ANALYSIS AND DESIGN OF BACKING BEAM FOR U10 UNDULATOR AT THE PLS

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Abstract

Pohang Accelerator Laboratory(PAL) had developed an U10 undulator to utilize low energy synchrotron radiation at Pohang Light Source (PLS). The U10 is a hybrid type device with 10cm period, minimum gap of 16mm, maximum flux density of 1.49 Tesla, 1625mm total magnetic structure length. The support locations and structure of an insertion device are optimized to achieve a minimum deflection due to the magnetic loads. First, Finite Element Analysis (FEA) are performed on the backing beam, support and drive structures of the insertion device under expected magnetic load of 10 tons to determine the maximum deflection and optimal support locations. To reduce the deflection further, springs that compensate the gap dependent magnetic loads are designed and implemented. The optimized maximum deflections are estimated to be about 20μm while the deflections before optimization are 214μm.

INTRODUCTION

The Pohang Light Source (PLS) is designed to provide intense, bright synchrotron radiation from VUV to hard X-rays. Four types of insertion device (U7, EPU6, U10 and MPW14) had been installed in the electron storage ring. The U10 undulator was installed on August 2001.

The U10 is a wedged-pole hybrid type undulator that has 34 poles (including end poles), 10 cm period and 1.53 T effective field at 16 mm gap. U10 is optimised for radiation between 6 and 1000 eV at 2.5 GeV electron energy [1]. The magnetic saturation of pole is avoided by increasing the thickness of the ferromagnetic pole for high field region. In addition, widening the pole tips reduces the higher order harmonic contents of the field.

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 to counteract the gap dependent magnetic force and system friction. In this paper, all the efforts to reduced the deflections in U10 undulator is summarized.

DESIGN OF U10 UNDULATOR

High performance rare earth permanent magnets (Neomax-44h, B_r=13300 Gauss, H_c=12600 Oe) and ferromagnetic poles (Vanadium Permendur) are used for higher peak field. Also the pole has a wedged shape to reduce pole saturation and to increase the effective magnetic field.

3D simulations using OPERA of VECTOR FIELDS have been completed to study the optimal magnetic geometry. In the final analysis, maximum magnetic field is 1.49 Tesla with effective field of 1.53 Tesla. This compares with maximum magnetic field is 1.51 Tesla with effective field of 1.44 Tesla for the case of hexahedron magnet blocks. Using wedged pole and magnet geometry, we estimate about 10% increase in manufacturing expenses and challenges in bonding and aligning blocks. 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 contents and correct the field integrals. The main parameters of U10 undulator are listed in Table 1, and the geometry configuration of half period is shown in Fig.1.

Table 1: Major parameters of U10 undulator

Period length	10 cm
Number of full field poles	28
Max. field	1.49 Tesla
Effective field	1.53 Tesla
Photon energy range	6~1000 eV
Device length	1.67 m
Magnetic gap range	16-126 mm
Max. gap movement speed	10 mm/sec
Nominal speed	5 mm/sec
Max. magnetic load	100 kN
Encoder type	Absolute rotating encoder
Encoder resolution	1.3 μm
Step motor	2phase stepper motor
Motor resolution	< 1 μm/step

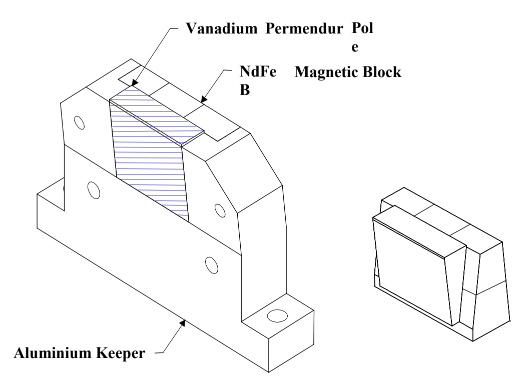

Figure 1: Geometry of the half period assembly

SUPPORT STRUCTURE AND DRIVE SYSTEM

Mechanical structure of U10 undulator

The U10 undulator consists of magnetic structure, support structure, drive system and control system. Magnetic gap is adjusted by the drive system and support structure. The support structure includes a L-frame for supporting the magnetic structure. The L-frame structure is selected for easy installation of the vacuum chamber and for easy magnetic measurement. The undulator shown in Fig. 2 was designed with very rigid moment of inertia to reduce deflections. The supporting points are selected to give minimal deformation when loads are applied. To reduce the deformation further for the whole gap range, a load compensation spring system [2] that closely counteracts the expected magnetic loads are designed and implemented. The compensation spring system also gives a better positional response from the drive system. It also reduces structure compression and no motor load holding torque is required at any magnetic gap.

The basic building block of the magnetic structure is the half-period pole assembly, Fig.1, which consists of an aluminium keeper, a Vanadium Permendur pole and six Nd-Fe-B magnetic blocks. A magnetic block has an average magnetization of 1.3 T and intrinsic coercive force of 1353 kA/m. The variations of the magnetic dipole moment of the blocks are controlled to be less than 1%. Also the transverse component of the magnetic moment was limited to give angular error of less than 1 degree.

Figure 2: Photograph of U10

The half period pole assemblies and end-pole assemblies are bolted to the backing beam using a milling machine and assembly fixture. The variation of pole heights from the lower surface of backing beam is within 25 μm and pole to pole longitudinal positioning accuracy is controlled within ±25μm.

The drive system provides the gap adjustment mechanism to separate the magnetic structure from gap 1.6 cm to 21.0 cm. The drive system includes two independent drive system groups in a standard structure. Each drive system is composed of step motor, gear reducer and absolute rotary encoder. The position accuracy is determined by the encoders attached on both ends of a ball screw. The 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 10 metric tons at the minimum gap. The support point for the backing beam is located to achieve minimum deflection. The backing beam was analysed by ANSYS [3] which is a commercial available 3D FEM code. The backing beam is made of aluminium A6061-T6 and the girder is made of nonmagnetic material stainless steel 316L. For study of the worst case for the backing beam, 10 metric tons of magnetic loads are 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 as shown in Fig. 3.

A minimum deformation at no load is 6 μm and a maximum deformation at a maximum magnetic load is 216.5 μm in the vertical direction. And the compensating reaction force is gradually increased to find optimal reaction force profile for minimal deformations.

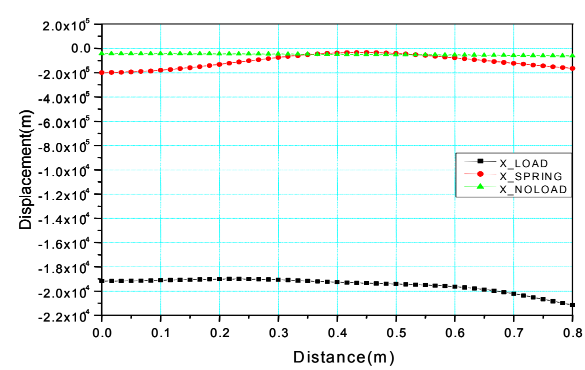

Figure 3: ANSYS result for the backing beam in the vertical (y) direction along Z-direction(beam pass) of backing beam at no load, maximum magnetic load and maximum magnetic load with reaction force.

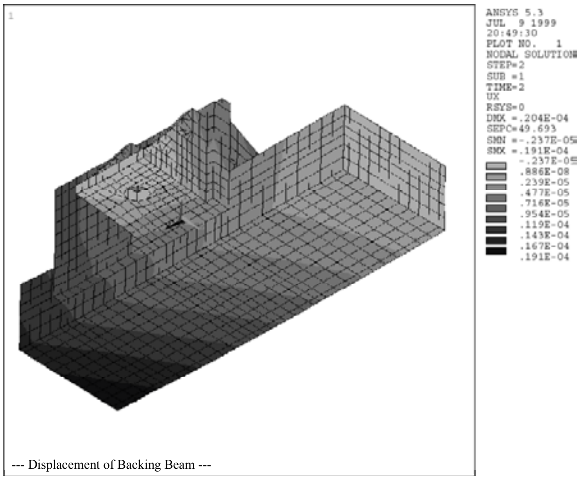

Figure 4: ANSYS result for the backing beam in the vertical (y) direction. The maximum deformation is about 20 µm if 10 metric tons of magnetic load and reaction forces from the compensation spring system are applied.

A optimized maximum deformation is 20 µm in the vertical direction when 84% of the magnetic loads are reacted by the load compensation spring system. The final analysis is shown in Fig.4. The deformations in the other two directions are negligible. Fig. 5 shows magnetic loads and reacting spring loads versus magnetic gap. The magnetic load compensation spring system, as shown in Fig. 6, consists of several stacks of Belleville washers to react the designed portion of the magnetic load..

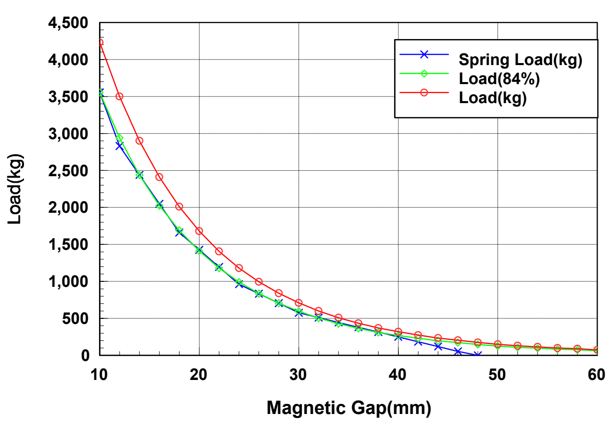

Figure 5: Magnetic load and spring load Vs magnetic gap

Drive and control system

The drive and control system opens and closes the magnet gap. Gap motion is achieved with stepping motors, 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

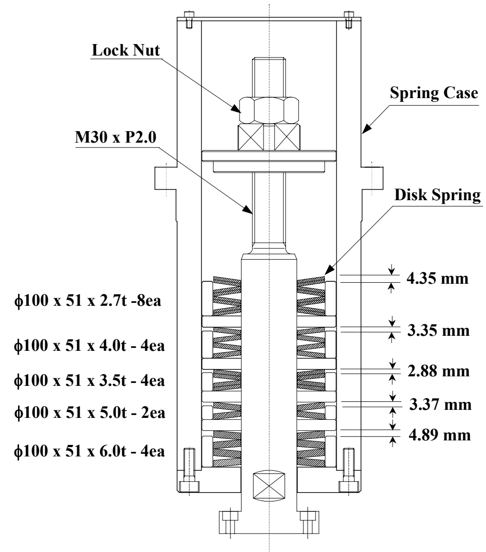

Figure 6: Design of magnetic load compensation spring system

the gear box which has 20:1 reduction ratio. A compumotor system is used to drive and control the magnetic gap. The stepper motor is a S106-250, the drive system is a SX-8 and the absolute rotary encoder is the AR-C. Test result of the structure and the control system are ±5µm of magnetic gap parallelism and 7 µm for the gap reproducibility.

SUMMARY

A wedged-pole hybrid 10 cm period U10 undulator has been developed at PLS. With optimum selection of the support position and applying compensating spring systems that counteract the gap dependent magnetic forces, the maximum deflections of backing beams for all magnetic gaps are controlled to within 20 µm. The gap reproducibility was less than 7 µm which is enough for our applications.

REFERENCES

[1] H.S. Suh, H.G. Lee, K.H. Park, Y.G. Jung, D.E. Kim, and C.W. Jung, “DEVELOPMENT OF U10 UNDULATOR AT THE PLS”, APAC, Beijing, China, 2001

[2] “U5.0 Undulator Conceptual Design Report” LBLPUB-5256, (November 1989).

[3] Program ANSYS, a product of Swanson Analysis System, Inc..