FABRICATION AND MEASUREMENT OF PLS EPU6 UNDULATOR *

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Abstract

Pohang Accelerator Laboratory(PAL) is developing an Elliptically Polarized Undulator to utilize the polarized synchrotron radiation at Pohang Light Source(PLS). EPU6 is a Sasaki-Type elliptical undulator, which changes the polarization of the field by translating the quadrants arrays. EPU6 features period of 6cm, minimum gap of 18mm, 25 full field periods,maximum vertical flux density of 0.69 Tesla, maximum horizontal flux density of 0.46 Tesla, and 1575mm total magnetic structure length. The support/drive structure from Danfysik Inc. which was used for ESRF undulators is adopted for faster fabrication. In this article, the design, fabrication, and the preliminary results of the magnetic measurements of EPU6 are described.

1 INTRODUCTION

Pohang Accelerator Laboratory (PAL) is constructing an Elliptically Polarized Undulator (EPU6) to utilize polarized light from Pohang Light Source (PLS). Major parameters were fixed at the end of 1996, and the most design, fabrication efforts were carried out during 1997. It's a Sasaki type elliptical undulator featuring strong magnetic field compared to other type of elliptical undulator[1]. EPU6 has 6cm period which is optimized for highly polarized radiation in 80 eV to 1500 eV at 2.0 GeV electron energy. The major parameters of EPU6 are summarized in Table 1. In this article, the efforts for developing EPU6 undulator for PLS are briefly described.

Table 1: Major parameters of EPU6 undulator

Period Length (λ_u)	6	cm
Gap Range	18-120	mm
Number of Period	25	
Length of Magnetic Structure	1575	mm
Peak Vertical Field (D=0)	0.69	Tesla
Peak Horizontal Field(D=0.5λ_u)	0.46	Tesla
Circular Polarized Field (D = 0.31 λ_u)	0.38	Tesla
Entrance/Exit Sequence	+0.5,-1,+1	
rms. Random Error	0.64	%
Switching Frequency	1/30	Hz
Photon Energy Range	80-1500	eV

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2 DESIGN AND FABRICATION OF EPU6

To reduce the fabrication cost and the project schedule, the existing support/drive structure which was used for ESRF undulators is purchased from Danfysik Inc. For a typical magnetic load of 10kN the deflection of the girder is less than 30μm. It can support and drive maximum magnetic load of 100kN. The gap reproducibility of the girder is less than 50 μm that is coming mostly from backlash. The motor resolution is less than 1μm/step.

The magnetic structure consists of 4 quadrants of NdFeB block arrays. Each block array is usual 4 block/period pure CSEM (Current Sheet Equivalent Material) configuration. Sliding the diagonal arrays together with the fixed other diagonal arrays changes the polarization of the magnetic field. A simple code that is based on the summation of the analytic expression for a single block is developed to calculate the magnetic properties of the EPU6 [2]. In Fig. 1, the typical magnetic field profile for minimum gap of 18 mm at phasing of 0.25 λ_u is illustrated.

The magnetic structures are assembled on the backing beam which is aluminum alloy(A6061-T6). Two movable quadrants are connected through very precise linear motion(L/M) guide for phase change between quadrants. The sliding of quadrants is carried out using ball screw and step motors. ANSYS code is used to analyze the possible deformations due to the gravity and the magnetic load. The results of ANSYS analysis showing the deformations and the stress level are shown in Fig. 2. It shows maximum deflection of 15 μm that is acceptable for EPU6. Also to resist the horizontal attraction/repulsion between quadrants, side plates with L/M guides are designed and implemented.

The magnetic structures assembled on the support/drive structure are shown in Fig. 3.

3 MAGNETIC MEASUREMENTS

The magnetic measurements of EPU6 should verify the transparency of the EPU6 to the stored electron beam for all gap ranges. Following the experience of PLS U7 measurements, the integrated dipole components should be less than 100 Gcm for both normal and skew components. The reproducibility of the field integral should be better than 10 Gcm. Also the pole to pole random error should be less than 0.64% after correction. 0.64% random errors are expected to result a 30% reduction in the peak spectral flux density of the 5-th harmonic undulator radiation[3]. Since EPU6 is using only pure CSEM, and the field is depending directly from the physical properties of the magnetic material which has *rms.* fluctuation about 2%. Therefore, achieving 0.64% *rms.* error level in the EPU6 is non trivial.

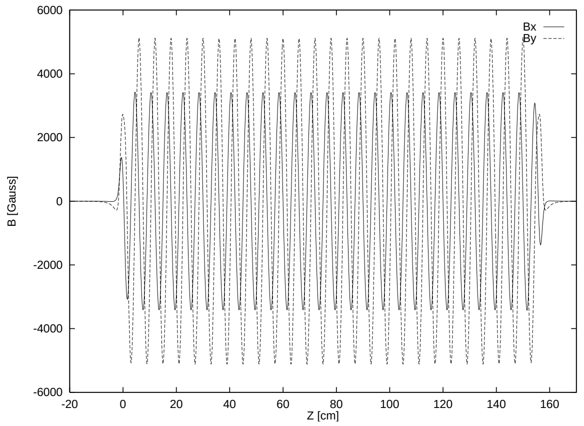

Figure 1: Typical B profile for 18 mm gap with $D = 0.25\lambda_u$.

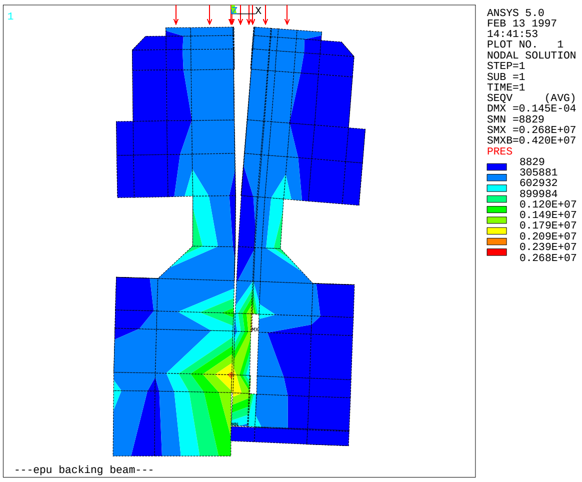

Figure 2: Ansys analysis of backing beam

The measurements should provide the necessary information to correct each of the magnetic keeper assemblies.

3.1 Measurement System

The magnetic measurements system consists of LMS(Linear Motion System), DAS(Data Acquisition System), Hall probes, point coils, DVM, and software integrating all of the components. The LMS(Model: LMS-2200C, Manufacturer: Dukin Co., Ltd) translates the probe assembly in longitudinal direction and has a linear scale which can resolve better than 0.5 μm with straightness better than 4μm. The scanning range is 2200mm and the maximum scanning speed is 200mm/sec. The LMS is optimal for the measurements of relatively short (about 1.5m) IDs.

3.2 Hall Probe Measurements

The scanning of Hall probe should be fast enough (less than 1min) to reduce signal drifts due to the temperature variation and to reduce the measurement time. The GROUP3 DTM-141 gauss meters and the MPT-141 Hall probes which have active area of $1.0\text{mm} \times 0.5\text{mm}$ are used for Hall probe measurements. A Hall sensor has a non-linear response to the magnetic field and to the temperature. The MPT series Hall probes have a calibration table in the PROM for compensation of these non-linearities. However, the data conversion rate of DTM gauss meter is so slow ($\sim$ 10 Hz) that the on-line PROM calibration can not be used for the measurement which requires about 100 readings/sec. For a fast data acquisition, the "raw" Hall voltage is calibrated off-line using the manufacturer supplied calibration table, instead of the relatively slow on-line PROM calibration. The analog DC output voltage of the gauss meter is read first and then calibration table is applied off-line to convert the voltage to the magnetic field. The necessity and the advantage of the off-line calibration are described in [4].

Reducing the system noise is an important task to guarantee the system stability, and to get a reliable data set for the Hall probe measurement. To reduce the electrical noise, we took the following measures. It is found that the noises from the stepping motor drivers are the dominant source of noise. To alleviate this problem, separate AC lines and grounds are used for motor drivers and other equipment. Also, two uninterruptable power supplies(UPS) which always generates true AC sine wave are used. A step down transformer from 220[V] to 100[V] is inserted between the UPS and the motor drivers to reduce the noise feed back through the AC line. In addition to this, all digital signals are isolated by photo couplers and all electronic equipment is designed to share the common ground.

The system noise level is measured at different aperture times while the Hall probe is located in a zero gauss chamber. The test shows that for $\simeq$ 10cm/sec longitudinal speed, 3 msec of aperture time is a good compromise between the noise and the spatial resolution[5]. For 3 msec of aperture time, the noise in terms of fields is about ± 0.5G. This corresponds about 100 μV in 1.2 T range of the gauss meter.

At present, the each half of the magnetic structure is being measured separately because correction of the block keeper assembly after the final assembly would be difficult. The intention is to measure, and correct the each part separately while verifying the accuracy, stability and reproducibility of the measurement system. After this procedure, the lower and upper part will be assembled as a final structure.

The preliminary measurement shows that the non-corrected lower (upper) magnetic structures have random pole to pole *rms.* error of 1.3% in B_y, and 0.8% in B_x which exceeds the design requirements of 0.64%. Correction procedures are being developed to compensate the local errors. Efforts are concentrated to optimize the errors for both left, right circular operation modes. The reproducibility of the field integral measurements showed fluctuations of $\pm$3Gcm that is satisfactory and well within the measurement requirements.

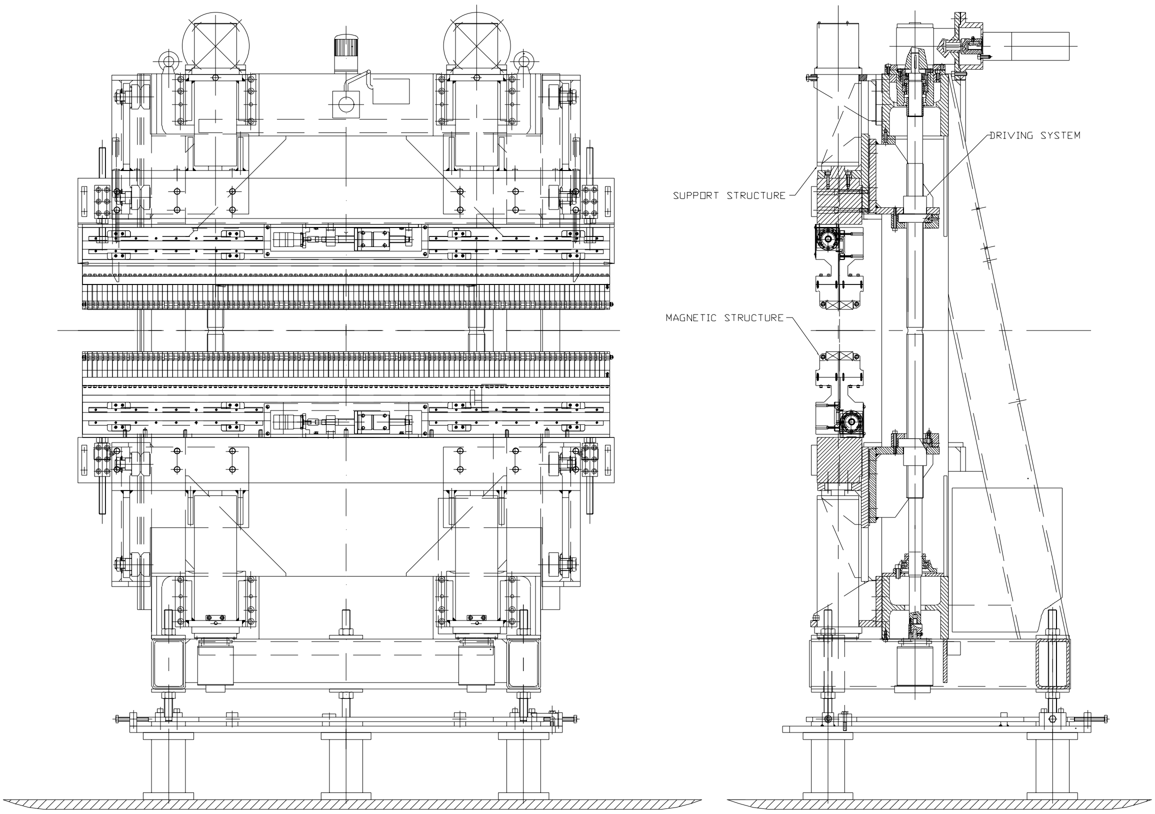

Figure 3: Assembly of PLS EPU6 Undulator

3.3 Point Coil Measurements

Also, point coils with flux meter are tested to measure the magnetic fields. It has difficulty in spatial resolution coming from the size of the coils (a few mm), and noise in the flux meter. The point coil measurement system is practically same with Hall probe scanning system. The Hall probe and the gauss meter are replaced by point coil and a flux meter. Point coils are wound on a rectangular mandrel of size 3 mm$\times$ 5mm with 60 turns. The coils are placed in a uniform field with flux meter to characterize the NA (area times number of turns). The field profile measurement using point coils follows closely the hall probe results. However, the peak field measurements by point coils showed a fluctuation of about 10G after linear drift corrections which exceeds the measurement requirements. The noise of the flux meter after the linear drift correction is the main reason for the errors. The noise is estimated to be about 7 mV and efforts are going on to reduce them. If this problem is solved, the point coil can be a useful probe.

4 CONCLUSIONS

PAL is developing an EPU6 to utilize the polarized synchrotron radiation at Pohang Light Source(PLS). EPU6 has 6 cm period which is optimized for highly polarized radiation in 80 eV to 1500 eV at 2.0 GeV electron energy. In this report, the design efforts and development of measurement system for the EPU6 are presented with some preliminary results of the magnetic measurements.

5 REFERENCES

[1] Shigemi Sasaki, “Analyses for a planar variably-polarizing undulator”, NIM in Physics Research A, Vol. A347, pp.83-86, 1994.

[2] D.E. Kim et al., “Analysis of PLS EPU6 Parameters”, PAL Internal Report PAL-PUB-97-001, 1997.

[3] B. Kincaid, “Random errors in undulators and their effects on the radiation spectrum”, NIM in Physics Research A, Vol. A246, pp.109-119, 1985.

[4] S. Marks, “Precise integration of undulator hall probe scans”, IEEE transactions on magnetics Vol 30, No4,pp. 2435-2438, 1994.

[5] K.H.Park et al., “Magnetic Measurement of PLS U7 Undulator”, MT-15 Conf. , Beijing, China, 1997.