AUTO-ALIGNMENT SYSTEM AND CALIBRATION PROCEDURE IN TPS GIRDER SYSTEM

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Abstract

The TPS (Taiwan photon source) project is under construction and will be finished in the December 2012. Considering the floor's deformation with time and frequent earthquakes at Taiwan, the survey and alignment procedure should be taken quite often. For dealing with these difficulties and improving accuracy of girder's position, a highly accurate auto-tuning girders system was designed to accomplish the alignment tasks. There are two cells of TPS girders and varied sensor modulus set up for testing the auto-tuning system. The adjustment of the system converges to less than 6um, and the repeatability of the testing is under 10 um. For improving the accuracy of girders position, that is critical thing to make sure all the calibration of sensors modulus correctly and accurately. The calibration procedure about sensor modular and testing results is described in this paper.

INTRODUCTION

Taiwan Photon Source is a new 3-GeV ring under construction at the NSRRC site in Taiwan, and the building will be finished in a short time. To install components accurately is demanded with the low emittence lattice design. However, due to the obstruction of intervisiblity, the network is of an annular type and error propagation inevitably occurs. It is hard to establish a sufficient survey network to meet the requirement.

Moreover, traditional survey-alignment method takes excessive time and human power each time. An auto-tuning girders system was designed to achieving the requirement. The structure of this auto-align system is built with motorized girders and multiple sensor systems set up between all girders. It is important to ensure all the sensor modulus calibrated in the correct and convenient procedure for improving the accuracy. This paper describes the calibration procedure of sensors and auto-alignment testing.

THE CALIBRATION PROCESS

The auto-alignment system includes precise 6-aix adjustable girders and sensor modulus between girders. The system is built according to the girders position from laser tracker and the sensors between girders, so it is important to calibrate the sensors modulus accurately.

There are three major parts need to been calibrated in the auto-alignment system. The first part is to compensate the dimension of girders. To promote the accurate of girder's dimension, there are 4 fiducial holes around the girder. All the lengths between each fiducial hole were measured with a laser interferometer position measurement system.

It is difficult to measure the distance between fiducial holes directly. To overcome the problem, an expansion arbor matched with fiducial holes is used in the calibration system as shown in Fig 1. All the repeatability of the measurement system is less than 5um in the calibrated process. The dimension and angles of this girder could be compensated with the four side length, two diagonal ling and two distances from fiducial holes to the datum edge.

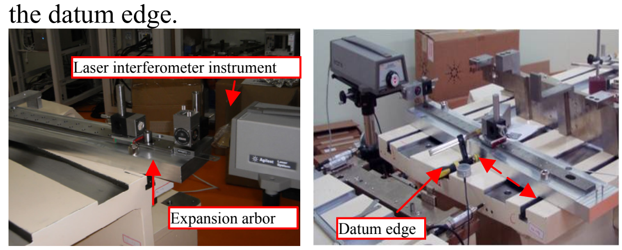

Figure 1: Laser interferometer system.

The following step is to calibrate the correlation of adjacent girders. After dimension calibration step finished, the jig and the sensor modulus was set up on the adjacent girders. In order to establish the local coordinate system, the distance between fiducial holes was measured in the adjacent girders.

The local coordinate was computed by building up the triangle geometry as shown in Fig. 2. The transfer matrix from sensor data to the local coordinate system could be established by geometric relation of sensors and fiducial holes. S_{z1}, S_{z2} , S_x are the sensors set up in X and Z coordinate direction respectively. LX_1 and LZ_1 mean the distance between sensors and the fiducial hole (P1) in X and Z direction, and LS is the distance between two sensors for computing the rotation angle. The local coordinates and sensors data was taken into Eq. 1 in the meantime, and the parameter of transfer matrix could be computed and recorded for the auto-alignment testing.

Considering the reliability of coordinates, the sensor modulus on girders would be adjusted and calibrated three times. To get the position of fiducial hole quickly and accurately, the calibrating work was used sealed linear encoders tool to get distance between each fiducial hole conveniently. The repeatability of the calibrating system is under 9um.

$$Z_1 = -[(S_{z1}-S_{z1i})+(S_{z2}-S_{z2i})]/2+[(S_{z2}-S_{z2i})-(S_{z1}-S_{z1i})]/LS\cdot[LZ_1+(S_x-S_{xi})]+c_1$$
$$X_1 = -[(S_{z2}-S_{z2i})+(S_{z1}-S_{z1i})]/LS\cdot[LX_1-[(S_{z1}-S_{z1i})+(S_{z2}-S_{z2i})]/2]-(S_x-S_{xi})]+c_2$$
$$\Rightarrow \quad [\mathrm{P1}]=[\mathrm{M}]\cdot[\mathrm{S}_{z1},\mathrm{S}_{z2},\mathrm{S}_x]+[\mathrm{C}] = \begin{bmatrix} \mathrm{M}_1 & \mathrm{M}_2 & \mathrm{M}_3 & \mathrm{C}_1 \\ \mathrm{M}_4 & \mathrm{M}_5 & \mathrm{M}_6 & \mathrm{C}_2 \end{bmatrix}\cdot\begin{bmatrix} S_{z1} \\ S_{z2} \\ S_x \\ 1 \end{bmatrix} \tag{1}$$

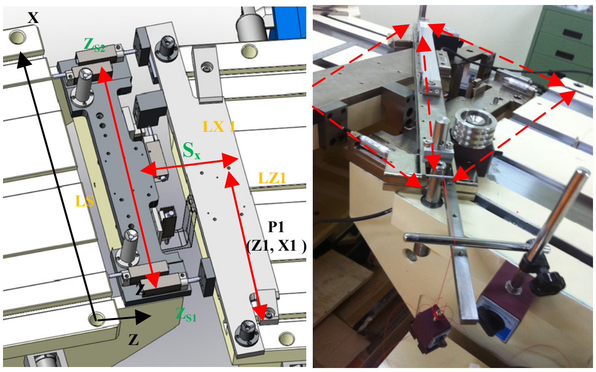

Figure 2: The local coordinate model and the linear encoder tool.

The last part is to calibrate the PSD modulus between girders in long straight section. The PSD system could provide a more accurate angle and position between long section girders. In the beginning, a laser beam is adjusted to be parallel with jig plane by using beam position device. The PSD modulus is set up on the jig plane, and the mirror stage is turned until origin laser beam not off-lying while passing mirrors as shown in Fig. 3. Finally the position of PSD sensor is adjusted in the center of a laser beam.


Figure 3: The illustration of PSD calibration and the adjusting mechanism.

The shift value of girders detected with the PSD system is influenced by the laser bean size and the assembling angle of PSD sensor as shown in Fig. 4. The PSD modulus must be calibrated with the touch sensors, and find the correction coefficient. After all the PSD modulus was set up, the distance from datum edge to the base plane of PSD system was measured by the touch sensor jig as shown in Fig. 4. The auto-alignment system would compensate the PSD signal by those calibration data in the end.

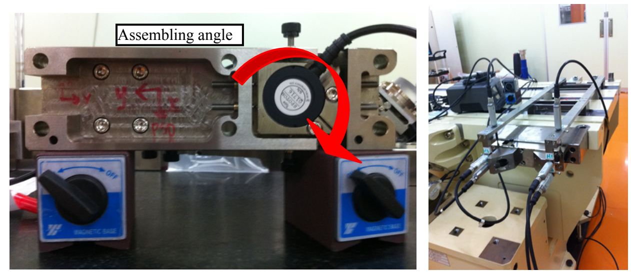

Figure 4: Assembling of the PSD sensor and the touch sensor jig.

THE TESTING SYSTEM

The testing system is constructed with two girder system sections as shown in Fig. 5. Each section is composed of girder systems and each girder system is composed of three pedestals with six motor driven cam movers to support and provide six-axis precise tuning[1, 2]. The two girder system sections for auto-alignment testing are identical with two of twenty-four of TPS. There are four sensors modulus set up totally. The sensors modulus provides the angle and position between adjacent girders. There was also a PSD system installed in the straight sections. It offers the angle and position between the distanceof two girders. Each girder was set up an electronic levelling instrument for maintain levelling of girders under align process accurately, and eliminate the Abbr error from the different angle.

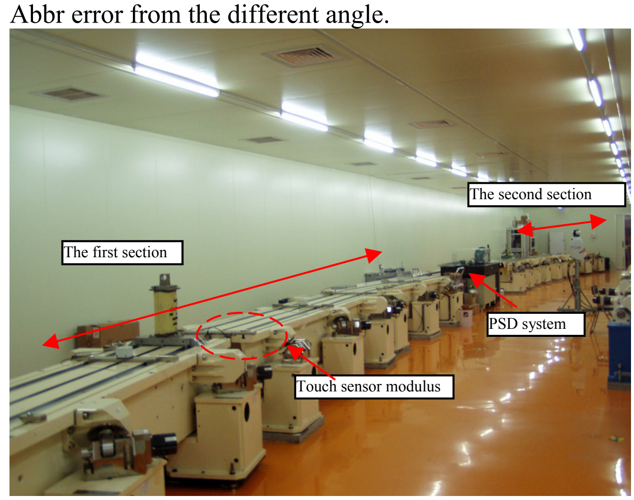

Figure 5: The structure of the auto-alignment testing.

Even though all the components are identical to the TPS system, the testing system cannot form a sensor feedback loop in only two sections. For testing the result of calibration and the algorithm programming, the testing was superadded a laser tracker to provide the connection from the end points to the first one. The process of an auto-alignment system and the testing results are described in the below.

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TESTING PROCESS AND RESULTS

With the combination of survey network and auto-alignment, the auto-alignment system uses laser trackers to provide an initial location of the girders. The program computes new coordinate with combining these initial coordinates and the connection between girders [3]. The auto-alignment procedure could be designed, as shown in Fig. 6.

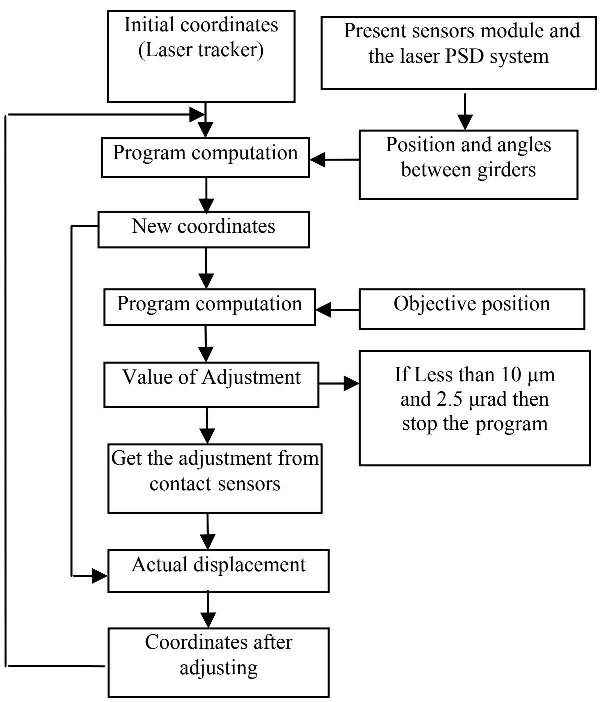

Figure 6: Illustration of testing procedure.

The test follows the same process interactively until the translation and rotation moving value converges to less than 10 μm and 2.5 μrad respectively.

Testing Results

In previous paper[3], the moving value of testing system converges to a bigger number because the angle between the pseudo-girder and girders is not accurate as the others. The reason is that the pseudo-girder is too short, and it is hard to get the angle between other girders accurately. In this testing, all the auto-alignment system is duplicate of the TPS system.

The auto-alignment testing system includes installing processes and components, calibrating varied sensor systems and the algorithm of program. For demonstrating the program could work in the same process of TPS system. All the processes and components are the same with the future TPS system. The adjustment of an auto-alignment system converges to target within 6 rounds as shown in Fig. 7. For observing adjustment state and ensuring all the system trustworthy, the testing process was extended 2 times to 13 round.

The symbols MX, MZ, MR are the adjusting values in transverse, beam direction, and yaw. The numeral means the assigning number of girder. The adjustments of the first and last girder are comparatively larger because the first and end point is connected by laser tracker. The measurement is unstable than other sensor system, so the moving value is varied obviously. However, the translation and rotation deviations of the system could still less than 10 μm and 2.5 μrad respectively. The system is tested 3 times and the repeatability is within 10 μm which is better than previous testing.

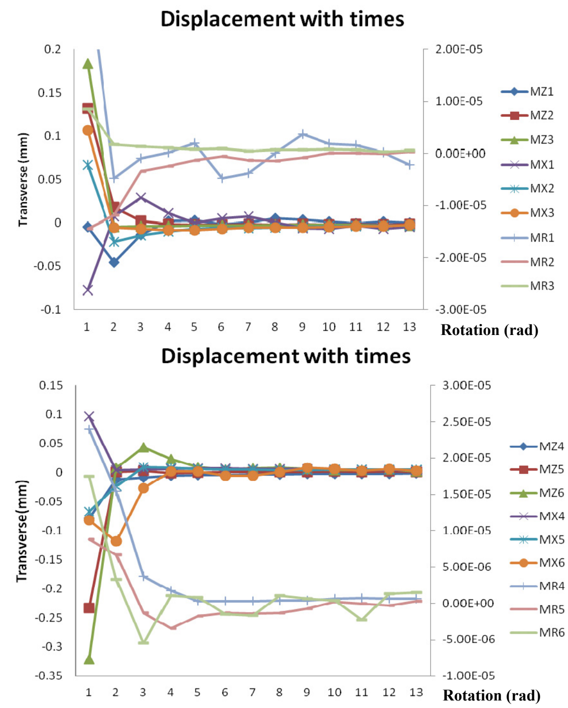

Figure 7: Variation of adjustment.

CONCLUSION

The calibration process is very important to improve the accuracy of the auto-alignment system. The test results of the auto-alignment system reveals that the translation and rotation of the girders converges within 6 μm and 2.1 μrad even with a laser tracker for connecting girders. The repeatability of the system is under 10μm and improves the problems of previous testing [3]. The auto-alignment system shows good convergence and repeatability from testing. The auto-alignment procedure will be executed while the TPS storage ring installation and the test will be more completely.

REFERENCES

[1] T.C. Tseng and others, “A Precise 6-axis Girder System with Can Mover Mechanism,” MEDSI, 2006
[2] T.C. Tseng and others, “Design and Prototype Testing of the Girder System for TPS,” SRI, 2008.
[3] W.Y. Lai and others, “From Survey Alignment toward Auto-Alignment for the Installation of the TPS Storage Ring Girder System”, PAC11, 2011.