ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPTS034

DESIGN AND PROGRESS OF MECHANICAL SUPPORT IN HEPS

Chunhua Li†, Haijing Wang, Ningchuang Zhou, Minxian Li, Zihao Wang, Lei Wu, Yi Jiao
Institute of High Energy Physics, Beijing, China

Abstract

HEPS is a new generation synchrotron facility with very low emittance. Stringent requirements are proposed to the design of mechanical support. The alignment error between girders should be less than 50 µm. Based on that, the adjusting resolution of the girder are required to be less than 5 µm in both transverse and vertical directions. Besides, the Eigen frequency of magnet & girder assembly should be higher than 54 Hz to avoid the amplification of ground vibrations. To fulfill these requirements, studies on mechanical support design is now being carried out in HEPS. This paper will describe the design and progress of those work.

INTRODUCTION

HEPS storage ring consists of 48 modified hybrid 7BA achromats. The circumference is 1360.4 m and each arc section is about 28 m. HEPS is designed with very low emittance of less than 60 pm.rad to provide much brighter synchrotron light. Precise positioning and stable supports of the magnets are required. The alignment error between magnets on a girder should be less than ±30 µm in horizontal and vertical direction, and that between girders should be less than ±50 µm. Also, Eigen frequency should be higher than 54 Hz to decrease amplification of ground vibrations, which is very challenging. The requirements are listed in Table 1& Table 2 [1].

Table 1: Alignment Tolerance

Tolerances	Magnet to Magnet	Girder to Girder
Transverse	±0.03µm	±0.05µm
Vertical	±0.03µm	±0.05µm
Longitudinal	±0.15mm	±0.2mm
Pitch/yaw/roll	0.2mrad	0.1mrad

Considering the support stability, concrete plinths are adopted as the installation plane. With the higher damping, concrete can depress the vibration amplitude effectively. According to the layout of the magnets, there are 6 support units for the multipoles in each arc section, including 2 FODO modules, 2 MULTIPLET modules and 2 Q-DOUNLET modules, as shown in Fig.1. The adjacent multipoles share one girder and are seated on the plinths through adjustable wedge mechanisms, while the 5 longitudinal dipoles are bridged between the plinths.

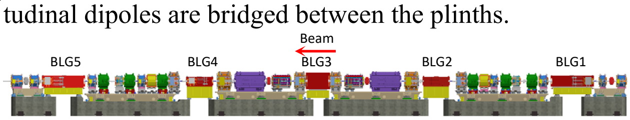

Figure 1: One arc section (1/48).

† lichunhua@ihep.ac.cn

Stringent alignment accuracy requests high adjusting resolution of the girders. Table 2 shows the requirements. The resolution should be better than 5µm in transverse and vertical directions and 15 µm in longitudinal direction. For the support unit, the mass of the magnets is a certain value and the natural frequency is mostly decided by the stiffness of the system. The mechanical design of the support is focused on the improvement of the stiffness of the whole system.

Table 2: Requirements for Support System

Parameter		**Value**
	Transverse	≤5µm
Resolution	Vertical	≤5µm
	Longitudinal	≤15µm
Eigen frequency		≥54Hz

DESIGN CONSIDERATIONS

The support unit consists of magnets, girder body, plinth and joints between each two parts and it can be simplified as Fig. 2 shows. All of above contribute to the overall stiffness of the support system and should be well designed. Mechanical design considerations include following aspects:

1. Girder supports should be as close as possible to beam height to reduce geometric amplification of ground vibrations.
2. Adequate section height of girder body will improve bending resistance and should be ensured.
3. Support span should be increased in transverse direction properly, to resist overturning moment effect.
4. Contact area between conjunction parts is critical for good stability of the whole support system.

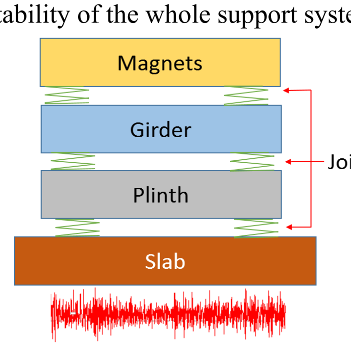

Figure 2: Support system diagram.

DESIGN OF THE SUPPORT SYSTEM

The support unit is designed as Fig. 3 shows. The girder should be capable of moving in 6 dimensions and the adjusting mechanisms are designed with 6 sets in vertical direction, 2 sets in transverse and 1 set in longitudinal

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPTS034

direction. The transverse adjusting mechanisms are located at both ends of the girder and wedges are placed vertically to give fine resolution. For the longitudinal adjusting, resolution requirement is much lower and screws are used.

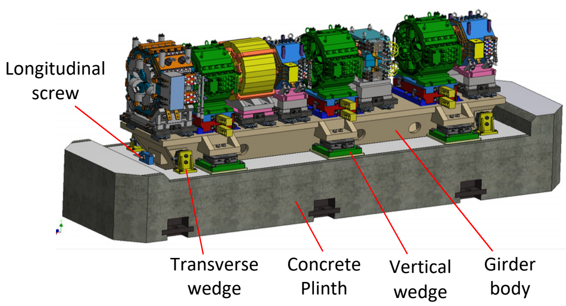

Figure 3: Support unit.

Girder Body

Girder Body should be designed with higher stiffness but less material. For a long girder, the number and location of the support points are important for bending reduction. 6-point is considered at the first place and static and modal FEA simulations were performed to determine the best arrangement of each point with a simplified model. The result is show in Fig. 4, and the best configuration are similar in both conditions.

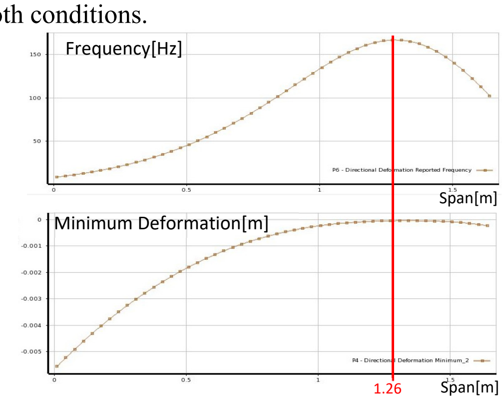

Figure 4: Support points arrangement.

Topological optimization aiming at getting the best compliance and the highest Eigen frequency of the girder was performed as well. The result is shown in Fig. 5, which gives the advice on how to distribute the certain material.

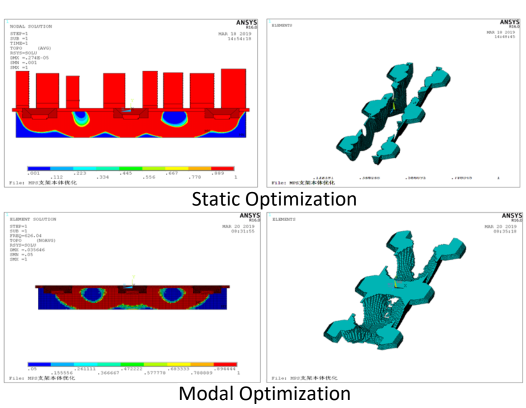

Figure 5: Topological optimization.

Support brackets are designed to raise the support height and they are designed to be strong enough to avoid becoming the weakest parts.

For the fabrication process, carbon steel weldment is easy to be fabricated, but residual stress is an issue and the deformation may destroy the alignment accuracy of the magnets, so cast steel is preferred now for the better stiffness, lower residual stress and similar costs.

Plinth

With the advantages of good stability and low cost, concrete plinth is adopted by many synchrotron accelerators [2, 3]. The normal Elastic modulus of concrete is about 30GPa, which is relative low to resist deformation. So high Elastic modulus recipe was developed and the sample achieved 53 GPa. Next the prototype of plinth will be produced and pouring test will be carried out to check the performance of the concrete plinth.

As is proved that plinth grouted on the ground will improve the contact area and increase stability substantially. The construction process is a problem. One option is to reserve steel bars for connecting on the ground during the foundation construction, then the mould and reinforcement cage are built on the spot and poured. However, in this way, the positioning accuracy is poor and hardly to improve despite of the good stability. The other solution is to precast the plinth in advance, align it in place and then do grouting, which is preferred by HEPS and test is in the plan.

The plinth is designed to be groove shape to match the girder installation, as shown in Fig. 6.

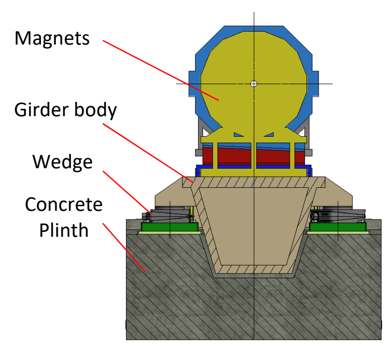

Figure 6: Sectional view of the support unit.

Adjusting Mechanism

High stiffness wedges are used as mechanisms for supporting and vertical motion. The top surface of the wedge is equipped with a spherical disc to compensate for the angle change during alignment operation and keep contact of the interface. It is beneficial to guarantee the stiffness and avoid joint stress.

Commercially wedge products have been tested on a press machine, as shown in Fig. 7. The deformation is monitored on both top and bottom surfaces by DVRT sensors and the static stiffness calculated is about 1.14E9 N/m, as shown in Fig. 8, which is lower than expected. So self-developed wedge prototype is now under study, aiming to

ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-THPTS034

obtain better performance and adaptability, as shown in Fig. 9.

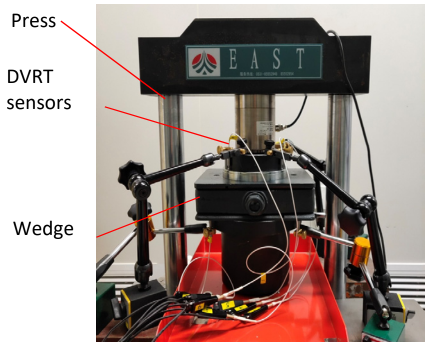

Figure 7: Wedge on test.

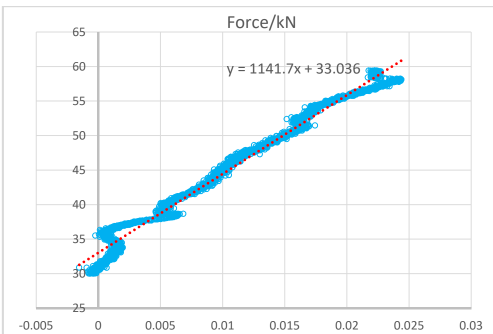

Figure 8: Wedge stiffness test result.

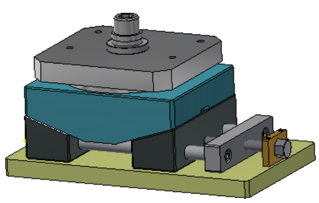

Figure 9: Self-developed wedge model.

FEA SIMULATION

FEA simulation has been performed on the support unit. Static mechanical analysis shows the maximum deformation is 15μm and the maximum stress is 2.5 MPa, which are both acceptable. The result is shown in Fig.10.

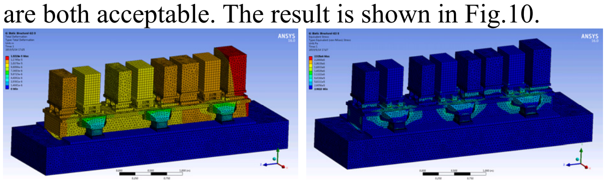

Figure10: Static mechanical analysis.

The modal analysis result is not as accurate as that of the static one. Assume that the wedge static stiffness can reach 3E9 N/m, the first natural frequency is about 90.7 Hz, which is much better than the design baseline of 54 Hz, as shown in Fig.11. In the next step, prototype will be developed and tested to check the design and further study is on the way aiming at precisely forecast the character of the support structure.

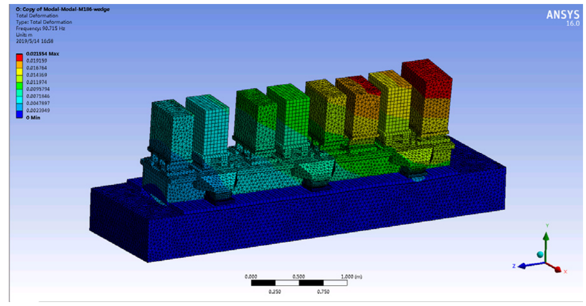

Figure 11: Modal simulation result.

CONCLUSION

The requirements of HEPS storage ring magnet support are very challenging. Detailed design is focused on the study of raising stiffness. Preliminary FEA simulation has been done, and optimization is under study to improve the performance. Prototypes are in the plan.

REFERENCES

[1] HEPS preliminary design report.

[2] Brian Norsk Jensen, "The MAX IV stability approach – From meters of clay to nanometers of optical stability", in *2nd Swedish-German Workshop on X-Ray Optics,* Berlin, Germany, April 2015.

[3] J. Collins et al., "Preliminary Design of the Magnet Support and Alignment Systems for the APS-U Storage Ring," in *Proceedings of MEDSI 2016,* Barcelona, Spain, Sep. 2016.