Status Report on CSR Survey and Alignment at IMP

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1. GENERAL INSTRUCTIONS

The HIRFL-CSR project is upgrade project of the Heavy Ion Research Facility in Lanzhou (HIRFL). It will greatly enhance the performance of HIRFL for those researches by using Radioactive Ion Beams and high-Z heavy ion beams in the fields of nuclear physics and atomic physics. The CSR (Cooling Storage Ring) consist of main ring (CSRm) and experimental ring (CSRe) (see Fig.1). The circumference of CSRm and CSRe is 161m and 128.8m respectively. The max energy will be extracted from CSRm is 1100MeV/u (C6+) and from CSRe is 600MeV/u (C6+) [1]. The total cost of the project is about 43million of US dollars.

The construction of CSR is half under ground (see Fig. 2). The floor in the tunnel is 2.6 meters lower than outside ground. The width is 7 meters and the height is 4 meters in the tunnel.

The concrete block is as the magnet support and the 3-D adjustable supports are used to adjust the position of components. Fig.3 shows a quadruple on CSR main ring.

The HIRFL-CSR project started in 2000. In 2004, the construction and installation of HIRFL-CSR storage ring complex is completion , all the components of CSR main ring have been aligned. The main task of HIRFL-CSR project in 2005 is the commissioning of the main ring CSRm. The first first-turn commissioning of CSRm has been successfully done at the beginning of 2005. The first stored beam in CSRm was observed on January 23, 2006 using 6.897MeV/u C4+ as the injection beam, and the stripping injection mode was used. The stored beam with lifetime of more than 10s was observed using Schottky spectroscopy. The stored beam was accelerated from 7MeV/u to 14 MeV/u.

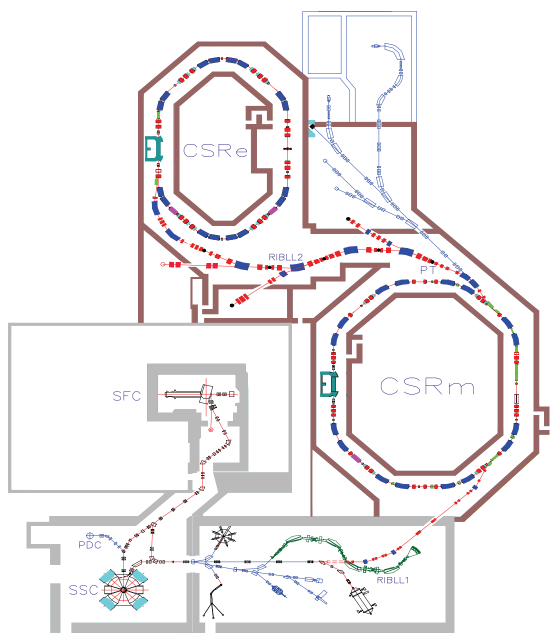

Fig. 1 Overall layout of HIRFL-CSR

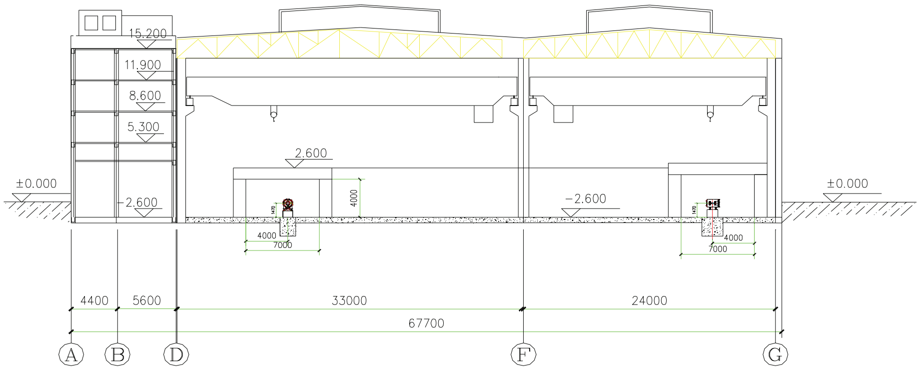

Fig.2 The cross section of CSR hall

Fig. 3 CSRm tunnel

Fig. 4 A quadruple magnet

Many technical progresses have been made before realizing the storage of the ion beam, such as the control of magnet power supplies, the improvement of Mg-jet, view screen, and the electronics of BPMs and Schottky detector and so on. All the components of the main ring have been carefully aligned and checked for several times, and the alignment errors are within 0.15mm.

This paper introduces the work we have done and discusses the methods we used to align the CSR main ring. The problems we meet, e.g. the temperature changes influences the scale of ring, will be discussed also.

2. FIDUCIALIZITION FOR MAGNETS

For the fiducializition of magnets, the 6 to 8 SMR nests are welded on each magnet, 4 on the top, and the others on the aisle side, as the fiducials for survey using tracker (see Fig.4). Before measuring the fiducials, the component reference frame (part frame) must be defined. For the transport line magnets, the origin of part frame is on its geometric centre, the special bar has been used to measure the head of magnet and define the geometrical symmetric centre. Actually, the magnetic centre is not on the geometrical center, there is a deviation, Fig. 5 shows the deviation between the geometrical center and magnetic center of a quadruple [3]. For the CSR main ring and experiment ring this deviation should be concerned. When the magnet is aligned, according to the results of magnetic measurement, the original fiducial data are amended to keep the magnetic centre installed on the theoretic point of the ring.

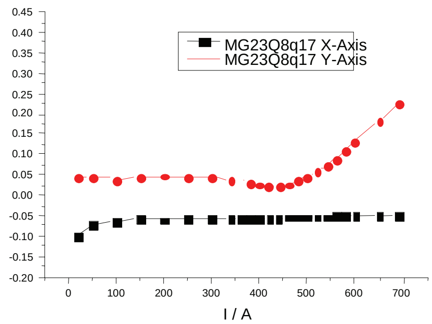

Fig.5 Deviation of magnetic centre and geometrical center

Fig.6 Special tool to define the rotate coil axis

Fig.6 shows the rotate coil used to measure the magnetic field. In order to use the same reference frame when the magnetic field and component fiducialization are measured, the special tools mounted on the axis are used to measure the rotate centre of the coil and define its axis to establish the part frame (Fig.6). This method can reduce the frame deviation between the magnetic field measuring and fiducials measuring, it needn't to precisely mount the rotate coil on the geometrical symmetric axis of the magnet when measure the magnetic field, since the two measuring use the same part frame and the deviation will be corrected.

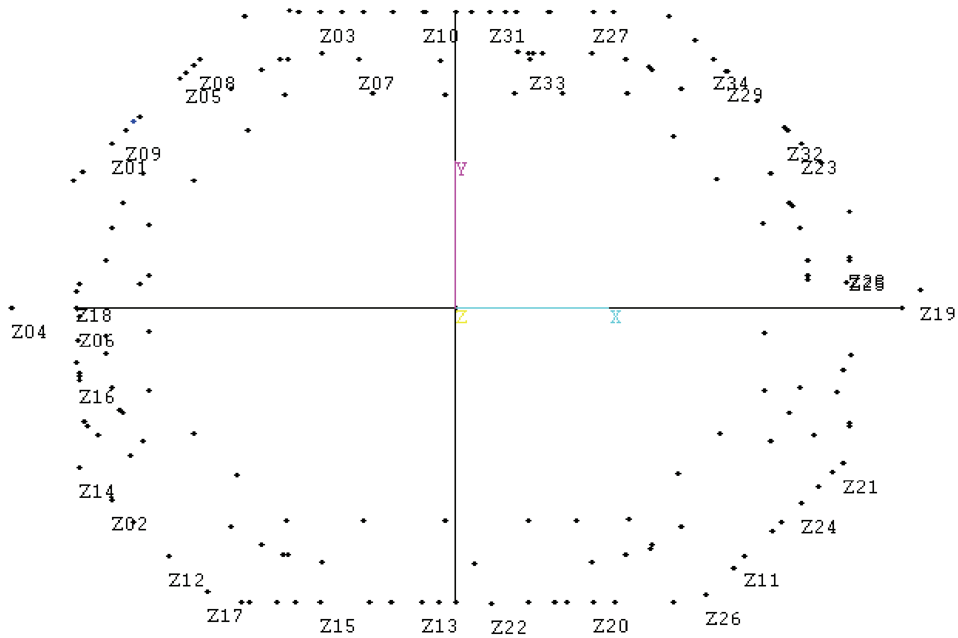

Fig. 7 The control network of CSRm

3. MEASURING THE CONTROL NETWORK OF CSR MAIN RING

The control network of CSRm is defined by 134 monuments，122 on the wall of tunnel, 10 on the floor surrounded the main ring as the level marks, another two are in the special pipe which is inserted deeply into the ground. Those two control point generate a line as the long axis of CSRm, the 10 level marks generate the Y axis of CSRm control network. Fig. 7 shows the construction of network. The circumference of CSRm is 161m, the station number for bundle is 17. Experiences tell us the less station number for bundle adjustment is not good for the precision of network.

3.1. Generate Precise Level Plane

As we know, the tracker has level function but it is not as accurate as the DNA03 digital level is. In order to generate a precise level plane, first the level marks are surveyed by the DNA03 level and adjusted by the NASEW95 software. After the network measured use the tracker, the level marks are measured also, so there are two data of the 10 level marks: one is from digital level and the other is from laser tracker (see the Fig. 8). Using the digital level’s data to correct the tracker’s data, the precise level plane can be obtained.

Take the point A for example, now there are two data of it, one is from digital level, it is the length of AB, the other datum is from tracker, it is the length of AE. Supposed At is the datum measured by the tracker, Ad is the datum measured by the digital level, then Ad=AB, At=AE. In the reference frame of tracker, let At-Ad, it is similar to move the point A from A to C (AC=AB) and the C is close to the digital level plane. Every points were taken order with this way, a grope of new points that closed to the digital level are generated. Using the best fit function, the grope of new points can generate a plan. Using this plane instead of the tracker level plane to form the CSRm reference frame. This reference frame is more accurate than the one only using the tracker level and can satisfy the requirement of CSR survey.

3.2. Analyze Deviation of Level Plane

Because point C is not on the digital plane, it is caused a deviation, but the length of CD is very small. By the analyzing of geometry we know:

AB=AC

CD=AD-AC=AD-AB=AB*cosα-1-AB=AB*(cosα-1-1)

Supposed angle α is 2 arc second (the level precision of tracker), the CD is obtained

CD=4.7e-11*AB ≈0

Because the 10 level marks are fixed on the floor, the level difference of them is not very much, AB is about two or four centimeters, and therefore CD is almost near zero. Actually, after the best fit the all level marks are not on the new plane exactly, the standard deviation is about 0.05mm because of the measurement error of laser tracker and digital level, but this new plane is enough good for CSRm control network.

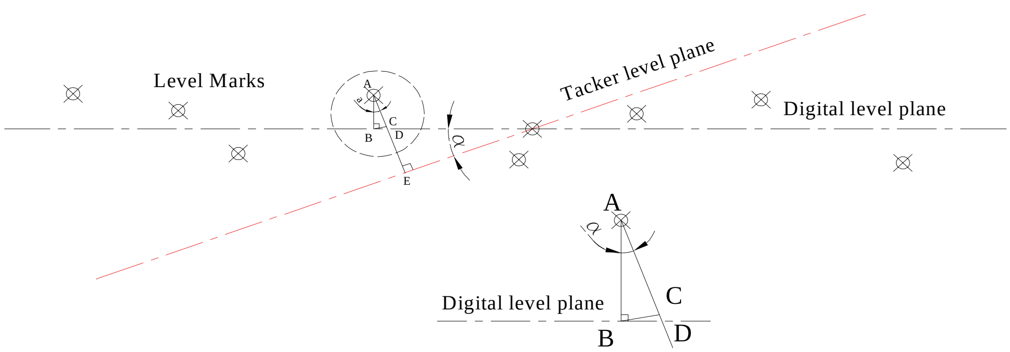

Fig. 8 The digital level and tracker level plane

3.3. Re-measure Control Network

Actually, when the control network re-measured, the fiducial points on the magnet are measured as much as possible also. Those points take place the calculation of networks and will improve the accuracy of networks. After treatment the data, the position of magnets measured in same time can be calculated simultaneously. The floor level marks are never used again when the all components put on the beam line, the 64 fiducial points on the top of dipoles are instead of the level marks, because their position is higher than the floor level marks and do not easy to be sheltered from other devices.

4. ALIGN THE MAGNETS

The instruments used to do the survey and alignment for CSR are SMX laser tracker 4500, Leica TCA2003 total station and DNA03 digital level. Due to the laser tracker and its powerful software-SMXInsight, the three dimensions survey and real time measuring are realized when adjust the position of magnet, it is very convenient and can get high precision.

The Function Editor and Bundle function of the SMXInsignt are very useful tools for the network measurement and magnets alignment. It is very easy to realize the reference frame definition and translation. When align the magnet, firstly, the network points around the laser tracker are measured, using the Bundle adjustment method of the SMXInsigt, the CSRm reference frame are restored, then we move and rotate the frame to translate the origin from the center of CSRm to the theory position of the magnet that will be align. Using the watch widow function to measure the fiducials on the magnet, comparing the measured data with the original fiducial data, the deviation of the magnet can be known. Adjusted the magnet, let the two data as same as possible. The Best-fit program that is made of our group is used to check the final result. This program can figure out the three deviations along the x y z direction and three roll angles surround the x y z axis of magnet according to the fiducial data and the data laser tracker measured.

Now, using the laser tracker and the survey method ,all components of CSRm have been surveyed and aligned many times, the 0.15mm position tolerance for magnets is not exceeded.

Fig.9 Align the magnet using laser tracker

5. THE PROBLEMS

Since 2004 measuring the control networks and align the magnets have been done many times. We find the scale of them changed with the temperature. It follows the rule of hot expand and cold shrink. Because the CSR construction is not underground and there are no air-conditioners in the CSR hall and beam tunnel. The maximum deference of temperature between summer and winter is 25 0C. This causes the much difference of the CSR ring scale. Seventy distances between each two net points on the inner wall of tunnel are observed from February to August to find its changes with temperature (fig. 10), and statistic calculation shows: the coefficient of thermal expansion is about 1*10-

6/m/m/0C. This is a big problem for us that must be solved. Because of the financial problems, the air-conditioners are not be used in the CSR hall. Now the methods we used are:

1) Using the ventilator to decrease the temperature in summer. Using the heater to increase the temperature in winter.
2) Paste the solar film on the rampant dormer, to stop the heat from sun into the hall. Experiment shows us that the solar film can reduce two degrees centigrade of temperature in the room.
3) Those methods can reduce the difference of temperature but not solve the problems entirely. Undoubtedly, the survey and alignment work should be done often to correcting the position deviation of components caused by temperature changes. We will observe the deformation continuously and to find the better method.

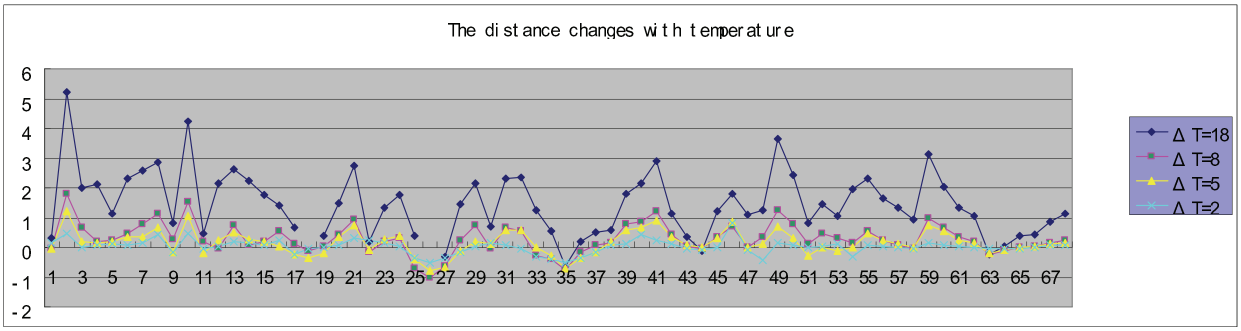

Fig.10 Distances between two net points on the inner wall of tunnel change with temperature

Acknowledgement

We are grateful to Dr. R. Ruland and G. Morlitz for their help at the beginning of our work.

References

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