ANALYSIS AND DESIGN OF BACKING BEAM FOR MULTIPOLE WIGGLER(MPW14) AT PLS

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Abstract

Pohang Accelerator Laboratory(PAL) had developed and installed a Multipole Wiggler (MPW14) to utilize high energy synchrotron radiation at Pohang Light Source (PLS). The MPW14 is a hybrid type device with period of 14 cm, minimum gap of 14 mm, maximum flux density of 2.02 Tesla and total magnetic structure length of 2056 mm. The support locations and structure of an insertion device are optimized to achieve a minimum deflection due to the magnetic loads. A Finite Element Analysis (FEA) is performed to find out the amount of maximum deflection and optimal support positions on the backing beam, the support and drive structures of the MPW14 under expected magnetic load of 14 tons. To reduce the deflection effect further, two springs are designed and installed to compensate the gap dependent magnetic loads. The optimized deflection is estimated to be about 20.6 μm while the deflection before optimization is 238 μm.

INTRODUCTION

Pohang Light Source (PLS) is a 2.0-2.5GeV 3rd generation synchrotron light source [1]. The critical photon energy of the synchrotron radiation from bending magnet is about 5.48 keV at 2.5 GeV electron energy. To utilize higher photon energy and more flux. PLS was developing a multipole wiggler that can generator high energy(~30keV) synchrotron radiation for X-ray diffraction and protein crystallography studies. The on-axis critical energy should be greater than 8 keV and central beam line should be able to operate at 3 or 4 times critical photon energy. To achieve the requirement, conventional hybrid type wiggler which used ferromagnetic poles and permanent magnet blocks was designed [2] and fabricated. Four types of insertion device (U7, EPU6, U10 and MPW14) had been installed in the electron storage ring.

The deformation of support structure from the magnetic load and gravity are analysed to optimise the deflection of the backing beam. A magnetic load compensating spring system was designed for reduced magnetic load and system friction.

MAGNETIC STRUCTURE

Hybrid magnetic configuration consists of Permanent magnets (Neomax-44h, Br=13300 Gauss, Hc=12600 Oe) and ferromagnetic poles (Vanadium Permendur) to increase the effective magnetic field of the MPW14.

3D simulations using OPERA of VECTOR FIELDS have been completed to study the optimal magnetic geometry. In the final analysis, maximum magnetic field is 2.02 Tesla The rotor magnets are used to compensate for the first integral and correct the electron trajectory. Multiple trim magnets are used to decrease the transverse multipole components and to correct the field integrals. The main parameters of MPW14 are listed in Table 1, and the geometry configuration of half period is shown in Fig.1.

The basic block of the magnetic structure is a half-period pole assembly which consists of an aluminium keeper, a Vanadium Permendur pole to achieve higher peak field and twelve Nd-Fe-B magnetized blocks. A magnetic block has an average magnetization of 1.3 T and intrinsic coercive force of 1353 kA/m. The variation of Mz from block to block affects the variation in the magnetic field from pole to pole, so the dipole moment variation and orientation error were limited on 1 % and 1 degree. The vanadium permendur pole will be machined, heat treated and then machined. Each pole will be pinned to its keeper. The magnetic block was bonded into the pole assembly. The half period pole assemblies and end-pole assemblies will be bolted to the backing beam using a milling machine and assembly holding fixture. The variation of pole heights from the lower surface of backing beam is to be within 25 μm and pole to pole longitudinal positioning accuracy is to be within ±25 μm.

Table 1: Main parameters of the MPW14 based on 2.5GeV and 250mA

Parameters	Value
Period length	14 cm
Number of full field poles	28
Peak field	2.02 Tesla
Max deflection parameter	26.4
Total power	8.30 kW
Device length	2.056 m
Magnetic gap range	10-200 mm
Max. speed	10 mm/sec
Nominal speed	5 mm/sec
Max. magnetic load	14 Tons
Encoder type	Absolute rotating encoder
Encoder resolution	1.3 ㎛
Step motor	2-phase stepper motor
Motor resolution	< 1 ㎛/step

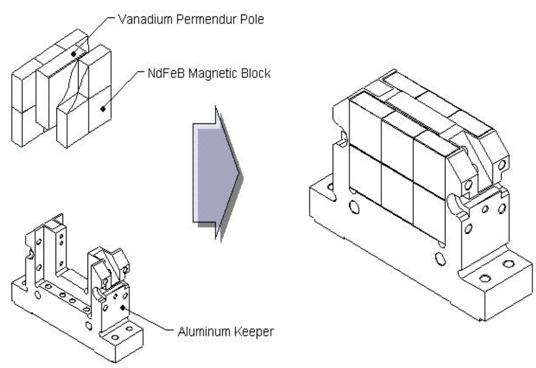

Figure 1: Geometry configuration of half period

SUPPORT STRUCTURE AND DRIVE SYSTEM

Mechanical structure of MPW14

The MPW14 consists of magnetic structure, support structure, drive system and control system. Magnetic gap is adjusted by the drive system and the support structure, which includes the L-frame to support the magnetic structure. The L-frame structure is designed to allow for easy installation of the vacuum chamber and for easy magnetic field measurement. The MPW14 shown in figure 2 was designed with very rigid moment of inertia to length ratio resulting in minimum deflection. A magnetic load compensation spring system [3] will be provided to the gap dependent. The compensation spring system will be reduced system friction, which gives better positional response from the drive system, reduced structure compression and no motor holding torque required at any magnetic gap.

The drive system provides the gap adjustment mechanism to align the magnetic structure from gap 1.0 to 20.0 cm. The drive system includes two independent drive system in a standard structure. Each drive system is composed of step motor, gear reducer and absolutely rotary encoder. The position accuracy is determined by two encoders attach on both ends of a ball screw. The measured gap repeatability is less than 7 μm.

Deformation of backing beam

The structural deformation of the backing beam depends on the pole gap. The backing beam is designed to support a maximum magnetic load of 14 metric tones at minimum gap. The support point for the backing beam will be located to achieve minimum deflection. The backing beam was analysed by ANSYS [4] using the commercial available 3D FEM code for easy modelling of the complicated geometry structure. The solid geometry was adopted for the backing beam including girder which was fixed at ball screw and linear motion guide. The backing beam is made of aluminium A6061-T6 and the girder is made of nonmagnetic material stainless steel

Figure 2: Photograph of MPW14

316L. For study of the worst case for the backing beam, 14 metric tons magnetic loads were applied for estimation of the backing beam deformation. The deformation of backing beam was analysed at no load, maximum magnetic load and maximum magnetic load with reaction force. The results are shown in figure 3.

A minimum deformation at no load is 6 μm and a maximum deformation at maximum magnetic load is 216.5 μm in the vertical direction, and then, gradually analysed with reaction force to reduce the magnetic load with a magnetic load compensation spring system.

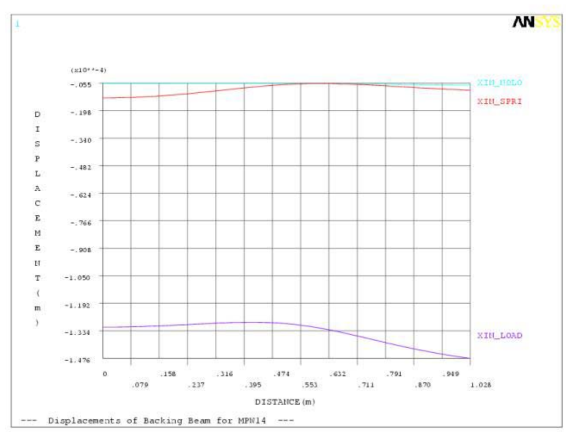

Figure 3: ANSYS results for the backing beam in the vertical (y) direction along Z-direction(beam pass) of backing beam at no load, maximum magnetic load and maximum magnetic load with reaction force.

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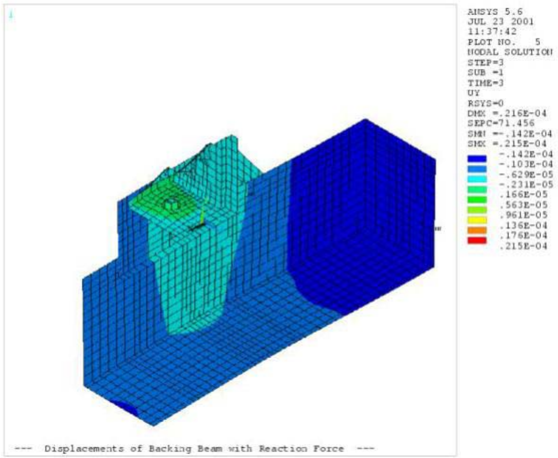

Figure 4: ANSYS result for the backing beam in the vertical (y) direction. The maximum deformation is about 21.60 μm if 14 metric tons of magnetic load and reaction force with magnetic load compensation spring system are applied.

A minimum deformation is 21.60 μm in the vertical direction at 90% of reaction force with magnetic load compensation spring system, as shown in Fig.4. The deformation in the other two directions can be neglect. The magnetic load compensation spring system will be provided for reacting the gap-dependent magnetic load. Figure 5 shows magnetic loads and spring loads versus magnetic gap-dependent. The magnetic load compensation spring system, as shown in Fig. 6, consists of several stacks of Belleville washers to match the 90% of magnetic load.

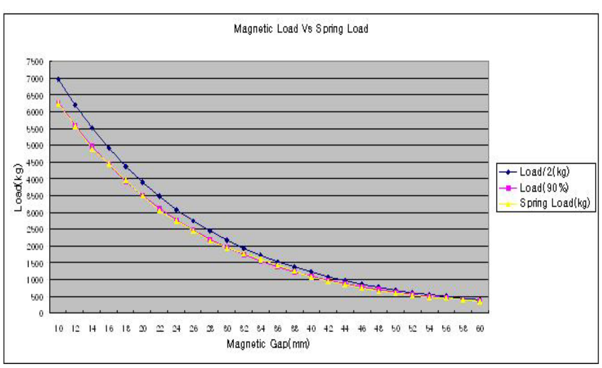

Figure 5: Magnetic load and spring load Vs magnetic gap-dependent

Drive and control system

The drive and control system can open and close the magnetic gap. Gap motion is achieved with a stepper motor, gear box and left-handed & right-handed 5 mm pitch ball screw at each side. The upper and lower backing beams are attached to ball screw and magnetic load compensation system. The stepper motor is connected to the gear box which is 20:1 reduction unit.

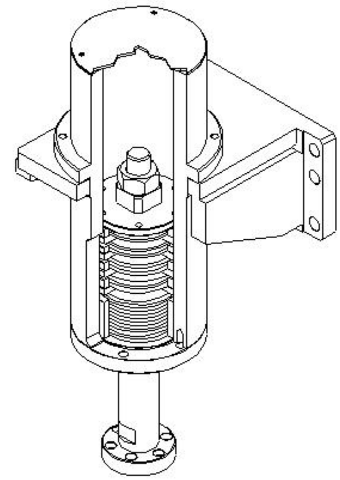

Figure 6: Design of magnetic load compensation spring system

Two S106-250 stepping motors and AR-C absolute rotary encoders from Paker Co. are used to control magnetic gap. The motor systems had sufficient position accuracy to satisfy the specification. Test result of the structure and the control system are less than ±5 μm of magnetic gap parallelism and 7 μm of gap reproducibility.

SUMMARY

PLS had developed 14 cm period multipole wiggler for the high flux macromolecular crystallography beam line. It features 2.02 Tesla, 24 poles at minimum magnetic gap of 14 mm. The maximum deflections of backing beams are estimated to be about 21.6 μm with the compensation spring under load of 14 metric tons and gap reproducibility of structures are 7 μm.

REFERENCES

[1] "PLS Conceptula Design Report", Pohang Accelerator Laboratory,(1992)
[2] D.E.Kim, et.al., "Conceptual design of 14cm period multipole Wiggler at PLS", Nucl. Inst. & Meth. A 470, 56(2001)
[3] "U5.0 Undulator Conceptual Design Report" LBLPUB-5256, (November 1989).
[4] Program ANSYS, a product of Swanson Analysis System, Inc., is a commercial available 3D code by using finite element method.