FROM SURVEY ALIGNMENT TOWARD AUTO-ALIGNMENT FOR THE INSTALLATION OF THE TPS STORAGE RING GIRDER SYSTEM

W.Y. Lai, M.H. Wu, T.C. Tseng, H.S. Wang, M.L. Chen, H.C. Ho, Y.L. Tsai, C.J. Lin, H.M. Luo, K.H. Hsu, S.Y. Perng, P.L.Sung, J.R. Chen*
National Synchrotron Radiation Research Center, No 101, Hsin-Ann Road, Hsinchu 30076, Taiwan
*also at Deparment of Biomedical Engineering & Environmental Sciences, National Tsing-Hua University, Taiwan

Abstract

The TPS (Taiwan Photon Source) project is now under civil construction. The whole building is constructed half underground and 12m deep compared to the TLS (Taiwan Light Source) due to the stability consideration, so the survey and alignment works are quite confined and difficult. For positioning the magnets precisely and quickly, a high accuracy auto-tuning girders system combined with survey network procedures were established to accomplish the installation tasks. The position data from the survey network will define a basis for the motorized girder system to auto-tune and improve the accuracy. A mock up of one twenty-fourth section (one cell) had been installed at NSRRC (National Synchrotron Radiation Research Center) for interface examination and further testing. In this paper, the procedures from the traditional survey network to auto-aliment system design and algorithm are described. Meanwhile, a preliminary testing result is also included.

INTRODUCTION

Taiwan Photon Source is a new 3-GeV ring under construction at the NSRRC site in Taiwan. For stability reasons, the entire building is being constructed half underground 12m deep. With the low emittence lattice design, precise components installation and building construction are demanded. A preliminary GPS (Global Positioning System) network formed by 36 granite pillars to establish the global control points is set up to monitor the building construction and then will be expanded to a laser tracker network for installation. 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. 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 combined with survey network was designed to accomplish the alignment tasks. [1,2,3]

SURVEY AND ALIGNMENT PROCESS

With the combination of survey network and auto-alignment, the TPS storage ring girder system installation processes are scheduled as follows.

1. Initial survey installation network establishing
2. Pedestals installation and adjustment
3. Girder section (6 girders) installation
4. Local survey – laser tracker local network
5. Girder section alignment
6. Local re-survey – laser tracker local network
7. Vacuum components & others installation
8. Repeat 3~7 till 12 sections installation completed
9. Whole ring survey – laser tracker network
10. Global auto-alignment – vertical
11. Global auto-alignment – horizontal

The survey dada from laser track network will be the initial value for the auto-alignment process.

THE TESTING SYSTEM

Since the girder system is still under manufacturing, a testing system was constructed to improve the control algorithm and programming. The construction of the testing system and the programming algorithm are described respectively.

Construction of Testing System

A testing mock up of one twenty-fourth section (one cell) had been installed at NSRRC as shown in Fig. 1.

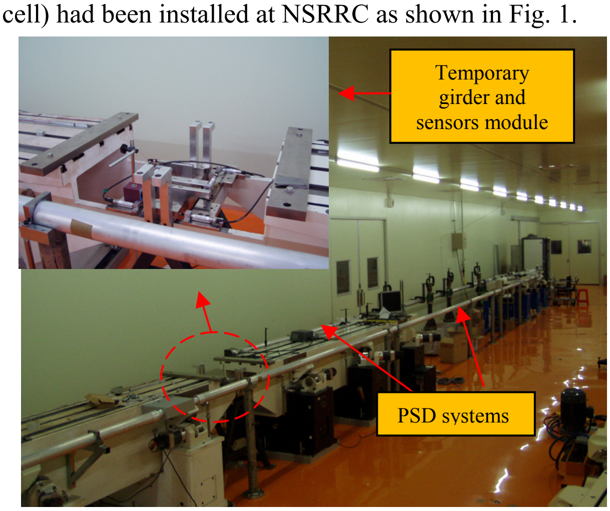

Figure 1: Construction of auto-align system.

Due to the limited place, Two girders and a small pseudo girder are placed to form one twenty-fourth section, another girder is placed away for testing different distance straight-section girders with the laser PSD (Photon Sensitive Device) system[4] assembled.

The laser PSD system and the contact sensors module between the consecutive girders combined with an additional PSD system at two side girders form a loop sensor system which is similar to the loop system of TPS. Each girder system is composed of three pedestals with six motor driven cam movers to support and provide six-axis precise tuning and an electronic levelling instrument to maintain levelling of girders under align process.

Operating Algorithm

The operating algorithm is established under a condition that the sensor accuracy is within a few microns, so the system can improve the initial position of laser tracker accuracy with data from precise sensors via iterative computation. The new position of each fiducial point is computed from the positions of two adjacent points and the data read from the sensor according to this equation (see Eq. 1).

$$\begin{aligned} G_{nL}(X,Y,Z)_1 = \{ & [G_{(n-1)R}(X,Y,Z)_i + W(S_{(n-1)n}(X,Y,Z)) \\ & + (1-W)[G_{nL}(X,Y,Z)_i - G_{(n-1)R}(X,Y,Z)_i]] \\ & + [G_{nR}(X,Y,Z)_i - WS_n(X,Y,Z)_i \\ & - (1-W)[G_{nR}(X,Y,Z)_i - G_{nL}(X,Y,Z)_i]]\}/2 \end{aligned} \qquad (1)$$

The symbols, $GnR(X,Y,Z)_i$ and $GnL(X,Y,Z)_i$ signify two end points of a girder (cf. Fig. 2), and n denotes the number of a girder. L and R denote left and right points on the girder, and suffix i denotes that the number of the point computed is the initial time. Symbols $S_n(X,Y,Z)$ and $S_{(n-1)n}(X,Y,Z)$ is defined as the angle between girders and the sensors module. W denotes a weighting value.

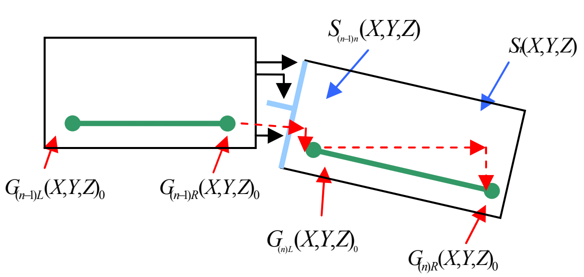

Figure 2: Illustration of symbols.

TESTING PROCESS AND RESULTS

The process of auto-align system uses laser trackers to provide an initial location of the girders and then combines these initial values with the relative position of consecutive and straight-section girders. The process of testing system and the testing results describe as follows.

Testing Process

The system gets the correlation between girders from sensors module and laser PSD at first, and then takes position of girders measured by laser tracker for initial coordinates. The new coordinates could be established by the more precise sensor module and laser PSD system. According to the objective position, the adjustment of each girder could be computed. After finishing the adjustment of girders, the system gets the actual moving value from the deviation of contact sensors. The system could compute the present position of girders by the actual moving value, and then gets the new correlation between girders for establishing the new coordinates again as shown in Fig. 3.

The test follows the same process interactively until the translation and rotation of adjustment converges to less than 10 μm and 5 μrad respectively.

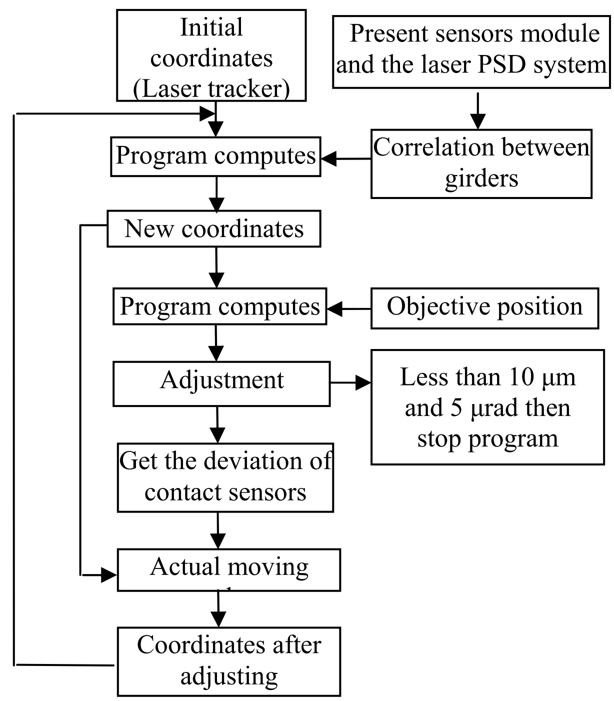

Figure 3: Illustration of testing process.

Testing Results

In previous study[3], the final position of girders was influenced by initial coordinates seriously in the prototype testing. For improving this problem, the system modifies the correlation between girders with two neighbouring angle between girders. The laser PSD system also builds up the correlation function between vertical and horizontal direction for improving system reliability as shown in Fig. 4. The actual using range of auto-align system is controlled within 100μm, so the variation of horizontal laser PSD factor is few.

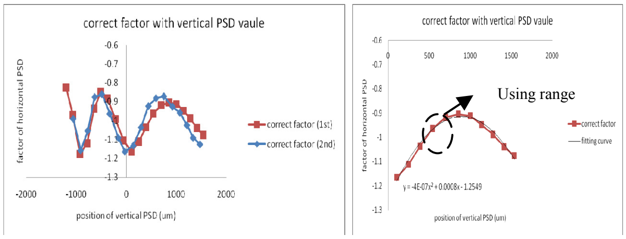

Figure 4: Correct factor of laser PSD system.

In order to confirm the stability of auto-align system, the auto-tuning process is executes the computation sixteen times in a process. The system convergence is attained after 10 runs, as shown in Fig. 5. The longest distance of laser PSD is up to 19 m at the auto-align system. The distance does not only influence the satiability of laser PSD but also be the major factor of computation in girder's correlation, so the adjustment of system is more obvious than further testing [3].

The final position of girders adjusting by auto-align system was under the accuracy of laser tracker (100μm in 20m range). In order to verify the repeatability of the system, there were two contact sensors installed at each side of a girder and also laser-tracker fiducials on the contact sensors to measure the relative position as shown in Fig. 6.

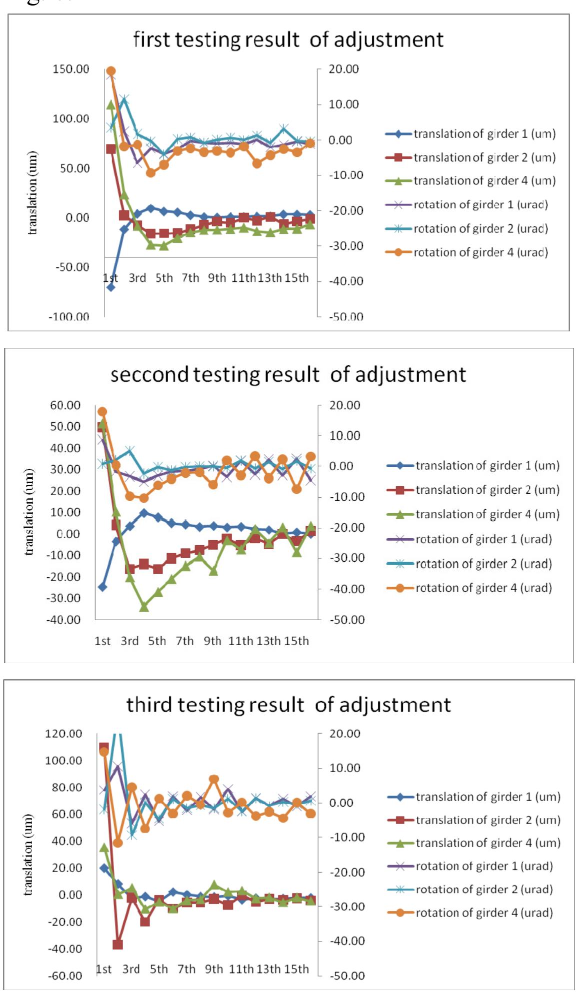

Figure 5: Variation of adjustment.

Figure 6: Contact sensors at side of girders.

The system would record sensors after system finishing adjustment. Fig. 7 is the result of side sensors comparing to second testing and third testing, and the system repeatability is within 31 μm. The error of sensor module and laser PSD system installed on girders is the major part to influence the repeatability of girder.

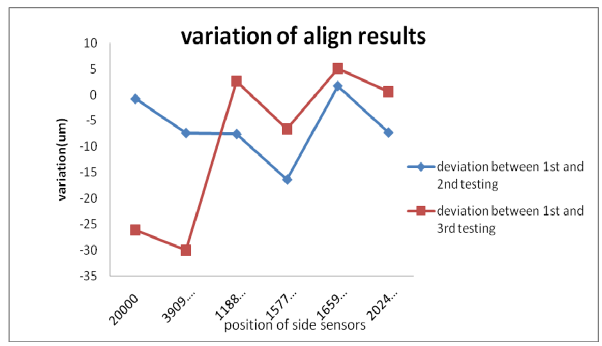

Figure 7: Repeatability of system test.

CONCLUSION

The Whole girder system is quite complicated and the auto-alignment process cannot be tested thoroughly until complete installation. The test results of the auto-align system reveal that the algorithm and program converges the translation and rotation of the girder system within 10 μm and 5 μrad. Even in different initial condition, the system can form a straight line automatically. However, the repeatability of the system is still 31μm. The sensing error of the PSD system between 19m long distance girders could be a major factor to the deviation of repeatability. The system could be ameliorated by further improving the accuracy of contact sensors and laser PSD system.

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