AN APPLICATION OF LASER POSITION SENSING DETECTOR FOR MAGNET CENTRALIZING SYSTEM

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Abstract

Taiwan Photon Source (TPS) project has been proposed to create a 3GeV synchrotron light source. The designated ultra-low emittance of this new light source requires high precision positioning of storage ring magnets. The alignment of all magnets is very importance since it directly affects the closed orbit of electron beams. Previously, conventional on-site alignment of the magnets was mainly relying on the theodolite performance. The cumulated errors could be in the order of 0.1mm. In this paper, a new alignment scheme is proposed to enhance the on-site alignment of magnets for TPS project. To achieve the high precision requirements, a device possessing the advantages of expansion mandrel in conjunction with Position Sensing Detector (PSD) is employed to provide a better mechanism to properly align the centers of the both quadrupole and sextupole magnets completely installed on girder.

INTRODUCTION

The accuracy and precision of magnet position play important roles for stability of electron beams during the operation of synchrotron radiation accelerator. The alignment of quadrupole magnets directly affects the closed orbit of electron beams in synchrotron light source. In past years, many efforts have been performed to accurately locate the magnetic center of quadrupole magnets, which include Hall probe measurement, pulsed wire technique, vibrating wire field measuring technique, moving wire technique, moving probe technique, and rotating coil technique, etc [1]. Through these techniques, individual quadrupole magnetic center could be identified with less than 50μm error. However, when aligning two or three quadrupole magnets on girder, the error generated from using fiducial and theodolite could be cumulative. In 2007, Tsai *etal* [2,3] uses the vibration wire method to check and align the magnetic center of multiple quadrupole magnets on a girder before installation of vacuum chambers. Although it has only been verified that the accuracy of this proposed method is better than the theodolite resolution, this novel method has the potential to align magnetic centers of multiple quadrupole magnets on one girder to 30μm. In 2011, Chen *et al* [4] designed novel optical inspection architectures for positioning the quadrupole and sextupole magnets, respectively. The laser positioning systems have been already employed to eliminate the error due to the magnets manufacture in 2012 [5]. In this paper, the laser positioning systems will be further applied to alignment inspection of quadrupole and sextupole magnets when the installation of magnets has been completed on a girder.

DESIGN OF PSD MODULE

The position sensitive detector (PSD) has been widely used in many engineering areas to precisely align multiple targets. It is composed of large area photodiodes to detect and record the position of an incident light beam. The PSD system can measure position movement with high resolution (to the sub-micron level depending on the active area of PSD). In a previous paper of the authors [5], a laser positioning system has been developed, which consists of one laser, two PSD and two granite blocks. The laser will be adjusted to parallel to and have equidistance to the girder's datum planes by reference to the two granite blocks. The two granite block is an assembling mechanism and can be corrected under 5 um error. The laser can represent to the datum line which is extended from girder's datum planes. The PSD is mounted on a circular jig and will be adapted on the pole center of magnet to stand for mechanical center of magnets.

The PSD module is designed to position the mechanical center of magnet. We mount the PSD sensor on a position circular steel module and can adjust the geometric center of the PSD sensor to be the same as the center of steel module. This circular PSD module will be applied to insert into quadrupole and sextupole magnet, as shown in Figure 1 (a). Due to the tolerance and errors obtained from manufacturing magnets, the circular jig contact magnet with only 2 points under the condition that the circular jig is smaller than magnet bore radius. Some gaps between PSD circular module and poles due to the errors obtained from manufacturing magnets, can be estimated by inserting thick gauge.

To reduce the effect of the errors obtained from manufacturing magnets, the manufacturing error must be estimated in advance. A stepped arbor is developed as a diameter gauge, and is ground to three steps diameter for suiting to magnets. There are two sets of three-stepped arbor fabricated. The diameters of these two sets of arbor are classified to six steps from 74mm+0.027mm to 74mm- 0.027mm. One of the 3-stepped arbor is shown in Figure 1 (b).

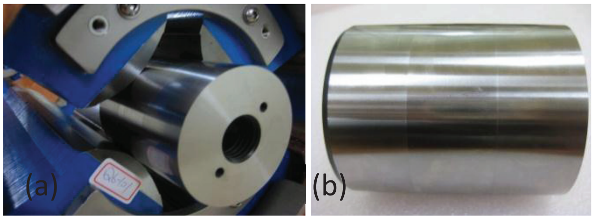

Figure 1: (a) The three-stepped arbor can be applied to insert into the quadrupole magnet. (b) The diameters of three-stepped arbor are 74.000mm, 73.991mm, and 73.973 mm, respectively.

To reduce the errors obtained from manufacturing magnets, the PSD circular module is considered to be in conjunction with an expansion mandrel, as shown in Figure 2 (a), which is specified for fitting for magnets. The diameter of the expansion mandrel can be expanded 95um at most by adjusting screw to alter internal oil pressure. The original diameter of the expansion mandrel is 73.95mm when unenforced a mandrel, and can be expanded to 74.045mm at most by altering internal oil pressure. No matter forced or unforced, the roundness of this expansion mandrel can keep under 3um.

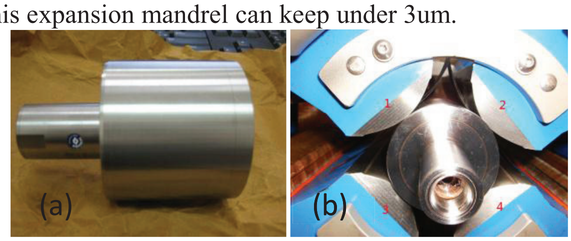

Figure 2: (a) Typical plot of the expansion mandrel (b) The expansion mandrel can be applied to insert into the quadrupole.

EXPERIMENT AND RESULT

Magnet Bore Radius Measurement

It follows almost the same procedure as used in the previous paper of authors [5]. Both stepped arbor and expansion mandrel are used to inspect the bore radius of magnets. The diameter of expansion mendrel is at unforced situation for inspection. The setup of magnet centralizing system is as shown in Figure 3.

Figure 3: The setup of magnet centralizing system.

Test of Laser Positioning System

A dual axis PSD is applied in system. Outputs of PSD are analog voltage signal for representing horizontal and vertical positions of laser spot centroid. The PSD output voltages have to transfer to micrometer scale for dimension quantification. The laser beam is disturbed by air and beam pointing is stable insufficiently. To eliminate the disturbance as described above, the foam tube has been used and adapted among the magnets. Figure 4 shows the facilities. Since foam is soft and may bend to interrupt the laser beam, an aluminium tube is fabricated to hold foams. After installing the foam tube, the stability of laser beam can be improved obviously.

Figure 4: A foam tube coated with aluminum tube is introduced for eliminating air disturbance.

Installation Test of PSD Expansion Mandrel Module

The circular PSD expansion mandrel module is adapted into quadrupole magnet on girder. To check the repetition of system, the expansion mandrel is inserted on three quadrupole magnets repeatedly, due to that the expansion mandrel is cylinder and will incline along the profile of the magnet pole. The consistent situation of the expansion mandrel is very significant for positioning the centers of magnets. To improve the repetition of magnet centralizing system, the following procedures should be done:

1. Apply fixed torque to expansion mandrel.
2. Add a level gauge on the expansion mandrel to keep the same orientation.
3. Insert the circular jig as the same depth and contact the same points on magnet

Test of Positioning the Centers of Magnets

The circular PSD expansion mandrel module is employed to position the centers of magnets. The bias of centers of magnets on 4th girder is in Figure 5, where linear variation of bias is observed. It may be due to the fact that magnet centralizing system causes systematic error. We can therefore centralize the mechanical centers of magnets through the offset from the measured bias against the ideal plane (constructed by the closed orbit of electron beams).

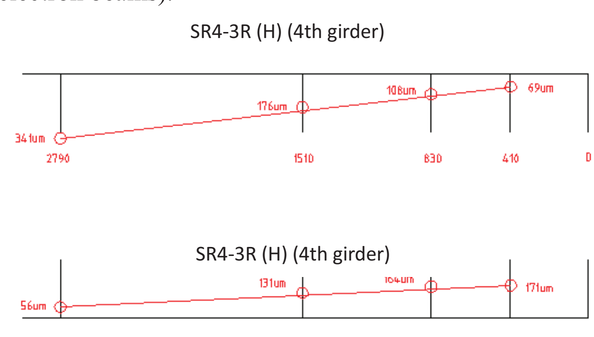

Figure 5: Typical plot of the bias of centers of magnets on 4th girder.

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Test of Straightness of Girders

To verify the effect of the variation of straightness of girders due to heavy loading from the weight of magnets, we further measure the straightness of girders after lifting all magnets on girders in R19 section. It should be mentioned that the difference in straightness of vertical direction of girders between with and without dipole magnet are somewhat larger, as shown in Figure 6, due to the increment from the weight of Dipole (bending) magnet. However, the difference in straightness of horizontal direction of girders between with and without dipole magnet is relatively small, as shown in Figure 7.

SUMMARY

In this paper, the laser positioning systems are applied to alignment inspection of quadrupole and sextupole magnets when the installation of magnets has been completed on a girder. From the linear variation of bias, due to magnet centralizing system causes systematic error, we can therefore centralize the mechanical centers of magnets through the offset obtained from the measured bias against the ideal plane constructed by the closed orbit of electron beams. In addition, we also verify the straightness of girders with or without dipole (bending) magnets. In general, due to due to the increment from the weight of Dipole (bending) magnet, the difference in straightness of horizontal direction of girders between with and without dipole magnet is relatively smaller than that of vertical direction of girders.

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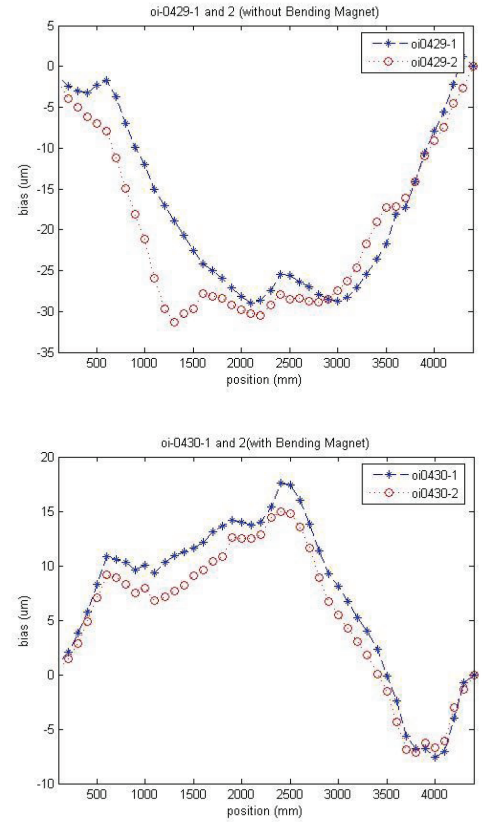

Figure 6: Typical plot of the difference in straightness of vertical direction of girders between with or without dipole magnet.

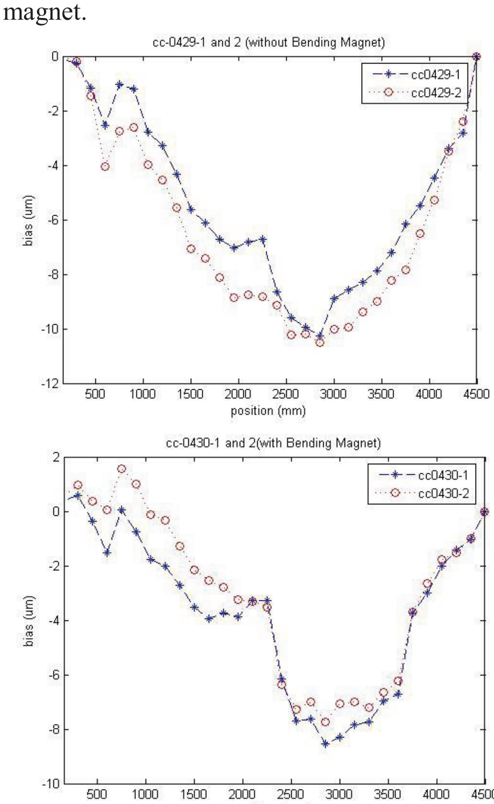

Figure 7: Typical plot of the difference in straightness of horizontal direction of girders between with or without dipole magnet.