Installation and Implementation of an Auto-Alignment Girder System for TPS Storage Ring

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Abstract **-**The girder system for TPS (Taiwan Photon Source) storage ring is of an auto-tuning design. Each girder can be fine adjusted in 6 axes with 6 motorized cam movers of kinematic mounting design. With sensors between each girder, there are 72 girders to make up a whole ring auto-alignment girder system. All the sub-systems were carefully assembled and calibrated in a ranted factory outside NSRRC during the civil construction period. Mockup systems were set up and the auto–alignment processes were examined to modify interferences or mistakes. After the TPS building was nearly completed, the laser tracker alignment network was set up first and then the preliminary installation was taken place. When all the girders and sensors were installed into the tunnel, the auto-alignment procedures were carried out to fine tune all the girders. This paper describes the preparation, installation and implementation of this auto-alignment girder system for TPS storage ring.

Keywords**:** TPS, girder, alignment, kinematic mounting

1. Introduction

The spec of the TPS (Taiwan Photon Source) project at NSRRC is going to construct a new 3 GeV ring in 518m circumference with high brilliance and low emittance characteristics and scheduled to open to the users at 2015. In order to align the girders precisely and quickly with less manpower, considering the deformation of the floor and limited space in the tunnel also frequent earthquake in Taiwan, a motorized automatic tuning girder system is thus proposed. The design goal of the girders system for TPS is:

- Firm support and precise positioning of magnets
- Whole ring automatic alignment
- Beam based girder alignment
-precise resolution (μm)

In order to fulfill these challenging ambitions, a 6-axis motorized adjusting mechanism thus demanded. This girder system design is a modification from the girder system used is Swiss Light Source by extending a 3 grooves type kinematic mounting from 3 balls to 6 balls as in Fig. 1 and with a few major considerations:

- More contact points with locking system to raise natural frequency and reduce deflection.

- All contact points persist rolling contact condition when adjusting to reduce friction and remain high mobility.
- Contact stress less than elastic limitation to reduce friction wear and keep high reliability

The whole ring girder system consists of 3 consecutive girders in an arc section of each lattice cell and 72 girders totally. With an electric leveling sensor on each girder and touch sensors between consecutive girders in addition with a laser PSD (Position Sensitive Detector) system between straight section girders, a feedback controlled full ring automatic tuning girder system is established as in Fig. 2.

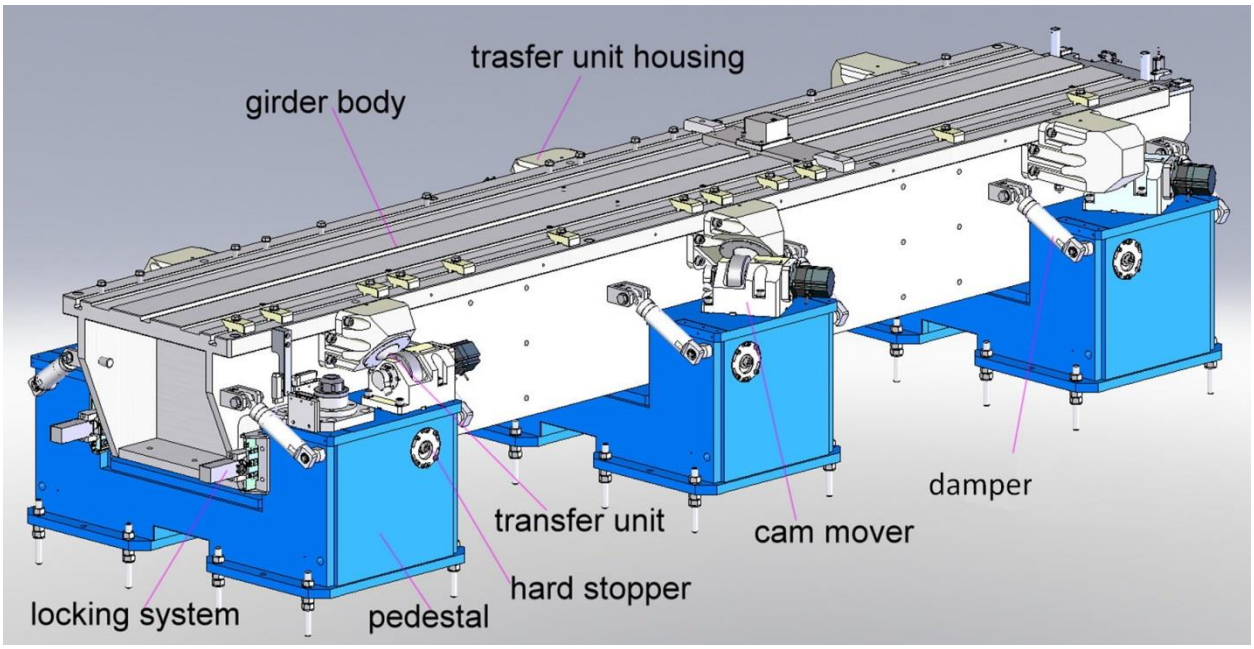

Fig. 1. One girder system configuration

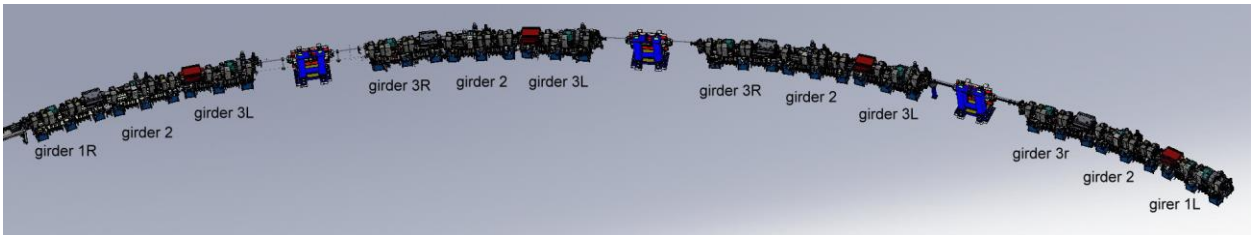

Fig. 2. 1/6 ring symmetry super-period configuration

A mock-up section was fabricated and assembled at NSRRC, a series of tests were carried out to examine the performances of the girder system. According to the test results, 1um adjusting resolution can be achieved. Without locking system, the natural frequency of the girder system assembled with magnets is 24 Hz. While with the locking system be applied, the natural can be raised to 32 Hz.

2. Preparations at a Rental Plant

When the main building was under civil construction, all components had been contracted out for manufacturing and a plant outside NSRRC was rented for assembling and testing. At first the sensors system assembling and calibration were carried out as in Fig. 3. The procedures include:

(1). Measure distances between reference holes on one girder with a laser interferometer.

(2). Measure distances between reference holes on adjacent girders with a encoder rule

(3). Touch sensor module assembling

(4). PSD module assembling, partially auto-alignment processing and sensor's data acquisition)

Fig. 3. Sensors system assembling and calibration

As the magnets were delivered, the magnet assemby process stared. Since there is no crane in the rental plant, a few toolkits for assembling and transportation had been fabricated and meet the requirement as in Fig. 4

Fig. 4. Magnets assembling and moving to the loading dock for transportation to NSRRC

3. Survey Alignment Works

Taiwan photon Source started to break ground at February 2010. Accompanying with construction of the main building, there are GPS pillars set up as civil construction control points. With the progress of construction, benchmark points were expanded to form the entire survey network for the accelerator installation as in Fig. 5(a).

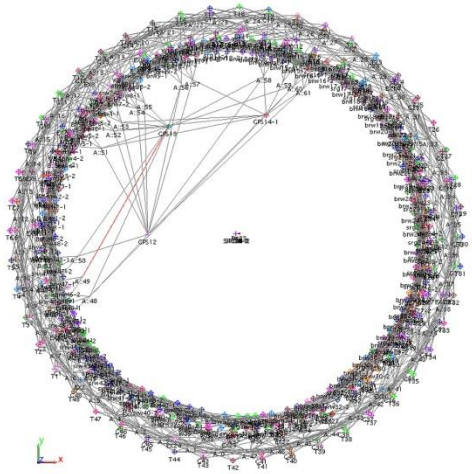

Fig. 5. (a) The entire survey network

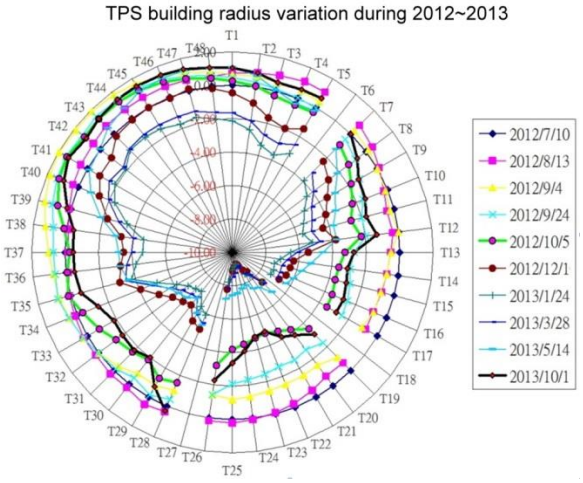

Fig. 5. (b) The TPS building variation in radius direction

With the survey data from the sockets at tunnel walls and experimental hall columns, a seasonal expansion and shrinkage about 3 mm in radius direction accoring temperature change can be observed and a small displacement of (-3,-1) and rotation of 0.0021 degree (about 5mm at lattice position) clockwise of the virtual center were derived and a coordinate values adjustment of all components were decided accordingly.

4. Girders Installation at TPS Tunnel

After the tunnel completed, starting in January 2013, the pedestals were to be set out, anchor bolts drilling and installed at the accuracy around ± 1mm. Upon completion of installation, the pedestals were grout. There were two bending sections installed at July as a mockup testing system and the entire system installation began from October at a rate of 2 sections per week as in Fig. 6. The whole storage ring girders were completed craned at March 2014 and finished control system installation test at May as in Fig.7.

Fig. 6. Pedestals alignment, movers assembling and girder installation with a cradle by crane

Fig. 7. The whole ring girders installed at TPS tunnel

As each 2 girder sections installed, the position deviation were examined with a laser tracker. The results show in Fig. 8 and mostly were around ±1mm while a few were more than 2mm. However, the deviations still within the adjusting range and were adjusted with local network to less than 0.1mm.

Fig. 8. The position deviations of each girder at installation before adjusted

5. Auto Alignment Preparation and Implementation

A laser PSD magnet centering measurement had been established to check the alignment deviations of each magnet machine center when installed at the girder. The work had been started at the rental plant at a repeatability of 2μm. Due to the tight schedule, 3/4 ring magnets were examined at tunnel at a repeatability of 10μm when the air conditioning and temperature control was still unavailable.

However, the RMS errors of 18.5μm and 20.4μm in vertical and horizontal direction respectively still meet the spec of beam dynamic.

Fig. 9. The position deviations of each magnet center when assembled on the girder

As the girders finished installation, the important works were the inspection of the connection of the sensors with the control system. After about 2 months examination and further calibration including some damage sensors replacing, in the middle August, the storage ring were preliminary automatically aligned and the booster ring were manual aligned according to the laser tracker survey network with the deviations within ± 0.5mm as Fig.10. The adjustment time for storage ring (72 girders) is about 1900 seconds once time.

Fig. 10. The laser tracker survey network errors of girders after first auto-alignment

6. Conclusion

TPS girder system including storage ring, booster ring and transport line were almost finished installation and the booster ring is now under commissioning.

A basically full ring auto-alignment according to the laser tracker survey result had been performed and shows good conditions.

The laser tracker survey results show that the full ring real accuracy might be about ± 0.5mm and the girder sensor's initial conditions should be further improved to optimiz the girder alignment.

A new adjustment will performed to reduce the vertical deviation and a beam based girder alignment might be also adopted.

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