THE CONTROL NETWORK DESIGN OF SSRF

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1. INTRODUCTION

The Shanghai Synchrotron Radiation Facility (SSRF)(shown in Fig 1. and 2.) is a low emittance 3rd-generation light source, which is planned to be in construction on 8 December in 2004 and finished in the year of 2009.Many efforts are paid to ensure the project's ground-breaking on time.

It is composed of a 20m-long LINAC(100Mev), 180m-circumference Booster(100Mev---3.5Gev), 432m-circumference Storage Ring(3.5Gev), the low-energy, high-energy beam

Fig. 1 The location of SSRF

transport lines and the beam lines and stations. See it in Fig.3.

We had a two-years period R&D, and we have done much jobs for all the survey and alignment questions that can be involved in the future's installation and positioning. A control network was figured out after a lot of theoretical analysis and practical simulation experiments. The time was the beginning of the year 2001.

Fig. 2 The Site of SSRF in Shanghai

After the R&D, nearly four years have past; The SSRF will at last be constructed. It's a rather long time for everything. Our physical parameters are changed, along with the support changed and building changed. We can't use the network designed four years' ago any more.

That's one reason for the change of control network; another is that we do have new ideas and considerations of survey and alignment. So, in this article I'd like to introduce the concept design of survey and alignment control network of SSRF.

2. THE DESIGN PHILOSOPHY

2.1. The budget tolerance

According to the particle dynamics, the accelerator physics group give the maximum alignment error as described in table 1 and table 2.

Table. 1 storage ring magnet alignment tolerance

Type	Quadrupole(in girder)	Sextupole (in girder)	Corrector (in girder)	Girder	Dipole
Type	Quadrupole(in girder)	Sextupole (in girder)	Corrector (in girder)	Between Girder	Dipole
Radial	0.08 mm	0.08 mm	0.2 mm	0.15mm	0.15mm
Vertical	0.08 mm	0.08 mm	0.2 mm	0.15mm	0.15mm
Longitudinal	0.5 mm	0.5 mm	0.5 mm	0.5mm	0.5mm
Rotation	0.2 mrad	0.2 mrad	0.5 mrad	0.2mrad	0.2mrad

Table. 2 booster magnet alignment tolerance

Tolerance	Dipole	Quadrupole	Sextupole	Injector
Radial	0.5mm	0.1mm	0.3mm	1.0mm
Vertical	0.2mm	0.1mm	0.3mm	1.0mm
Longitudinal	0.5mm	1mm	1mm	2.0mm
Rotation	0.2mrad			1.0mrad

There are many procedures to position the accelerator components correctively and precisely such as: (1) design a high reliably control network and use appropriate measure method and technology to measure it; (2) adjust the measured data to produce best-fit network coordinates. (3) design the alignment plan for all of the accelerator components; (4) calibrate the position relation between magnet centreline and fiducial points; (5) raft the co-girder system in which the relative position among quadrupole, sextupole and other components is aligned right; (6) according to the control network, align the co-girder system in the actual tunnel floor and secure the right relative position.

In these procedures, there are many data-gathering work and computation work that can induce error and uncertainty. Thus, we should keep to the least square principle and follow the error propagation rule to assign the maximum error in every procedure. According to the simulation, if the control network is confined within the accuracy of 0.1mm, our aim of 0.15mm can be guaranteed.

In the following paragraphs we'll expound how the 0.1mm network relative accuracy is achieved.

2.2. The main consideration

Usually when we manipulate a small facility such as LINAC or magnet, there is no control network or only one. Because it's small, the relative position relation is rather simple. But when we face to the big facility such as any of the synchrotron, there will be sophisticated control network that can be made of lots of points and may be classified to several orders. The aim of classification is to harmonize the conflict between accuracy and costs.

We classify our control network to two kinds: the global network and local ones. The global network is used as the global control of the whole synchrotron. After the measurement of it, the relative position among LINAC, booster and storage ring can be make sure rather precisely. And the function of the local one is to assure the relative position of all of the accelerator components, which is much more important in the alignment of accelerator.

Another classification familiar to everybody is the horizontal control network and vertical one. They both have the mature technical method to realize high precision. In the global network we use this classification method. Total Station and Level will be used to measure the network

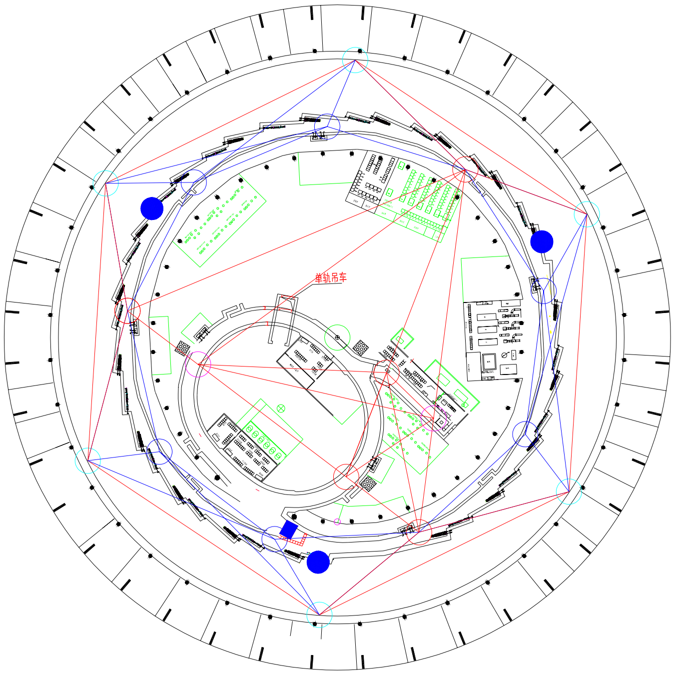

Fig. 3 SSRF global control network

respectively. But, as for the local network, the traditional method is disused because it is laborious and inefficient. We plan to use the real 3D manner to measure the local network. The main instruments are the Laser Tracker and Total Station from Leica. We have the Axyz software platform to gather the two kinds of different data and adjust them together. The measure and calculation is in real 3D mode. In the following we will relate these deliberately.

3. GLOBAL NETWORK

3.1. The shape of global network

The global network is composed of 19 points that spread around the accelerator complex. See it in Fig.3. There are 2 points in LINAC and booster each, 9 points in storage ring and 6 points in the experimental hall.

The network points are designed in a manner that can be used not only by horizontal measurement, but also by elevation measurement. The points are buried in the tunnel floor. As a control network, key net points should be seen each other. It's obvious that the line of sight is obstructed by the tunnel's wall. In order to solve this problem, two ways are used: heightening points and clearing the obstruction such as the experimental hall's inner walls.

Because making holes in tunnel's wall may cause serious radiation problem, it's not encouraged inefficient to drill too many penetrated holes or windows in the wall. But on the roof the danger may be littler. This means that we can firstly make holes on the roof, secondly heighten the instrument and targets, and thirdly measure on the roof. If they can be centred well enough onto the points in the tunnel floor, the accuracy can be assured. So in gravity direction,

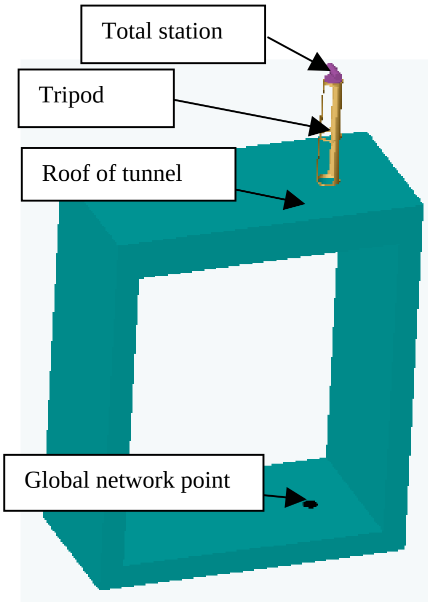

Fig. 4 the survey sketch of global network

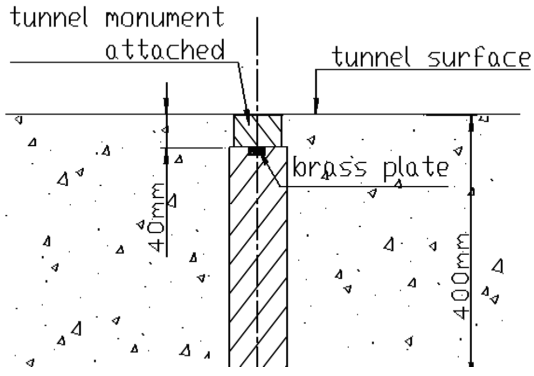

Fig.5 the sketch of global network point

there is a hole (Φ150mm) on the top of each point in the tunnel roof which makes the line of sight can pass through the tough roof. When the accelerator is running, the hole will be sealed.

That can't solve all the problems. LINAC and booster has a technical aisle on the top of the tunnel's roof each. They need be holed on the roof too. As for the horizontal direction, in places where the line of sight may be obstructed by the wall of the experimental hall, LINAC and booster's technical aisle, a movable glass window will appear which make the observation feasible. Because the pillar of experimental hall can't be moved or drilled, the position of the points are carefully chosen.

Table. 3 the designed coordinates of global network

Point	Z	X	Point	Z	X
R1	40.61827	-53.40273	E1	79.16092	-39.15411
R2	25.93807	61.8791	E2	73.48888	48.9784
R3	-66.5588	-8.475245	E3	-5.67209	88.1325
R4	65.4431	-14.7988	E4	-79.161	39.1541
R5	59.64482	30.72945	E5	-73.489	-48.97837
R6	-19.9054	64.0748	E6	5.671989	-88.13247
R7	-56.4349	36.28921	B1	-44.1554	8.51134
R8	-45.5377	-49.276	B2	2.808583	44.3005
R9	-3.20992	-67.0187	L1	30.55257	25.7008
			L2	17.84155	13.3647

In this way, we can use a precise plummet to transfer the floor point to the top of the tunnel roof. Then a classical horizontal control network can be constructed without causing too much radiation effect. The principle can be seen in Fig. 4.

According to the architecture design, the tunnel floor in different sections will not be made simultaneously. But tunnel wall will be built up along with the floor at the same section. So we can't measure all the points without obstruction before wall is erected. The first time measurement can be carried out only after all the building activities almost being finished.

As for the elevation network, we can measure those points directly on the tunnel floor. There are three holes (blue dot in fig.3) in the storage ring's tunnel wall to make sure the height difference can be transferred between the storage ring and the experimental hall.

Those points and other local floor points are mixed up to form a uniform elevation network. There are two functions of the elevation network: on the one hand, to measure the relative high difference of all the global points and to provide a datum for the vertical positioning; on the other hand, to monitor the differential settlement of the tunnel floor.

3.2. The burying of the points

All the global network points are designed to be stainless steel frusta. See Fig.5. On the top surface of the structure, there is a cross line. They will be buried in the tunnel floor according to the designed coordinates within the accuracy of 5mm. The frusta is buried 40mm lower than the tunnel floor surface, which will give facilities for the burying of the tunnel network point (see Fig.9) when the tunnel surface is finished. In this way, the global points can be not only the datum of infrastructure constructing, but also the setting-out reference of other local control points.

3.3. Instrumentation

The main instruments for horizontal network is Total Station and plummet, and for elevation measurement is Level. The model of Total Station is TDM5005, which specification is ±0.3mm in distance measurement (within 120mm) and±0.5" in angular measurement. The model of plummet is NL, which specification is 1:200000. The model of Level is N3 and NA3003, which specification is ±0.2mm/km and ±0.4mm/km respectively.

As for the horizontal measurement, the observation elements are angles and distances. Because of the low efficiency of angle measurement, some angle measurements may be omitted according to the optimal design. Each distance will be measured in each end.

The elevation network measurement will be done in normal mode, so we won't talk about it here.

3.4. Point error

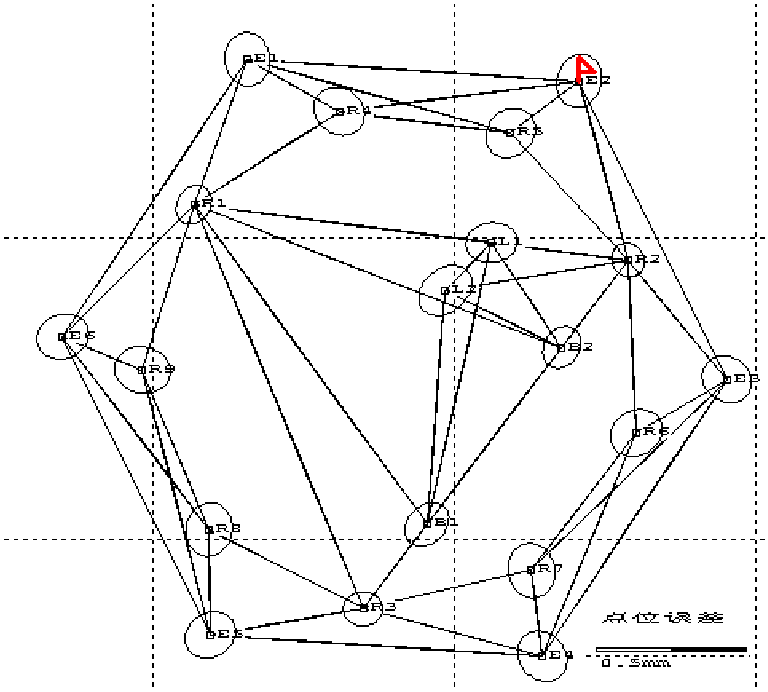

Fig.6 Absolute error ellipse of global network

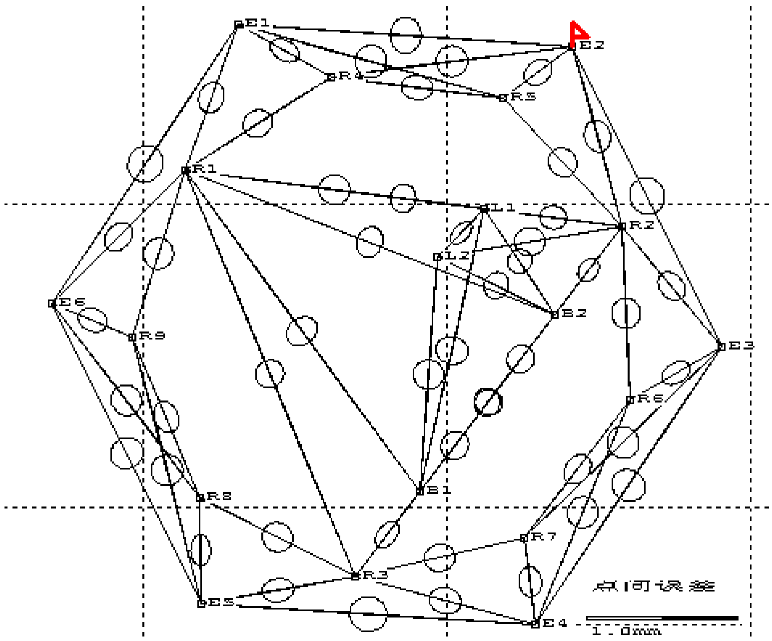

Fig.7 Relative error ellipse of global network

According to the free net adjusting principle, the global horizontal network is calculated using software named NASEW95. The error of the distance is assumed as Ms=±0.5mm and angle as Ma=±2”, which deduce the maximum point error is ±0. 243mm and the maximum error between points is ±0. 335mm. The absolute and relative point error ellipse is displayed in Fig.6 and Fig.7 respectively. From the result, we can expect high relative accuracy of each sub-accelerator. Farther calculation will be carried out to do the optimal design so as to deduce the number of low efficiency angle measurements.

4. LOCAL NETWORK (3D TUNNEL NETWORK)

4.1. Construction

The local control network is scattered almost in the whole space of SSRF. According to the classification of accelerator, the control network is classified as network of LINAC, Booster, Storage Ring, Injection and extraction parts, and experimental hall. There are about 32 network points in LINAC, including 2 global points L1and L2; about 100 points in Booster, including 2 global points S1and S2; 20 points in injection and extraction parts; about 300 points in Storage Ring, including 3 global points R1, R2 and R3; and about 200 points in experimental hall

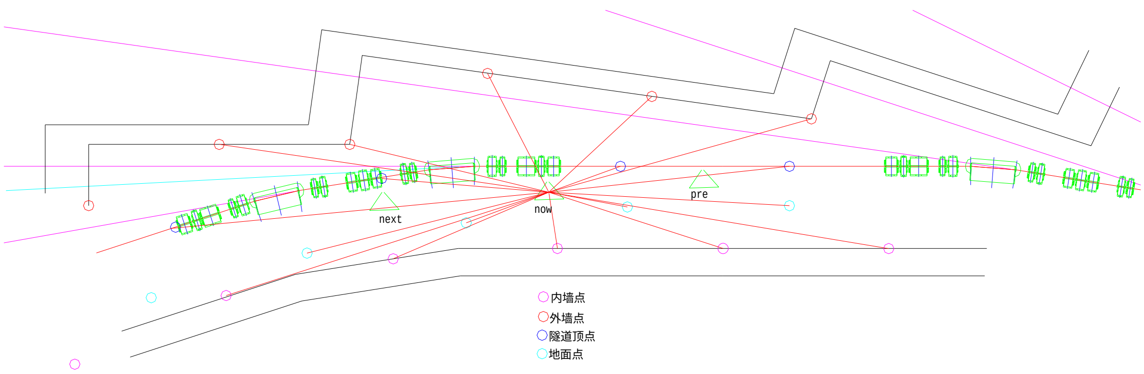

Fig.8 the sketch of local network measured in 3D manner

including the 6 globe ones.

Laser Tracker will measure each of the local control networks in real 3D manner. This type of network needs the control points to be scattered in space. For example, In the Storage Ring, the points will be located in the outer wall, inner wall, floor, and ceiling of tunnel. Each group contains all of the four points, and the space between them is 6m. One part of the tunnel network measured in 3D manner is shown in Fig.8. In each station, Laser Tracker measures the points around it reading the distance, horizontal angle, and vertical angle simultaneously.

Because of the high accuracy of the Storage Ring, the network will be measured not only by Laser Tracker, but also by Total Station which is intended to compensate the shortcoming of Laser Tracker's angular decode. They both act in 3D manner.

4.2. Burying

All of the monuments are force-centring structure, which can fit exactly for the Φ1.5" ball. The sketch of floor point is shown in Fig.9, and wall point is shown in Fig.10.

When burying the floor monument, firstly, use instrument to set out the point location; secondly, drill a hole to accommodate the structure; thirdly, bury the structure using epoxy to cling. In usual condition, the cover is in position. When the point is being measured, its cover is moved. The fixing of the wall point is rather easy. Drill expanding nuts in the wall, and then fix the point.

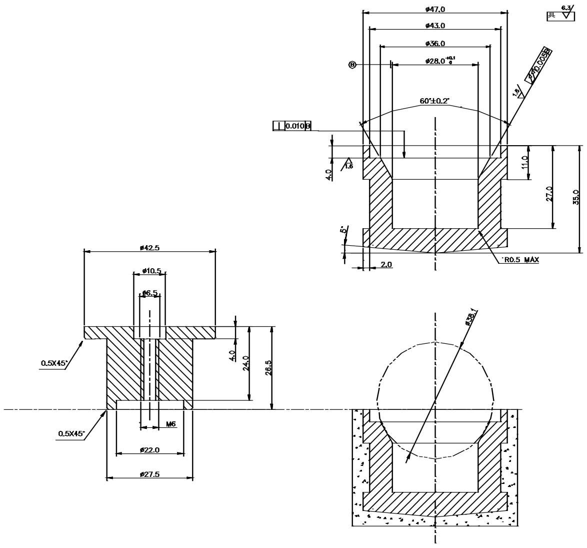

Fig.9 Floor control point

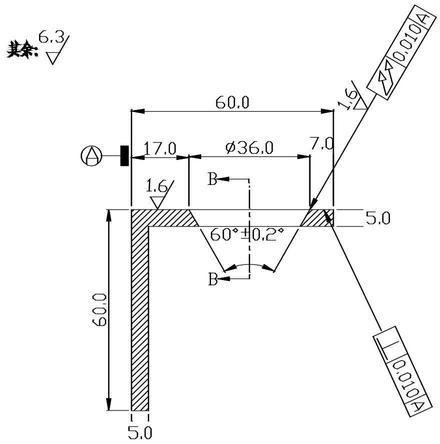

Fig.10 Wall control point

4.3. Instrumentation and method

The main instrument is the Laser tracker LTD500. Its specification is 0.10mm±10ppm (2σ). It's rather high precise and high efficiency.

Set-up the Laser Tracker in first station, measure all of the points that its distance is shorter than 12m around the instrument. See Fig.8. Then move the instrument, set-up a new station, measure all of the points as station 1. In this way there should be many re-measured points among stations. The software Axyz uses these re-measured points to establish the relation between the adjacent stations, and change the new-measured points to the coordinate system of station 1. Then the instrument is moved to station 3,4 and so on. All of the control points are in a uniform coordinate system. Then the control network is built up.

This full 3D measure method is rather different from the traditional measure method. The shortcoming of the traditional method is low efficiency. If we use the traditional method, we'll have very boring, huge work and the time for survey and alignment will be lengthened several times which may affect the whole project progress and future normal light-supplying time for users. We measure the entire local network in this way.

Because of the high accuracy requirement, The Storage Ring control network is specially considered. Except for the Laser Tracker measurement, the Total Station TDM5005 will be used to measure in the same manner to compensate the Laser Tracker's angular error. There is no need to plummet and force-centring which is much more laborious. The Total Station's station space is 20m. In each station, it can aim long distance, and points needn't be overlapped.

4.4. Adjustment

We expect that accuracy of network points is better than 0.08mm.The software Axyz gives the same platform to manipulate the two instruments' data. After the different weighting progress, the software does the orientation. The coordinates calculated will present the precise distance from Laser Tracker and angle from Total Station.

But Level's data can't be adjusted altogether. Level's data can be used to check the accuracy of coordinates.

Another software will be developed to adjust all the measured data together.

5. THE CONSTRUCTION AND MONITORING CONTROL NETWORK

There is almost nothing where SSRF will locate. Many building will be constructed. There should be construction survey control network that directs the relative position of all the buildings. The function of the control points can also be monitoring the inclination and sinkage of the building.

GPS can be set on L1 and S1 and a baseline can be gotten relative to the city's construction network system. Thus, an absolute datum can be gotten.

The control network designed above will measure the relative change between accelerator foundations.

HLS will be set to monitor the real-time fluctuation of magnets and girders.

6. CONCLUSION

The situation of SSRF is introduced swiftly. We try to design the control network that can be measured easily and reliably. The control network of SSRF is classified to global network and local network. In the local network measurements, a true 3D manner will be performed.

7. ACKNOWLEDGEMENT

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