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PRELIMINARY DESIGN OF MECHANICAL SUPPORTS FOR THE BOOSTER OF HEPS

H. Wang*, C.H. Li, C. Meng, H. Qu
Institute of High Energy Physics, Beijing, China

Abstract

The Booster of High Energy Photon Source (HEPS) is a 454 meters ring with the repeat frequency of 1 Hz. The natural frequency of the magnets and their support assembly should be higher than 30 Hz. The alignment requirements on quadrupole and sextupole are better than 0.1 mm in x and y direction. This paper will discuss the preliminary design of the mechanical supports in Booster ring, as well as the discussion of finite element analyses results.

INTRODUCTION

HEPS (High Energy Photon Source) is an ultralow-emittance synchrotron light source to be built in Beijing, which includes Linac, Booster, storage ring and transport lines. The Booster has four-fold symmetric FODO lattice design. The main parameters are listed in Table 1.

Table 1: Main Parameters of the Booster

Parameters	Units	Injection	Extraction
Energy	GeV	0.5	6
Current	mA	11	13
Emittance	nm.rad	41	35
Repetition rate	Hz		1
Circumference	m		454.066

The magnet support is composed by steel girder and concrete plinth. In the FODO section, the adjacent quadrupoles, sextupoles and correctors share a common girder and are pre-aligned before tunnel installation, while the dipole magnets have an individual girder each, which crosses over two plinth. In the straight section, the adjacent quadrupoles and correctors share a common girder and other magnets all have individual girders. Figure 1 shows one eighth of the Booster magnets and their supports.

Table 2 shows the alignment requirements on the magnets in Booster, based on which the adjusting ranges and resolution has been determined, which is listed in Table 3.

The repetition rate of the booster is 1Hz. The physics requirement on natural frequency of magnets and support assembly is above 30 Hz, to decrease the transmission of vibration to storage ring. The stiffness of the support should be considered.

Table 2: Requirements on Alignment

Magnets	Direction	Alignment error	Units
Dipole	x/y/z	0.2	mm
	Roll	0.2	mrad
Quadrupole	x/y	0.1	mm
	z	0.2	mm
	Roll	0.2	mrad
Sextupole	x/y	0.1	mm
	z	0.2	mm
	Roll	0.2	mrad
Corrector	x/y/z	0.2	mm
	Roll	0.4	mrad

Table 3: Adjusting Ranges and Resolution

Direction	Adjusting range	Resolution	Units
x	≥±10	≤0.02	mm
y	≥±10	≤0.02	mm
z	≥±10	≤0.02	mm

STRUCTURE DESIGN

Pre-aligned Girder

The adjacent quadrupoles, sextupoles and correctors which share a common girder will be pre-aligned first, both for the FODO section and the straight section. One typical pre-aligned girder is shown as Fig. 2. The welded girder is at the top centre of the plinth. To avoid long-term deformation, stress relieving will be done sufficiently. Aluminium thin supports are used at both ends of vacuum tubes.

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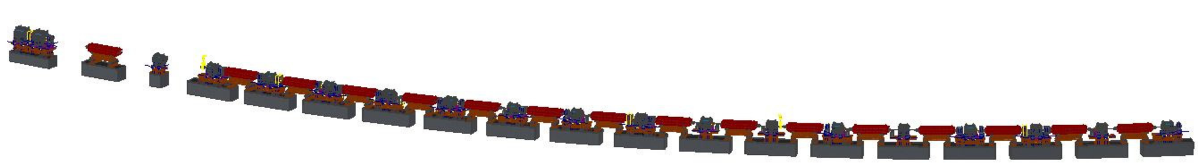

Figure 1: One eighth of the Booster magnets and their supports

* Email: wanghaijing@ihep.ac.cn

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Four wedge jacks are used for vertical adjusting and locking, which have high stiffness to improve the natural frequency of the girder as well as high resolution. The wedge jacks are responsible for the adjusting direction of y, roll (rotation around z-axis) and pitch (rotation around x-axis). Three sets of push-pull screws are used for horizontal adjusting. Two sets are responsible for the direction of x and yaw (rotation around y-axis) and one set for the z direction.

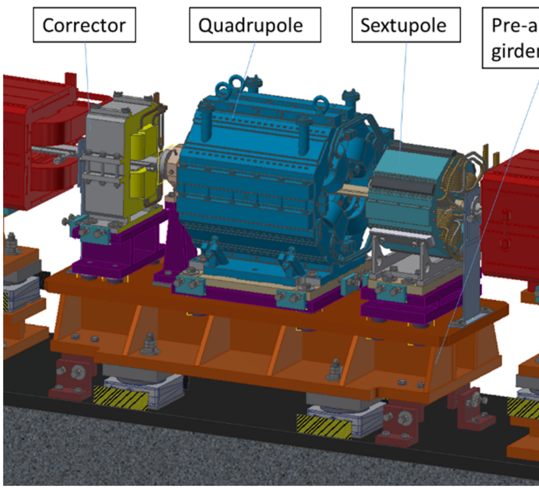

Figure 2: One typical pre-aligned girder.

For the 1 Hz repetition rate, we are not sure if the vibration isolation components are necessary. The space is reserved and the final decision will be made according to prototype experiments.

For the magnets on pre-aligned girder, four sets of concentric screws are designed for vertical adjustment while three sets of push-pull screws for horizontal adjustment, as shown in Fig. 3. For the quadrupoles and sextupoles on which the alignment requirements are high, a fine machined plate is designed between the magnet and girder.

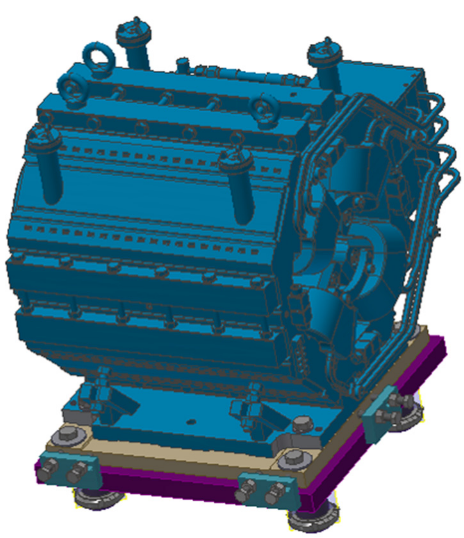

Figure 3: Adjusting mechanism for magnet on pre-aligned girder.

The concentric screw is composed by one spherical spacer, one hollow big screw, one small screw and locknut, as shown in Fig. 4. The contact surfaces shown as red lines are the lower surfaces of the big screw when adjusting and upper surfaces when locking, which make the big screw has no free stroke theoretically. Prototypes will be done to test this structure before final determination.

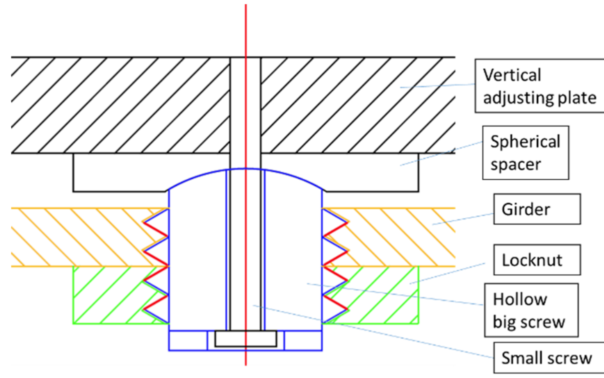

Figure 4: Schematic of concentric screw.

Individual Girder

All the dipoles and part of other magnets in the straight section have an individual girder each. Figure 5 shows two typical magnets and their supports. Similarly, the welded girder of dipole magnet is supported by four wedge jacks for vertical adjusting and locking, and three sets of push-pull bolts for horizontal adjusting. There is also reserved space for vibration isolation components. However, the welded girder of quadrupole magnet is supported by four sets of concentric screws for vertical adjusting and locking.

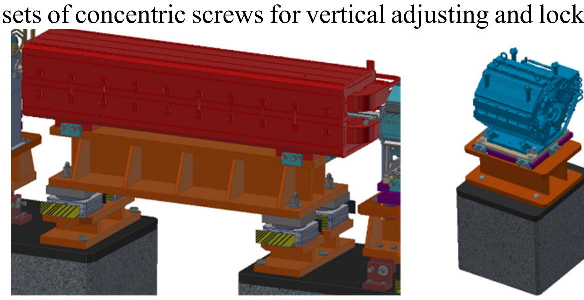

Figure 5: Dipole and its girder at FODO section.

Plinth

All the magnet girders are designed to be mounted to plinths composed by concrete and pre-embed steel plates. There are totally 5 types of plinths, one type in the FODO section with the length of 2200 mm and width of 620 mm, and another four types in the straight section according to the girder size on them. The plinths will be pre-fabricated and then grouted to the floor by epoxy or concrete. The detailed construction technology will be further studied and tested in the future.

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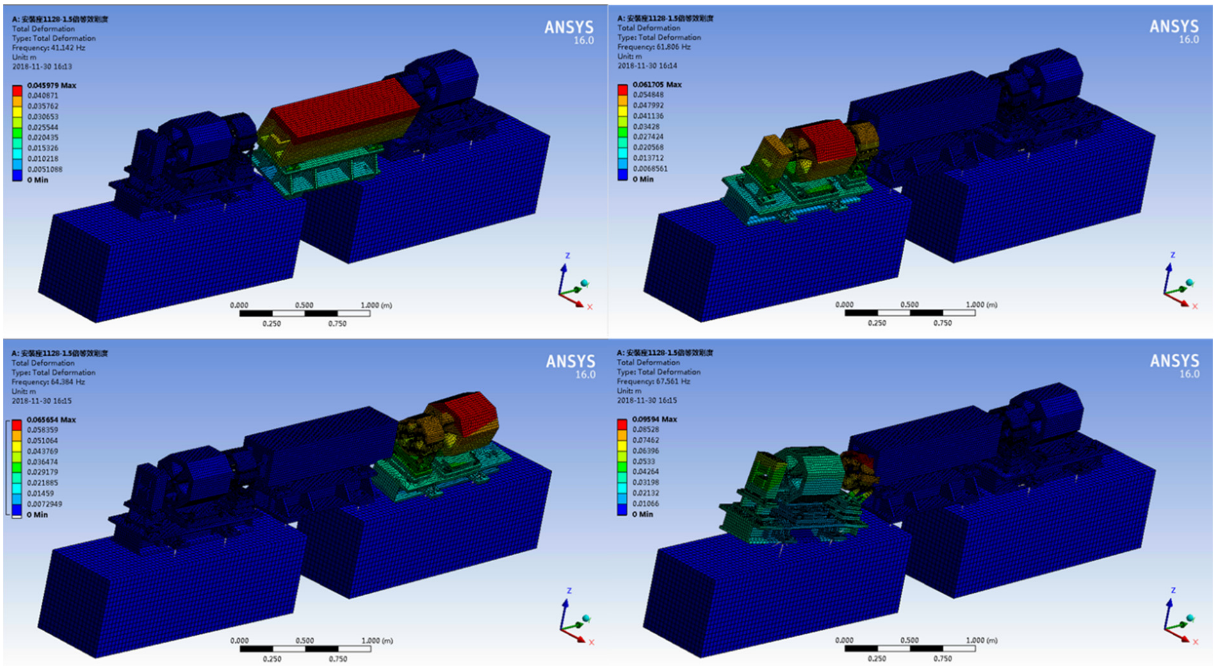

Figure 6: The first four orders of mode of typical units using spring constraints.

FEA OF THE SUPPORTS

The FEA in ANSYS has been adopted in the structure design and evolution. In the FODO section, all the girders are locked to the plinths by wedge jacks. The wedge jacks have relatively high stiffness but it is not so easy to abstract like screws, owing to the structure complexity and loads effect such as friction.

Two FEA method has been done for the modal analyses. One uses springs as the connection method between girder and plinth. The airlock 2120KSKC is selected. Supposing the stiffness is proportional to the load capacity, then the stiffness in three directions can be induced from the tested data of 414KSKC of ESRF-EBS [1]. Figure 6 shows the first four orders of mode of typical units in FODO section.

Table 4: Modal Analyses Comparison of Two FEA Methods

Order of mode	Frequency (Hz)		Vibration element
	Using spring connection	Using frictional connection	
1	41.1	57.2	Dipole
2	61.8	71.8	Pre-aligned assembly I
3	64.4	76.0	Pre-aligned assembly II

Another method uses the frictional contact of 3D model and setting the friction coefficient as 0.1 in all contact surfaces. The 2120KSKC uses M16 bolt for locking, the preload of which is set as 3e4 Newton. The preloads of other bolt connections are set as 2e4 Newton. This method has a big safe margin according to the study of APS-U [2], the first natural frequency is also higher than 30 Hz.

Table 4 shows the comparison of the two methods, from which we can roughly induce the natural frequency can fulfil the physics requirement of 30 Hz. More detailed FEA methods are under studying. Besides, prototypes and tests will be done to match the FEA results, then the analyses can forecast the performance more precisely.

CONCLUSION

The preliminary design of mechanical supports for the Booster of HEPS has been done. The welded girder with wedge jacks for vertical adjusting and locking has been designed for pre-aligned girders and dipole girders, while magnets on the pre-aligned girder or supported individually use concentric screws. The preliminary FEA has been done for typical Booster supports, which shows the natural frequency can fulfil the physics requirement of 30 Hz. More detailed FEA methods are under study, aiming to forecast the performance more precisely.

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