DESIGN AND DEVELOPMENT OF A LASER POSITIONING SYSTEM FOR TPS MAGNETS ALIGNMENT INSPECTION DURING THE INSTALLATION ON A GIRDER

M.L. Chen, H.C. Ho, W.Y. Lai, Y.L. Tsai, K.H. Hsu, S.Y. Perng, H.S. Wang, T.C. Tseng, J.R. Chen
NSRRC, Hsinchu, Taiwan

Abstract

A novel optical inspection architecture is designed and developed for positioning the TPS (Taiwan Photon Source) quadrupole and sextupole magnets on the girder within 30 um. This positioning system is a laser-based scheme consists of two laser position sensing devices (PSD) and two granite blocks as the standard reference of magnets. The laser position sensing device (PSD) is mounted on an adjustable circular steel module and the module is installed in a granite block. With the PSD position being adjusted and corrected, the PSD module center can be identical to the ideal pole position of magnets on the girder within 15um. The laser ray is also adjusted and aligned according to the ideal reference line of magnets. Finally the granite blocks are replaced with the quadrupole and sextupole magnets at installation, the assembling error of magnets can be detected from the PSD module. This paper describes the detail of the system development and current testing results.

INTRODUCTION

Taiwan Photon Source (TPS) is under construction. The lattice of the storage ring is a 24-cell DBA design with 24 straight sections and a 518.4 meter-circumference [1]. The magnets of a lattice cell are installed on three girder sets separately (shown as in Fig.1) and there will be an auto-align system to precise align all girder sets [2, 3,4]. For higher efficiency, the magnets installed on one girder should be aligned within 30 μm. To meet this requirement, there are fine polished assembling datum planes on both magnets and girders within 15 μm respectively. However, there might be still some errors induced during installation. In order to detect these errors and establish proper procedure for assembling quadrupole and sextupole magnets on each girder, a laser positioning system is designed and developed. With this system, further shimming is also taken into consideration to compensate the 30 μm spec even better if there is sufficient time for assembling.

DESIGN AND DEVELOPMENT

Design concept

Magnets installed on girders of one -cell DBA lattice are shown as figure 1. The laser positioning system is designed to concenter quadrupole and sextupole magnets on one girder. Since laser has linear propagation characteristics, the laser ray is good to play a role as the alignment reference of magnets and a laser positioning system is developed accordingly. The laser positioning system consists of one laser, two laser position sensing devices (PSD) and two granite blocks. Fig 2 shows whole laser positioning architecture. This positioning architecture consists of three main portions, Laser, two PSD modules and two granite position jigs. The PSD is mounted on an adjustable circular steel module and the steel module will be installed in a granite block, shown as figure 3. Two granite blocks will be installed on girder by datum planes. The laser ray will be adjusted to the center of two PSD. After adjustment, the laser will parallel to and have equidistance to the girder's center datum plane. Then the laser can represent to the datum line of girder. Once the laser ray is adjusted to correct position, the granite position jigs will be removed and replace with magnets. The PSD steel circular module will be inserted on the center of magnets. When the quadrupole and sextupole magnets incline to the reference laser ray, both horizontal and vertical offsets can be detected by PSD. The steel shims will be inserted between magnet and girder for manufacturing and installation error compensation. The details of each portion are described as following.

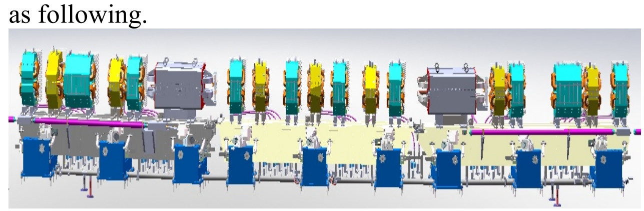

Figure 1: The arrangement of 1-cell DBA lattice magnets on three girders.

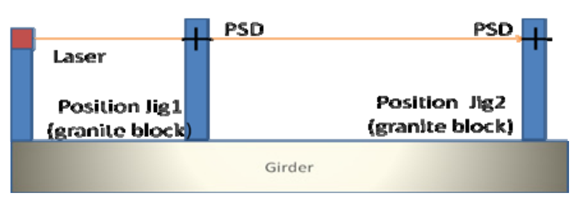

Figure 2: The architecture of laser positioning.

system

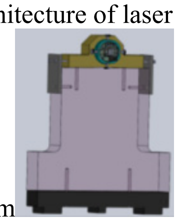

Figure 3: The PSD circular steel module is installed in position jig for laser adjustment.

Laser

Laser is the fundamental of this laser positioning system for magnet inspection. A stable and uniform laser is required. The length of girder is 4m. So the beam profiles of laser should be symmetrical when ray propagates from 0m to 4m. The beam center and centroid center of laser spot should be coincident and beam pointing stability should be within 5um.

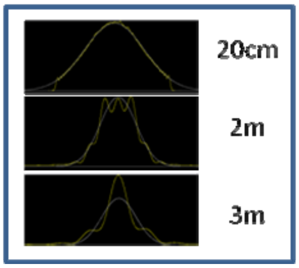

Figure 4: The beam distribution from 20cm to 3m.

PSD Module

The chosen PSD for positioning system is a dual axis position sensing device with better than 0.5 um resolution. The PSD, used to represent to center position of magnet pole center, is mounted on a steel circular module, shown as fig5. For being the ideal center position, the PSD should be mounted on the center of the circular steel jig. In order to achieve target, the steel module is designed with horizontal and vertical adjusting function. PSD adjustment is a linear transmission and the direction is guided by steel balls and v-cut tracks. Forward or backward process is controlled by precise adjusting screws. (Shown as fig5 (b)) The v-cut tracks are separated to two levels for horizontal and vertical adjustment. Corresponding to pole boundary diameters of quadrupole and sextupole magnets, two diameters (74mm and 78mm) of circular steel are manufactured. For adapting on magnets, the diameters of circular steel jig are designed to 5um smaller than the pole boundary diameters of quadrupole and sextupole magnets. Besides the diameter, the roundness of circular steel modules are grinded within 5um.

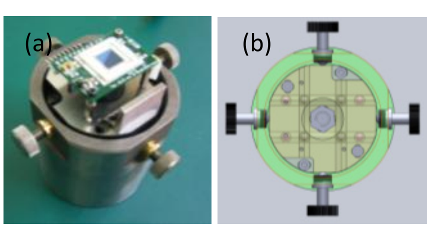

Figure 5: (a) The picture of the PSD circular steel module (b) Horizontal and vertical directions is guided by steel balls and v-cut tracks.

Granite Position Jig

Two position jigs are defined as an ideal model of quadrupole and sextupole magnets. Pole boundary diameters of quadrupole and sextupole magnets are 74mm and 78mm respectively. The heights of pole center of quadrupole and sextupole magnets are 500mm (shown as figure6). So the position jigs are designed according to these magnet dimensions. Since the height of position jig is 500mm, the influence of thermal expansion effect should be concerned and decreased.

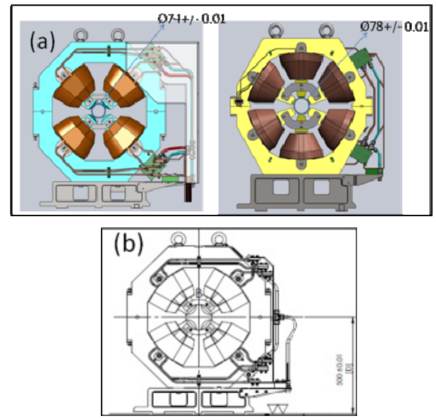

Figure 6: (a) Pole boundary diameters of quadrupole and sextupole magnets are 74mm and 78mm respectively (b) The dimension diagram of the quadrupole magnet.

The position jig is an assembling mechanism, including three portions. The main portion of position jig is made up of low thermal expansion granite (TEC:3um/deg C) to lower the thermal effect. The other two main fixtures, the installation datum plane and cylindrical hole, are made up of steel with precise manufacturing and grinding. These three main portions are assembled together and can be adjusted by screw with precise pitch (0.13mm). After adjustment and inspected by Coordinate Measuring Machine (CMM) (shown as figure7), the cylinder center position can be corrected and fixed under 5 um error.

Figure 7: The adjusting process of position jig.

System Error Analysis

The positioning system includes several main parts and every part contributes error. The following lists dominative errors of this positioning system.

1. Laser drift: laser drifts within ± 2.5um through 4m
2. Assembling error: when the steel circular PSD Jig installed on the position jig, the assembling errors are induces. The assembling tolerance is within 5 um based on the diameter arrangement between circular PSD jig and hole of position jig.
3. Installation error of position jig: when the position jig installed on the girder, position jig may tilt caused by flatness of datum plane. The flatness specification of datum plane is 5um. Since the width of girder datum pane is 480mm and the height of position jig is 500mm. The maximum

position offset caused by tilt is 5.2um. So the errors is ± 2.6um

4. The PSD module is fixed by the screw and the stability of PSD module is predicted to within 3um.

The accumulating error of the positioning system should be under 14.1um from above analysis.

EXPERIMENT AND RESULT

PSD Module Adjustment and Stability Test

In order to align the PSD on the center of the steel circular module, a precise V-cut granite block is applied. A jig laser is used to indicate as the center point of the circular module. The PSD circular module is rotated on the V-cut and the PSD position is fine tuned with two axes adjustment screws. When the PSD is on the mechanical center, the laser beam will be always on the same position no matter how the circular module is rotated. Then the circular module will be fixed by screws.

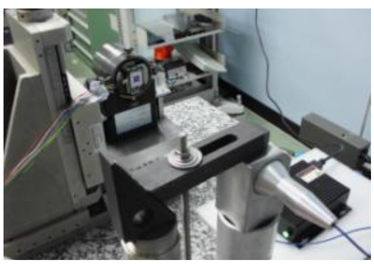

Figure 8: The arrangement of stability test of circular PSD module.

Since the circular PSD module will be representative to the magnet center, the circular PSD module must be stable. For stability confirmation, one laser beam spread on PSD to monitor the drift of the circular PSD module continually. During 192 hours monitoring, the position variation is in 1-3 um range.

Assembling Test

For system application, the PSD module will be adapted into quadrupole and sextupole magnet. As in figure 9, the circular PSD module is adapted to the quadrupole magnet. Since magnets are also manufactured with errors, there are gaps between PSD module and pole. As current case, 50um thick slice can be inserted between PSD module and poles. That means the magnet manufacturing error will be included in position system and much over the system errors.

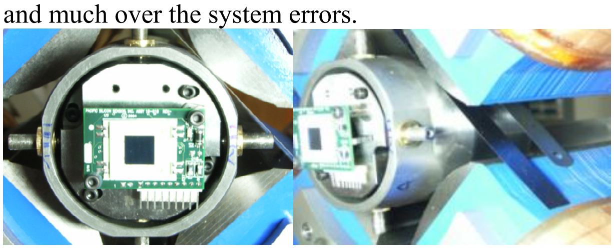

Figure 9: The PSD circular module is installed in quadrupole magnet. The gap between the PSD module and pole of magnet are over 50um.

In order to eliminate the influence of magnet manufacturing errors on system, two revised PSD circular jigs, stepped type and expansible type, are designed and developing. First, the diameter of stepped circular jig is classified to six steps for differentiating and suiting to the diameters of magnets. The diameter tolerances of 2 sets of three-stepped circular jig are classified form +0.027mm to -0.027mm to overcome the magnet manufacturing errors.

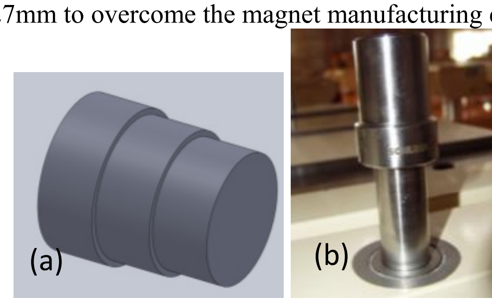

Figure 10: (a) The diagram of stepped circular PSD module (b) The picture of expansible diameter jig.

Second, a diameter expansible jig is specified and purchased. The diameter can expand 50um more by adjust the screw to alter internal oil pressure. The PSD will also be mounted on the expansible jig as current design. Based on the operation experience of this kind of diameter expansible jig, the concentricity can achieve 1um. After expanded, the reliability of diameter roundness can keep under 3um.

These two types of circular PSD jig are still developing. The accuracy of the positioning system will be checked when two types of jigs are manufactured.

SUMMARY

The first version of laser position system is developed and tested. The laser positioning system is verified and the concept works. The system accuracy from analysis is under 14.1um. But the collocation between the circular PSD jig and magnets are still not well. The errors reach 50um scale currently. In order to eliminate the influence of magnet manufacturing error, developing a steeped and a diameter expansible jig are current solutions. The effect still needs to be checked when jigs have developed.

REFERENCE

[1] http://www.nsrrc.org.tw/english/tps.aspx

[2] T.C. Tseng and others, "A Precise 6-axis Girder System with Cam Mover Mechanism", MEDSI, 2006.

[3] W.Y. Lai and others, "Design and Prototype Tests of Auto-Alignment of a Whole-ring Girder", Proceedings of PAC09, Vancouver, BC, Canada, pp.3663~3665.

[4] W.Y. Lai and others, "From Survey Alignment toward Auto-Alignment for the Installation of the TPS Storage Ring Girder System", IPAC11.