SURVEY AND ALIGNMENT DESIGN OF NSRL BASED ON LASER TRACKER

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Abstract

The accelerator alignment methods at NSRL have been three stages. The first stage used steel wire to establish the construction control network to guide the installation during the accelerator installation processes. The second stage optimized the network to monitor the deformation of the machine. Now is the third phase of the transformation. This stage is benefited from the latest developments of measuring technology and measuring instrumentation. Laser Tracker now is used as a major measurement tool. It is a high-efficiency, high-precision manner to monitor the deformation of accelerator. This paper will outline the design of the process.

Construction control network

From the beginning to the normal operation, the accelerator has experienced three different epochs from the point of view of alignment, using three different survey control networks corresponding to the three different measurement processes.

The accelerator alignment in the early process of the beginning build, the major task was the establishment of construction survey control network. Construction control network also included first class control network and second class control network. The major task of first class control network was determining the overall location and establishing permanent signs. The first class control network was not only used for the observation of surface deformation, but also used as construction survey control network for the accelerator civil engineering. It was built on the ground, also known as surface network. It supervised the build of underground tunnel excavation or indoor construction and established underground or indoor control network. Its survey and alignment generally used trilateration survey, triangulateration, precision leveling measurement. Its main technique criterion:

- Control points were generally used to the apparatus or the targets，and had equipment constraints for aiming at center(better than 0.1 mm).
- The network used the simulation method to optimize the design.
- When the coordinates of gravity standard network was transferring to the network of tunnels or indoors, should ensure the accuracy of casted point.

The second control network mostly guided tunnel construction or interior construction, which link between the first control network and installation control network. Several points were casted on the network from the ground. The accuracy of indoor or tunnel control points calculated from the accuracy of ground control points and the precision of casted points.

Installation Control Network

When during the process of installing accelerator components, we established installation control network. Installation control network was designed for the installation of accelerator components in place. It included the magnets and other important components, which was the expansion of the second control network; it usually designed as a triangulation network, which was fully of redundant observation and good enough intensity of graphics. It generally included principium positioning and precision positioning two steps: the principium positioning usually followed by polar coordinates of points and the intersection of sideline to determine the location of the signs of equipments; precision positioning was used of gradually approach to the setover of arc to determine the relative position between devices. Now generally on the basis of the principium positioning, directly use of the logo on the equipment to establish Installation control network, which integrate with the precision positioning.

It should be showed that all of control networks include horizontal control network and vertical control network. The design and settlement of the vertical control network is relatively simple, therefore, the main discussion is horizontal control network.

After the accelerator built finished and became into normal operation, it needed to establish control network to monitor the deformation of accelerator. We must regularly monitored the deformation the main components of accelerator and timely found theirs position change, then adjusted the parts which position changed more than a certain threshold. Some control network for monitoring the deformation was appropriately improved from installation control networks. Some installation control networks could be directly used as control network for monitoring the deformation. But they should established solid signs at all control points. The technique criterion here considered, beside the target of above control networks, the sensitivity of control network for monitoring the deformation: The lower bound of the vector be found significant deformation under a given probability.

All the main constructions of NSRL were carried out with open wide, without tunnel excavation. Therefore all the first class control network of NSRL and the second class control network of NSRL integrated as one network. The installation control network of NSRL was made up from 28 control points (Figure 1).There were four center points (Figure 1 points of the 25, 26, 27, 28) in the 28 control points. The remaining 24 points (Figure 1 1-24 points) were fixed in the top of 12 dipole magnet. 86 sidelines made up of a precision triangulation network. The sideline lengths were measured by steel wire which was demarcated by the dual-band laser interferometer. The accuracy of measured distance was $\sigma_0 = \pm 0 \cdot 03mm.$ The reason why used triangulation network was because angle survey was affected by factors such as centering error, focusing error, bearing error and the level of refraction. It was hard to achieve the accuracy of control network required. In this 86-Measurement, there were 48-Measurement must be measured which could kept the dipole magnet along the radial orientation and tangential orientation. And the other 38-Measurements were redundant observation variables used to improve the entire ring stiffness and the precision of the relative position of magnet.

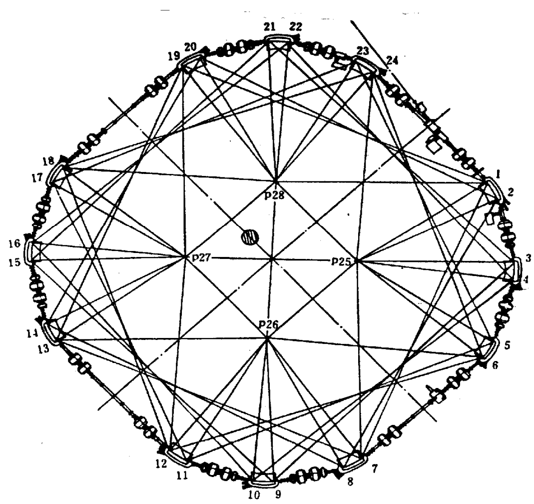

Figure 1:The installation control network of NSRL

The purpose of the installation control network was setting out the location of dipole magnet, further positioning the location of quadrupole magnet and precision positioning the components of liner section. So the orientation accuracy of 24 points on dipole magnet was the ultimate standard of construction control network. According to physical design, dipole magnet's X and Y direction location error allowable

$$\text{value}\begin{cases}|\Delta X| \le 0.15, \\ |\Delta Y| \le 0.15.\end{cases}$$

The precision of installation control network of NSRL was very high, originally after little transformation could used be as control network for monitoring the deformation. But, after the ring competed, the equipments inside the ring destroyed the integrity of network. Therefore, after the 1990s study and design we optimized a new control network for monitoring the deformation. It was high precision and high reliability for monitoring the deformation without moving any facilities inside the ring and guided the adjustment of magnet position. Figure 2 shows that the diagram of control network for monitoring the deformation.

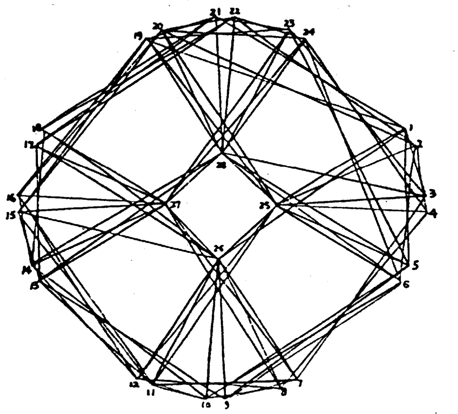

Figure 2:The control network for monitoring the deformation of NSRL

This control network for monitoring the deformation has been used until the second phase project completed. With the end of the second phase project, the equipments inside the ring became more and more. Above control network could not be measured normally. After we acquired Laser Tracker, we could survey NSRL based on Laser Tracker.

Survey Control Network Based on Laser Tracker

Laser Tracker could directly measure the three-dimensional spatial coordinates of points with high precision and its accuracy of measured distance is15μm+6μm/m. Laser Tracker could unify all spatial coordinates of measured points into a coordinates system with using its function of transfer station. Further it could do the needs for the transformation of coordinates system.

Laser Tracker measurement could greatly improve the efficiency of measurement. In order to overcome the inadequate of Laser Tracker's survey accuracy, total station and level could be used while vertical control survey and angle survey.

Demands of Survey Control Network

Benchmark points which were setting in the design and construction process of NSRL could not meet the requirements of network building with Laser Tracker. Therefore, we must increase points for measurement. Beside the original reference points on the dipole magnet, there need to add two points (Figure 3). The two new benchmark points can be welded or bonded in the very top of dipole magnet. The accuracy of theirs location is no specific requirements, however, as separate as possible. In addition we need to grind a regional on the top of dipole magnet to control the level.

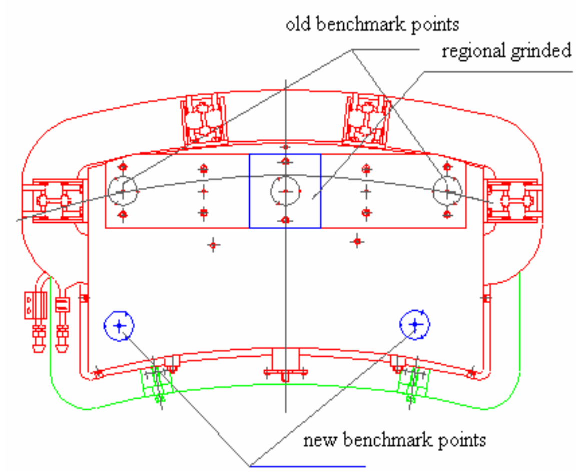

Figure 3:The two new control points on the dipole magnet and grinded surface

Transfer station survey of Laser Tracker need joining survey between stations. Generally in order to improve the accuracy, a new station measured not less than 6 points which in the last station must also be measured.

In order to meet up with the needs of transfer station, we must resettle a number of measured points internal the ring and the wall around the ring. There is no request for these points with its location, but requires stability. We can dig tunnels on the ground and feel them with adhesive. On other side we can firmly installed them in the wall with screws or adhesives. Surround of the ring layout diagram shown in figure 4.

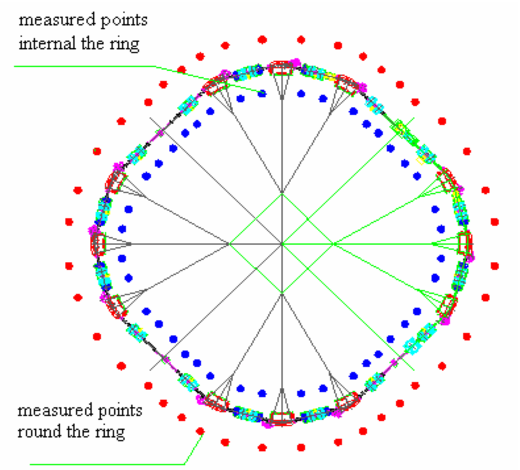

Figure 4: Measured points surround of the ring

In theory, there is a clear relationship between all measured benchmarks of dipole magnet and the center of each magnet. After measure these benchmark position, we are able to calculate the center of each magnet and beam position is or not consistent, then decide whether or not to adjust. However, conduct each magnet of NSRL is currently impossible. Therefore, before using Laser Tracker, we need use the original deformation monitoring network to do a serious measurement, recording the existing location of each magnet. At the same time the level monitoring level situation on the top of each dipole magnet, the bubble monitoring vertical situation of dipole magnet、quadrupole magnet and other very important components, and record them. Then do the measurement for the first time using Laser Tracker and record the measurement of each point, including the coordinate of the measuring points in the magnet and the surrounding space of the ring. These data are the original baseline measurement for Laser Tracker, in this case measurement can be reduced.

Laser Tracker survey network

Laser Tracker will be placed in the ring to do the measurement. There are many equipments in the center caused poor conditions of the visibility, we would transfer station 8 times. Each transfer station ensure a station have six points lap to the last station. The sketch map of survey network is shown in Figure 5.

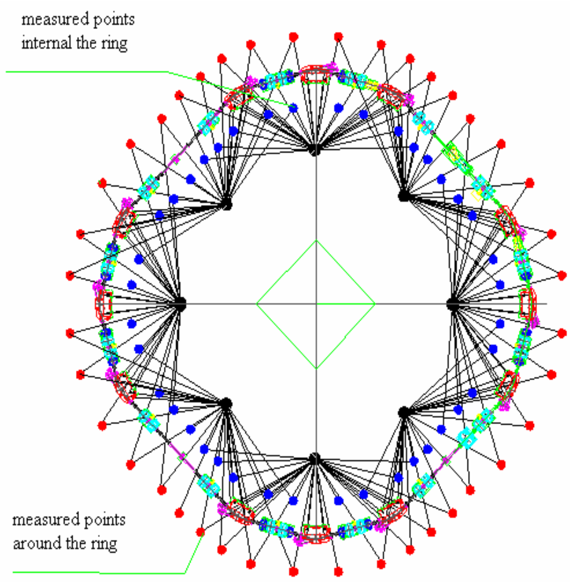

Figure 5:Laser Tracker survey network diagram

A necessary complement of the alignment

The accuracy of Laser Tracker's vertical angle survey is relatively poor. This will directly affect the accuracy of vertical survey for the magnet. Therefore, in addition there need the optical Level to measure vertical separately.

In order to improve the accuracy and reliability during the precision measurement, we often use different instruments to measure the same control network. We will use the Total Station to measure the entire network separately, then compare to the measurement results, which guarantee the accuracy of Laser Tracker survey.

References

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