THE IMPROVEMENT AND TEST OF LASER POSITIONING SYSTEM FOR TPS MAGNETS ALIGNMENT INSPECTION

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Abstract

A Laser positioning system, consist of a laser, laser position sensing devices (PSD) module and two granite blocks, is developed for the alignment inspection of TPS (Taiwan Photon Source) quadrupole and sextupole magnets during installation on a girder. The PSD module is adapted on the pole center of magnet and is designed to stand for mechanical center of magnets. For higher accuracy, eliminating the influence of magnets manufacturing errors between PSD modules is a major work. The PSD is mounted on a precise diameter expansion mandrel. The real roundness of expansion mandrel can keep under 3um during diameter 95um expansion. Since the PSD position is adjusted and corrected to the module center, the PSD center is identical to the ideal pole center of magnets within 15um and the magnet will be aligned and adjusted by laser position on PSD. This paper describes how to eliminate the measuring error caused by magnet manufacturing error and the detail of laser positioning system.

INTRODUCTION

Taiwan Photon Source (TPS) is under construction from year 2009 and contains the storage ring with a 24-cell DBA lattice, 24 straight sections and a 518.4 meter-circumference design [1]. Magnets of one cell are installed on three girder sets separately. A motor-controlled auto-align system is developed to align all girder sets precisely [2, 3, 4]. For higher efficiency, the girders and magnets are fabricated with fine polished assembling datum planes within 15 um respectively, and the magnets should be aligned within 30 um after installation on one girder.

In order to detect the installation errors and assemble quadrupole and sextupole magnets on proper position of each girder, a laser positioning system is designed and developed [5]. The first version of laser position system is verified and the accuracy is under 14.1um. As the pervious description, the assembling error caused by magnets manufacturing error was over 50 um. For minimizing the assembling errors, an expansion mandrel is specified and purchased for fitting to magnets. With this laser positioning system, further shimming will be taken into consideration to compensate the 30 um spec even better if there is sufficient time for assembling.

DEVELOPMENT AND IMPROVEMENT

The laser positioning system consists of one laser, two laser position sensing devices (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.

PSD Circular Module Improvement

The PSD module is designed and developed as an indication of magnet center. The PSD sensor is mounted on a position adjustable circular steel module and is adjusted to the center of steel module. Then this circular PSD module will be inserted into quadrupole and sextupole magnet. Since magnets are manufactured with tolerance and errors, the contact between circular jig and magnet are only 2 points when the circular jig is smaller than magnet bore radius. There are some gaps between PSD circular module and poles. These gaps, manufacturing error, can be measured by inserting thick gauge to check and confirm the gap size.

In order to eliminate the influence of magnet manufacturing errors on system, the manufacturing error must be checked in advance. A stepped arbor is developed as a diameter gauge. The stepped arbor 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 arbors is shown as Figure 1.

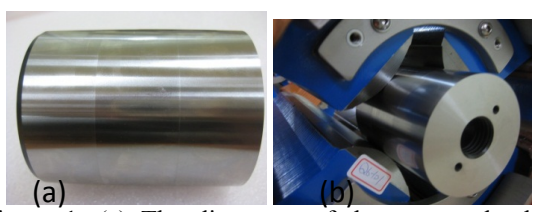

Figure 1: (a) The diameters of three-stepped arbor are 74.000mm, 73.991mm, and 73.973 mm respectively. (b) The three-stepped arbor is inserted in the quadrupole magnet.

For absorbing the manufacturing error, the PSD circular module is attached on an expansion mandrel, which is specified and purchased for fitting for magnets, shown as figure2. The diameter of the expansion mandrel can expand 95um by adjusting screw to alter internal oil pressure. When the mandrel is unenforced, the diameter is minimum size, 73.95mm. The diameter can be expanded to 74.045mm by altering the pressure to maximum. No

ISBN 978-3-95450-115-1

matter forced or unforced, this expansion mandrel can keep roundness under 3um.

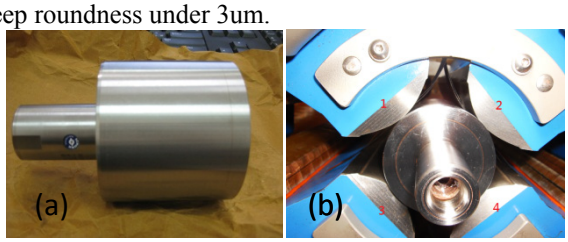

Figure 2: (a) The picture of the expansion mandrel (b) the expansion mandrel is inserted in the quadrupole.

Setup Improvement

The laser positioning system, including laser and PSD, is setup as the following figure3-5. The laser sets on a horizontal and vertical adjustable stage. Since laser has linear propagation characteristics, the laser ray can play a role as an alignment reference of magnets. Magnets install on the girder and the PSD expansion mandrel module is installed on the center of magnets. The position, pith and yaw tilt angles of laser are adjusted by referring to the first and the last PSD on magnets.

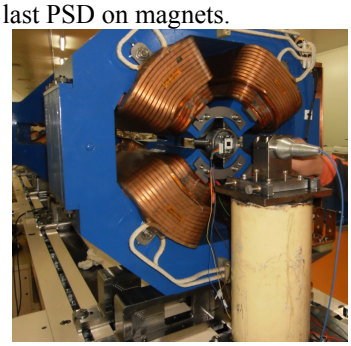

Figure 3: The laser is held on a position and angle adjustable stage.

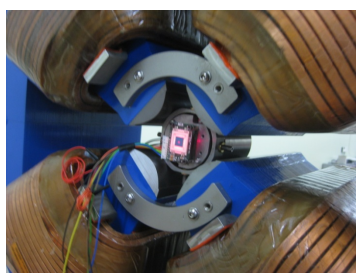

Figure 4: The laser beam spreads on the PSD expansion mandrel

Figure 5: The architecture of laser position system on girder

EXPERIMENT AND RESULT

Magnet Bore Radius Measurement

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. For preventing the thermal expansion effect, four sets of quadrupole magnets are moved to a 25℃ constant temperature laboratory. The setup is shown as below Fig6. Magnets stay in laboratory 2 days more for thermal balance and then the bore radius is measured, shown as Fig2. The jigs contact magnet only 2points. Gaps between jig and pole surfaces are measured by thickness gauge. The test result is as below table1. The difference of two jigs measurement results are within 0.01mm. The bore radiuses distribute from 74.09mm to 73.98mm. Besides the QT-PT1, the manufacturing errors of the other magnets are within the expansion quantity +0.045/-0.05mm of expansion mandrel. The errors can be absorbed.

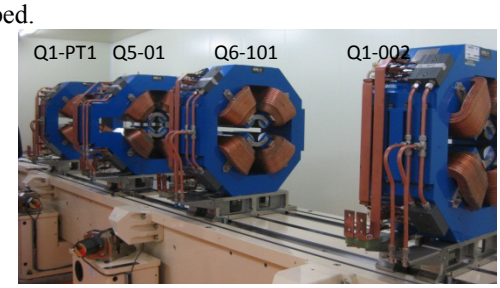

Figure 6: Magnets are moved to a laboratory for bore radius measurement

Table 1: Measurement Result of Bore Radius of Magnets.

Magnet serial number			QT-PT1		Q5-01		Q6-101		Q1-002	
Surface#			1	2	1	2	1	2	1	2
Stepped Arbor	Gap (mm)	front insert	0	0.05	x	x	x	x	0.02	0.05
		back insert	0.02	0.08	x	x	Δ	Δ	0.01	0.03
Expansion Mandrel	Gap (mm)	front insert	0.05	0.1	0.05	0.03	0.04	0.03	0.07	0.1
		back insert	0.07	0.14	0.04	0.03	0.04	0.03	0.06	0.07
Stepped Arbor	Diameter(mm)	front insert	74	74.05					74.02	74.05
		back insert	74.02	74.08					74.01	74.03
Expansion Mandrel	Diameter(mm)	front insert	74	74.05	74	73.98	73.99	73.98	74.02	74.05
		back insert	74.02	74.09	73.99	73.98	73.99	73.98	74.01	74.02
Measurement Difference- front (mm)			0	0					0	0
Measurement Difference- back (mm)			0	0.01					0	-0.01

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 transfer functions are measured and shown as figure 7. Both transfer function of horizontal and vertical directions are linear. The transition scale is 1 mV output equals to 0.27um.

After installation, the laser propagates three meters far on the girder. The laser beam is disturbed by air and beam pointing is not stable enough. The beam pointing at 3 m is around 50mV (13.5um). For disturbance elimination, the foam tube is introduced and adapted between magnets. Below figure 8 shows the facilities. Since foam is soft and may bend to interrupt the laser beam, an aluminium tube is fabricated to hold foams.

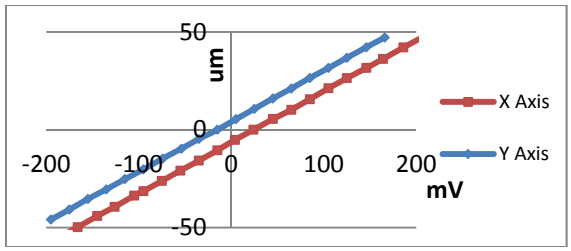

Figure7: Horizontal and vertical transfer function of PSD

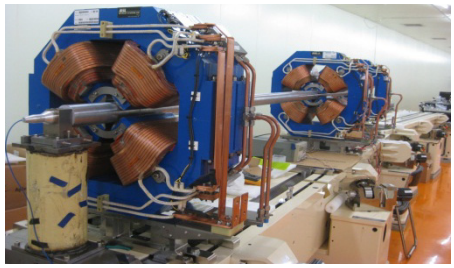
Figure8: A foam tube coated with aluminum tube is introduced for eliminating air disturbance

After foam tube installation, the laser beam stability can be improved to under 3mV(0.8um) during 30 minutes. Below figure 9, 10 present the beam variation during five hours. The drift value of horizontal and vertical directions are 4mV (1um) and 17mV (4.5um) respectively per 5 hour duration.

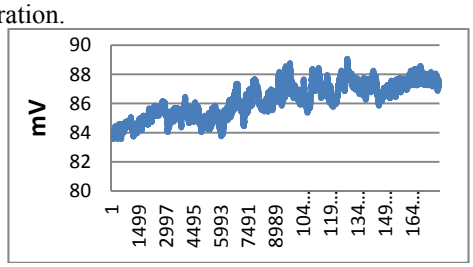

Figure 9: Horizontal beam position variation

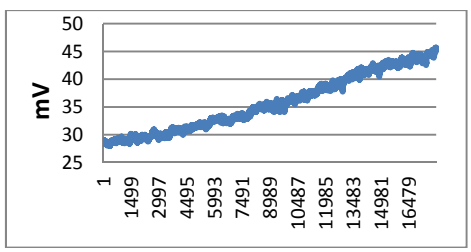

Figure10: Vertical beam position variation

Installation Test of PSD Expansion Mandrel Module

The circular PSD expansion mandrel module is adapted into quadrupole magnet on girder. In order to check the repetition of system, the expansion mandrel is inserted on three quadrupole magnets repeatedly. The maximum difference of twice insertion is 142um (As table 2) and is over the system stability. The reason is evaluated as following. The expansion mandrel is cylinder and will incline along the profile of the magnet pole. When the mandrel expands, mandrel contacts the magnet by three points. So the fixed position, orientation and contact force of expansion mandrel influence to the PSD position. The situation of the expansion mandrel on every magnet needs to control to identical.

For repetition improvement, there are several woks need to do.

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 in the same depth for contact the same points on magnet

Table 2: Repetition of PSD Position

PSD Variation	Vertical (mm)		Horizontal(mm)	
Magnet#	V (mv)	V(um)	H (mv)	H(um)
#1	-547	-142	108	28
#2	-77	-20	64	17
#3	-457	-119	-275	-71

SUMMARY

Bore radius of 4 sets of quadrupole magnet are inspected in the laboratory with constant temperature (25 degC). The bore radiuses of quadrupole magnet are from 74.090mm to 73.980mm and the manufacturing error range is 0.11 mm. An expansion mandrel is designed and purchased for eliminating the influence of magnets manufacturing errors. The diameter of expansion mandrel can expand from 73.950 to 74.045mm. Only one set of magnet is over the capacity of expansion mandrel during the inspection. Most of magnet manufacturing errors can be absorbed by expansion mandrel. The manufacturing errors can be eliminated well.

By adding the foam tube for air disturbance reduction, the stability of laser position system is minimized from 13.5um to 0.8um. But the repetition of PSD expansion mandrel insertion still needs to be minimized. Once the repetition is improved, the laser positioning system will be applied to alignment inspection of quadrupole and sextupole magnets during installation on a girder. The magnets will be aligned within 30 um after installation.

REFERENCE

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ISBN 978-3-95450-115-1