DESIGN AND PROTOTYPE TESTS OF AUTO-ALIGNMENT OF A WHOLE-RING GIRDER *

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Abstract

TPS (Taiwan Photon Source) is a new 3-GeV ring to be constructed at NSRRC Taiwan. A motorized magnet girder system with six cam movers on three pedestals was designed and tested to provide precise adjustments about six axes. With three consecutive girders to form one section, the entire ring contains 72 girders. To align these girders precisely and quickly with little manpower, considering the deformation of the floor, limited space in the tunnel and frequent earthquakes in Taiwan, a whole-ring auto-alignment system is proposed for these girders. This system includes contact sensors between consecutive girders and a laser-PSD system between straight-section girders, in addition to electric-levelling sensors on each girder. An algorithm to operate the system has been defined and a program fulfilled for testing on a three-girder prototype system. The detailed design of the system and testing results are described in this paper.

INTRODUCTION

To align all magnets precisely is critical for a low-emittance ring. The traditional survey-alignment method takes excessive time and human power, and still fails to provide sufficient accuracy of position to adjust the girder system efficiently. An auto-alignment system was thus proposed to improve alignment accuracy with little manpower and decreased installation period. This system consists of motorized girder systems and sensors between each girder to form a feedback-controlled auto-tuning system. A prototype system with three girders was constructed for testing. The system construction, operating algorithm and testing results are described in this paper.

CONSTRUCTION OF THE SYSTEM

For convenient, quick and precise purposes, the girder was designed with reference channels to pre-align the magnets on one girder within 30 µm. The total mass of a girder assembly is about 12 tons.

The prototype system consists of three girder systems to form one twenty-fourth section of the storage ring. Each girder system is composed of three pedestals with six cam movers to support and provide six-axis precise tuning [1,2], and an electronic levelling instrument to control the pitch and roll deviations of the girder .

There are four contact sensors between consecutive girders to record sway, heave, surge and yaw relations. Between the straight-section girders, a dist-invar wire system is adopted to measure the surge distance and a laser-PSD [3] to record sway, heave and yaw.

The traditional survey-alignment network using laser trackers provides an initial location of the girders. Combining these initial values with the relative position of consecutive and straight-section girders, the location of the girder in the entire ring is computed iteratively with a programme described as follows.

OPERATING ALGORITHM

The operating algorithm is established under a condition that the sensor accuracy is a few µm, so we can improve the position accuracy from the measured data for the original survey-alignment network combined with data from 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.

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

The symbols, $G_{nR}(X,Y,Z)_i$ and $G_{nL}(X,Y,Z)_i$ signify two end points of a girder (cf. Fig. 1), 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 and W denote the distance of girders and the weighting value.

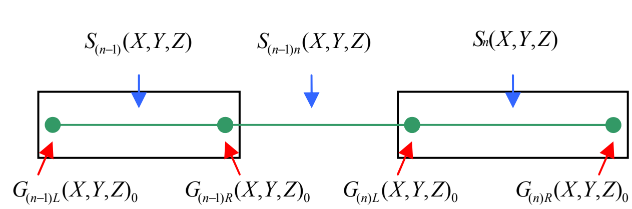

Figure 1: Illustration of symbols.

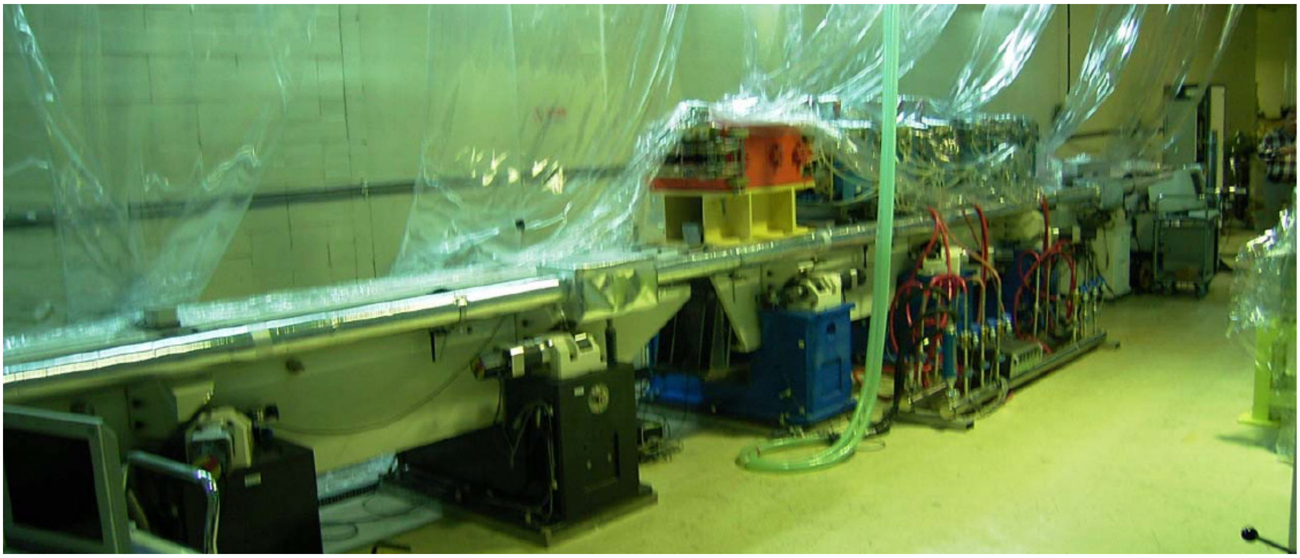

Figure 2: Construction of a prototype.

TESTING AND RESULTS

Because the standard measurement points are located underneath (see Fig. 2, 3), we must remove the heat-shielding shelter before measuring initial coordinates with a laser tracker. Next we take the initial data and the sensor signal into a program, and obtain new coordinates of the girders.

A best-fit line according to the lattice design can be defined with the fiducial positions. The translational and rotational deviations from the fitted line are determined and the girders are adjusted. After the girders finish moving, we re-enter the position data and sensor signals into the program. The test follows the same process until the adjustment converges to less than 10 µm. The test repeats the process three times in total.

Figure 3: Shelter and measure point.

For safety reasons, the auto-tuning process is performed manually. It executes the computation nine times in a process, and convergence is attained after 4~5 runs, as shown in Fig. 4. The computations of these tests demonstrate that the system could converge to a stable situation. The fiducial points of a girder can form a straight line gradually as shown in Fig. 5.

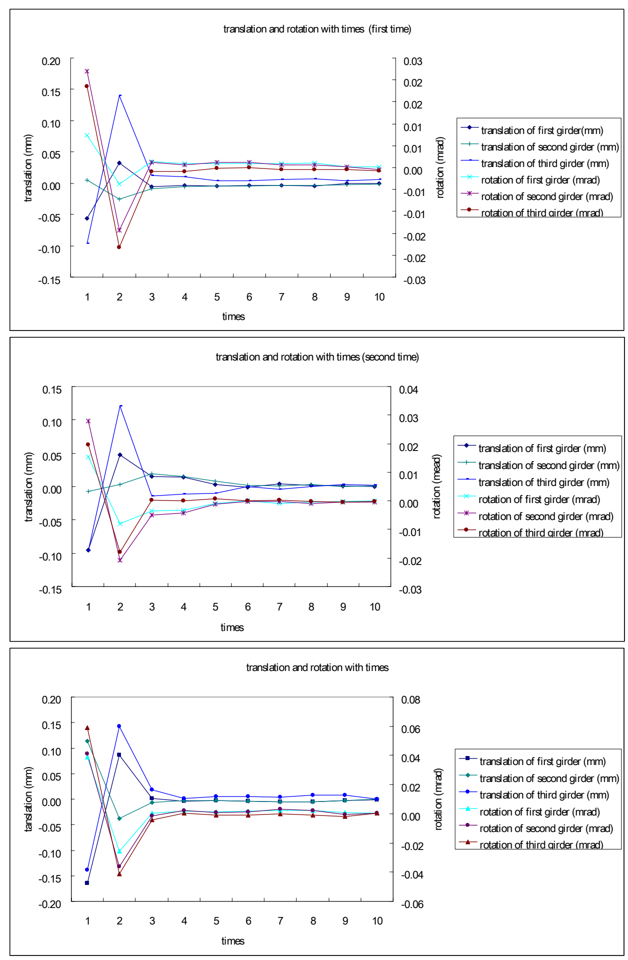

Figure 4: Variation of translation and rotation.

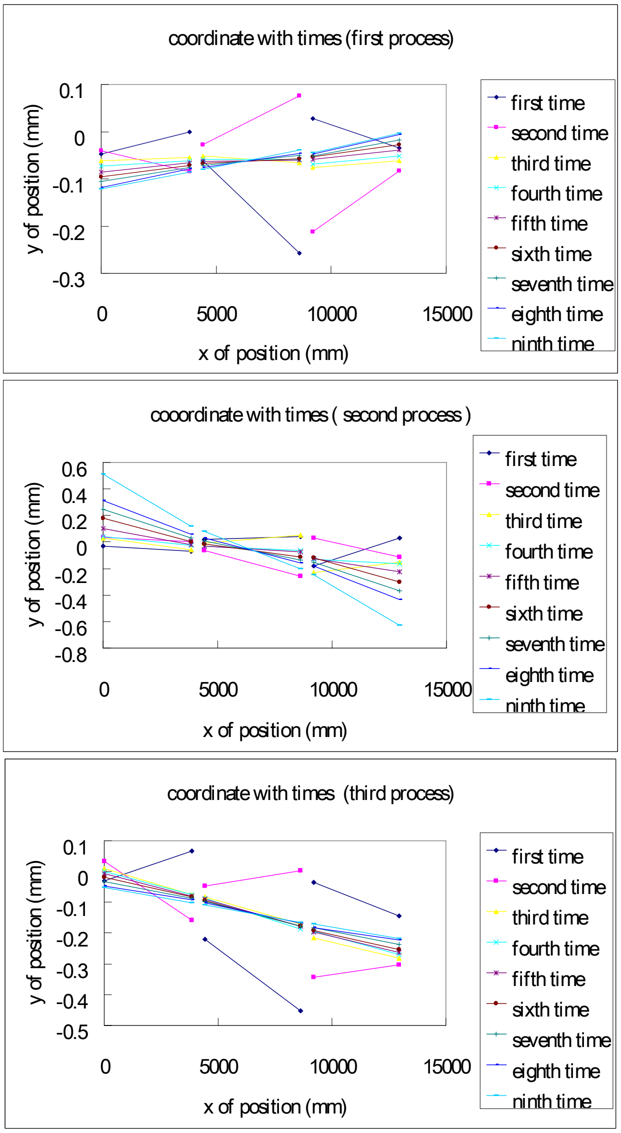

Figure 5: Coordinate trend.

To verify the repeatability of the algorithm, two dial gauges were installed at each side of a girder (see Fig. 6). There were also laser-tracker fiducials to measure the relative position of the six dial gauges.

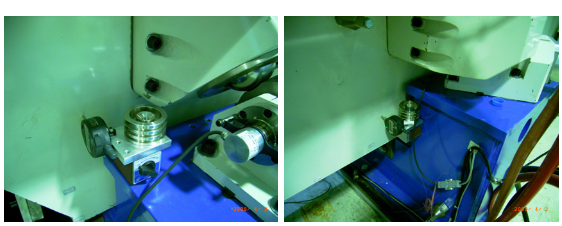

Figure 6: Position of a dial gauge.

The dial gauges were set to zero reading when the system completed convergence the first time; the three girders were then adjusted randomly. The process was performed a further three times, and attains the position repeatability of girders according to the dial gauge (see Fig. 7).

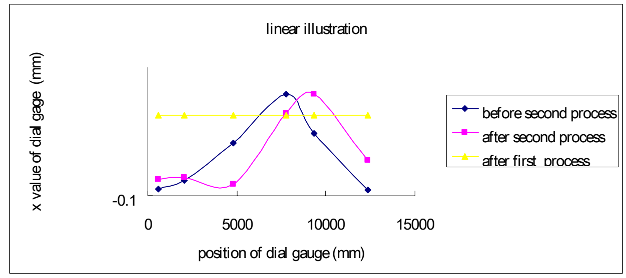

Figure 7-a: Position of a dial gauge at the second process.

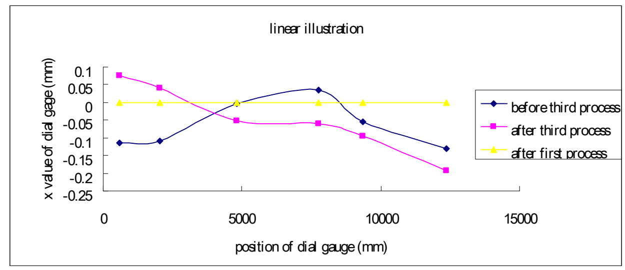

Figure 7-b: Position of a dial gauge at the third process.

The maximum deviations were 0.051 mm and 0.023 mm respectively, as shown in Fig. 7.

Although the relation of the six dial-gauge readings is nonlinear, it is discovered that "G1, G2, G3" "G2, G3, G4" and "G1, G2, G6" fall on a line, respectively, in Fig.7-a. ("G1" signifies dial gauge 1) It seems that the program could not compensate the angular deviations between girders. The system merely converged to several line segments (see Fig. 8), so the algorithm should be modified.

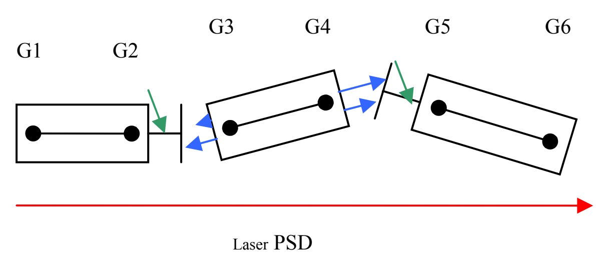

Figure 8: Illustration of the system.

CONCLUSION

The prototype test results reveal that the algorithm and program can converge the translation and rotation of the girder system within 10 μm and 2 μrad, but a repeatability test showed that the program could not compensate for angular deviations between girders. The algorithm will be modified in further testing.

REFERENCES

[1] T.C. Tseng and others, “A Precise 6-axis Girder System with Cam Mover Mechanism”, MEDSI, 2006.
[2] T.C. Tseng and others, “A Precise 6-axis Girder System with Cam Mover Mechanism”, SRI, 2008.
[3] H.S. Wang and others, “Design and test of a PSD System for the TPS Girder”, MEDSI, 2008.