GIRDER AND SUPPORT SYSTEM FOR PLS-II PROJECT

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Abstract

Pohang Accelerator Laboratory(PAL) is planning to upgrade the Pohang Light Source (PLS) which is a 3rd generation light source operating since 1995. We have designed a new steel magnet girder using new schemes to achieve long-term mechanical stability, vibration suppression and precision adjusting system. Each half cell of girder is composed of three pieces, two multipole magnet girder(MMG) and one dipole magnet girder(DMG). The storage ring girders consist of 48 multipole magnet girders and 24 dipole magnet girders. The new girder systems have been fabricated and tested. Recently the girders have been installing and testing the moving mechanism in the storage ring. In this report, the design consideration for the PLSII girder and support systems are reported.

INTRODUCTION

The storage ring girder consist of 48 multipole magnet girders and 24 dipole magnet girders. Each half cell of girder is composed of three pieces, two multipole magnet girders and one dipole magnet girder. One of the multipole girder assemblies with two quadrupole and two sextupole magnets is shown in Figure 1. Each girder assembly has three parts, the girder, the adjusting mechanism and the support. These girders have adequate transverse and torsional stiffness to satisfy deflection and vibration requirement in addition to the stability requirements due to thermal distortion. As all girders must be aligned to a designed position, an adequate adjusting mechanism should be implemented. The center of the E-beam is designed to be at a height of 1.4 m to accommodate some old beamlines. The ring has in total 72 girders. The eigenfrequencies of the girder loaded with all magnets and equipped with the movers and eventual further support structure should be above 30 Hz. Maximum vertical deformation under full load should be below 50 μm [1].

The individual elements on the girder should be aligned to better than 30 μm. The precision fixation of the magnets on the girder is to be realized by precision grooves in the girder and in the supports of the individual elements. This would also allow for the fiducialization of the girder by a jig. The girder will be equipped with a leveling device above each mover for the vertical plane.

Each magnet on the girders must be separable or close to the mid plane of the magnets in order to allow the installation. The multipole magnet girder assembly should allow to speed up the installation of the storage ring tunnel. The dipole magnets will be installed individually after the installation of the multipole magnet girder assembly.

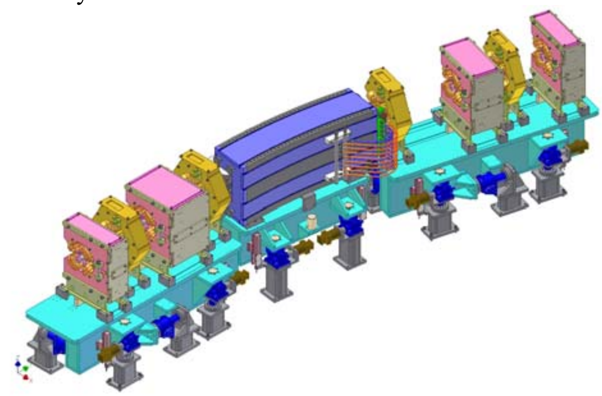

Figure 1: Girder layout for half cell of the storage ring.

GIRDER SYSTEM DESIGN

Girders are designed based on experience with the PLS I girder systems. It consisting of three supports with each vertical degrees of motorized adjustment and considering the length of the girder. We would like to make some modifications to reduce the higher gravitation deflection of the girder body and increase the adjusting range with screw jack.

Girders are used to support and to position with high precision for the storage ring magnets. Each girder together with the magnets that is placed on it (quadrupoles and sextupoles) form an assembly. The girder is a welded box structure of rectangular cross section with inner ribs and side supports. The upper girder plate serves as a reference surface and contains a high precision axial guide groove that coincides in the longitudinal direction with the electron beam direction in the straight section. The upper plate forms the interface surface between the magnets and the girder [2].

The girder has two types, referred to as MMG for the 2.4 m long girder and DMG for the 1.7 m long girder. Relative positioning of the assemblies is achieved with the help of the girder movers that form the part of the girder supports. Six movers per MMGs are used to form a three vertical support, two horizontal adjustment support and one beam direction adjustment support. A girder mover consists of base support, stepping motor, encoder and screw jacks. The girder movers are placed on supports which have a hollow box with base and top plates. Figure 2 shows girder system with moving mechanism.

The complete magnets/girders/movers package has been modeled with an FEM code and its static and dynamic properties have been optimized. The results of the optimization provided the basis of the present design and were used to define the main dimensions.

Main tolerances for the assembly:

- Magnets positioning:
  - horizontal < 30 µm
  - vertical < 30 µm
- Movers precision (step size)
  - horizontal < 3 µm
  - vertical < 3 µm

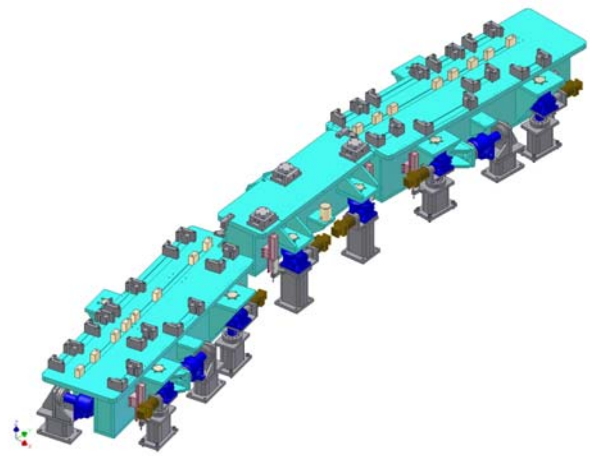

Figure 2: Girder system with moving mechanism.

Girder Body Design

The girder body is a hollow box structure with internal ribs and side brackets that are placed onto the movers. The two types of girders differ mainly in their length. The structure has rectangular cross section. In the preliminary design included here, the top plate thickness is 50 mm, the rest of the walls, ribs and side supports have the same thickness of 30 mm. The axial locations of the inner ribs and side support surfaces are defined to maximize the girder transverse and torsional stiffness and at the same time minimizing the amount of material and simplifying the construction. The vertical placement of the side supports is designed to minimize the lever arm of the applied torsion.

The finish of the side brackets bottom surfaces has tight tolerances to enable high precision alignment and positioning of the girders. Three grooves in the top plate will be used as high precision reference surfaces. The magnets will be referenced with interface blocks to these surfaces, thus pre-aligned to high tolerances, without provisions for any further alignment needed. The positioning in the horizontal plane in the transverse direction will be achieved with the help of the centre high precision groove. The transverse interface block references to the precision ground side surfaces of the groove in the top plate and to the corresponding surfaces in the end-plates of the magnets.

Table 1: Main Parameters of the Girder System

Parameters	MMG	DMG
Total length [m]	2.4	1.7
Distance between supports [m]	1.33	0.99
Height ground to the girder top [m]	0.84	0.95
Support point of girder	3	3

Vertical positioning is done using the other two grooves in the upper girder plate that are positioned symmetrically to the central groove. Here the interface blocks reference to the precision ground bottom surfaces of these grooves and to the corresponding precision surfaces on the magnet end-plates. The positioning in the horizontal plane (in both transverse and longitudinal direction) will be achieved with the help of three high precision grooves in the top plate. Vertical positioning is done using two strip-like grinded horizontal surfaces on the upper girder plate that is positioned symmetrically relative to the central groove.

Dipole magnet, equipped with three horizontal and beam direction adjustment supports, will isolated from the girder by its own supports. These supports will reference to the high precision grooves on the girders. This mechanism is adjusted by bolt. The range of adjustment for the magnet is ±5 mm. Before the final machining of the reference surfaces, the girder should be exposed to high temperature annealing in order to reduce inner stresses remaining after welding and preliminary machining and to prevent possible long term deformations.

Table 2: Mechanical Parameters of the Girder System

Parameters	Tolerance
Distance between supports, axial	± 0.1 mm
Support surfaces, vertical difference between	± 0.1 mm
Groove geometry, width	- 0.025 mm
Top girder surface	0.03 mm
Top girder surface finish (roughness)	2.5 µm
Support surfaces finish (roughness)	2.5 µm
Groove surfaces finish (roughness)	2.5 µm

GIRDER MOVER AND SUPPORT

Each girder mover system consists of screw jack system and base support. The screw jack was adjusted by stepping motor to adjust height and manually to adjust horizontal and longitudinal direction. Screw jack system consists of screw jack, gear box, stepping motor, and absolute linear encoder. The girder is mounted on the screw shafts via spherical plain bearings. Spherical plain bearings are self-aligning and enable multi-directional alignment movement to be made. It should be possible to exchange the individual movers with the whole girder assembly in place.

Table 3: Parameters List of the Mover System

Parameters	Value
Screw jack(fore), load capacity	10 ton
Screw jack(back), load capacity	20 ton
Stepping motor, max. torque (after gear box)	200 N·m
Stepping motor, number of steps	200
Gear box with 3 stages, gears ratio	320 : 1
Screw jack working range	100 mm
Absolute linear encoder, accuracy class	±5 μm
Absolute linear encoder, reproducibility	< 0.2 μm

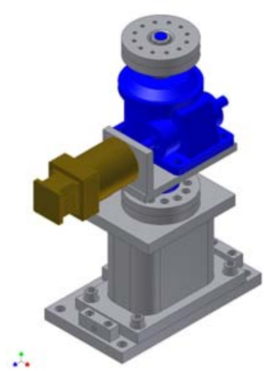

Figure 3: Base support and moving systems.

The base support is designed to be a strong foundation for the screw jack to firmly support and precisely adjust the girder. The base supports have a hollow box with base and top plates which is made of steel plate. Figure 3 shows base support and moving systems including screw jack.

ANALYSIS OF GIRDER SYSTEM

The structural deformation of the girder depends on the upper magnet. There are three vertical support, two transverse and one longitudinal support. The girder support is analysed using ANSYS [3], including the complicated geometry structure. A solid geometry is adopted for the girder and screw systems including magnets, which is fixed on the girder top plate. The support girder material is structural steel.

ANSYS result for the multipole magnet girder system in the vertical direction is shown in figure 4. The minimum deformation is 18.4μm, and the maximum deformation is 32.3μm in the vertical direction with magnet systems. Figure 5 shows the displacement of dipole magnet girder. The minimum deformation is 12.2 μm, and the maximum deformation is 21.0 μm.

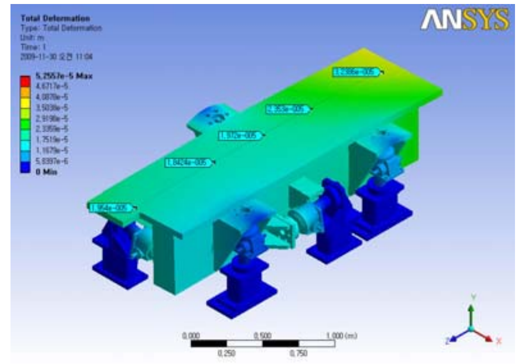

Figure 4: Displacement of MMG.

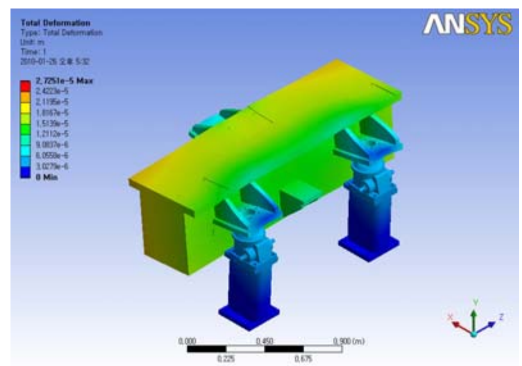

Figure 5: Displacement of MMG.

SUMMARY

The status of the PLS-II girder system is briefly summarized. The new girder system was adopted active moving system for the vertical adjustment with screw jack and stepping motors.

REFERENCES

[1] "PLS-II Technical Design Report", Pohang Accelerator Laboratory(2010).

[2] "Specification for the SLS Storage Ring Magnetic Elements and Girders" SLS-SPC-TA-1998-0301, Feb.1998.

[3] Program ANSYS, a product of Swanson Analysis System, Inc., is a commercial available 3D code by using finite element method.