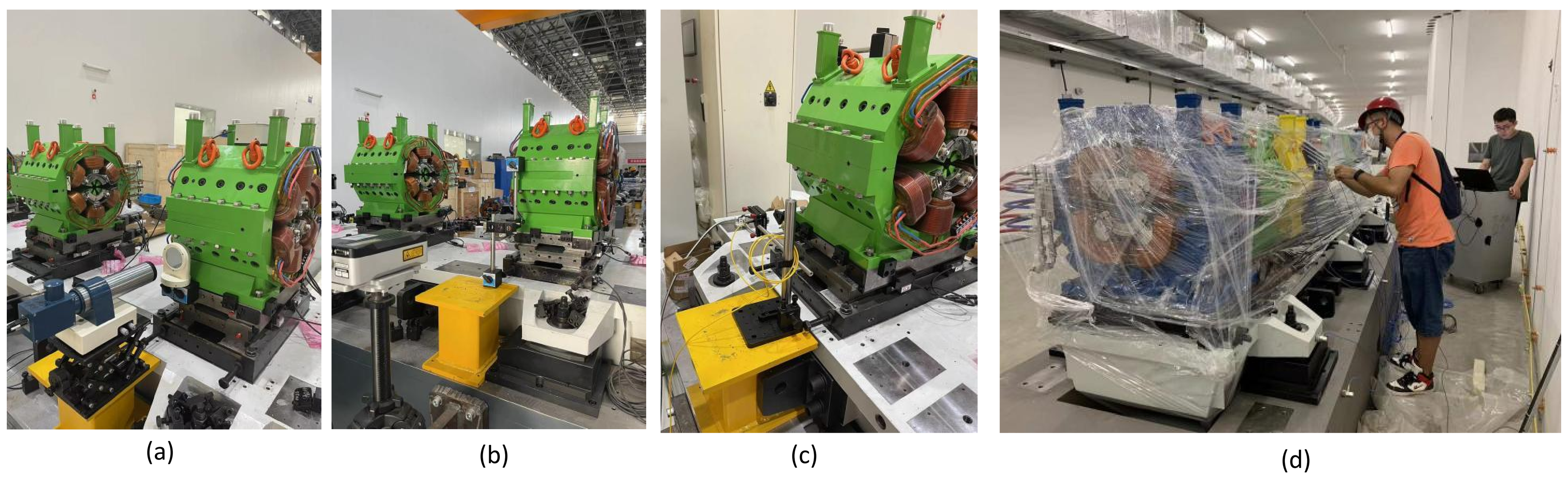

Figure 11. Measurement situation of (a)attitude angle, (b) positioning arruracy, (c) coupled error, (d) natural frequency.

Results

Three prototypes all satisfy the requirements of positioning accuracy and attitude angle. However, the natural frequency of support system which three-layer prototype with rolling guide is installed is just 25Hz. The three-layer prototype with sliding guide can both satisfy the moving requirement and the stability of support system.

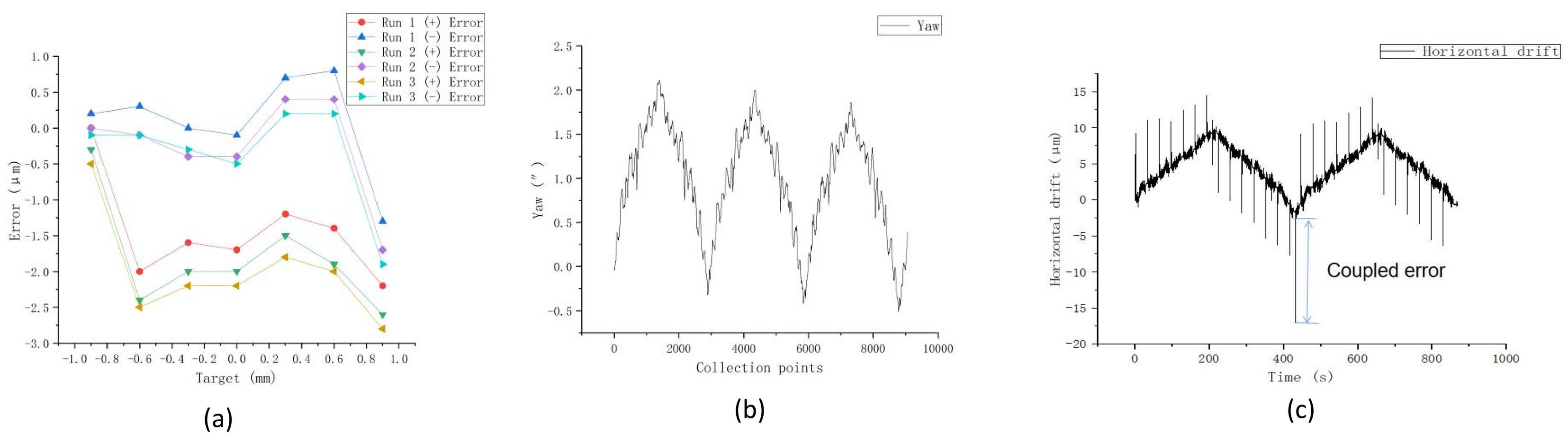

Figure 12. Result of (a) positioning accuracy, (b) attitude angle, (c) coupled error.

Table 2. Results of three prototypes of Mover.

Content		Four-layer with sliding guide		Three-layer with rolling guide		Three-layer with sliding guide	
		Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
Positioning Accuracy		1.9μm	1.3μm	0.5μm	2.7μm	1.8μm	1.5μm
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		13μm		1.5μm		15μm	
Natural Frequency		58Hz		25Hz(Fail)		74Hz	
Manufacture Difficulty		Hard		Normal		Normal	

Conclusions

The three-layer Mover with a sliding guide successfully meets the requirements. This batch of Movers is suitable for application in HEPS. The coupled error could be decrease more by enhancing the quality of contact surface. This research will be continued.

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