

THE VACUUM CHAMBER FOR THE SSRF STORAGE RING

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Abstract

The antechamber type vacuum chamber design is chosen in the SSRF storage ring. Each chamber will be machined from two thick plates of A5083-H321 aluminum alloy and welded at their perimeter. The design, manufacture and test of a 6-meter long vacuum chamber prototype has been successfully completed in the R & D period. The flatness of the chamber is 0.23 mm and the maximum error in the horizontal direction is 1.4 mm. The design and manufacture of the chamber is described in this paper.

1 INTRODUCTION

The Shanghai Synchrotron Radiation Facility (SSRF) is a new third-generation light source which will be constructed in Shanghai. The 3.5 GeV electron storage ring is composed of 20 standard cells and 20 long straight sections. The ultra-high vacuum system provides the necessary operating environment for the electron beam. It is composed of 40 6-meter long bending chambers, 40 straight chambers and other chambers connected with RF shielded bellows. The vacuum evacuation and measuring equipment, photon absorbers and other system equipment such as beam diagnostic instruments are installed on the vacuum chambers.

The vacuum chamber with its pumping system is designed to maintain a beam-on pressure of 1.3×10^{-7} Pa or less to enable the attainment of a beam lifetime of approximately 20 hours. The high power load of the synchrotron radiation (SR) and the large gas load induced

by the SR form severe challenge to the vacuum system designer. In order to deal with these loads, every step including the general system design, the vacuum parts design, the machine technique and the surface treatment should be executed strictly. Based on the practical requirements of the SSRF project, a prototype of the vacuum chamber has been developed in the R & D period in order to expose and solve the possible problems that may be met during the construction. The prototype is shown in Figure 1. A series of standard on the chamber designing, machining, cleaning, welding and testing have been established. The necessary techniques have been prepared for engineering chamber fabrication during project construction.

2 CHAMBER DESIGN

As the direct exterior environment of the electron beam, the chamber not only need to meet the requirements of vacuum, but also need to meet the requirements of beam dynamics, SR extraction and absorption. Because the beam position monitors (BPM) are directly mounted on it, the chamber structure must also have high position accuracy and high stability.

Considering the features of SSRF and referring the chamber design of the third-generation light source in the world[1] [2], we select aluminum alloy as the material of the vacuum chamber. Antechamber type structure is adopted in this design because of its many advantages. The system is designed to permit all SR photons on the median plane to escape from the electron channel and go into the antechamber through a 12-mm high slot. This slot



Figure 1: The prototype of UHV chamber for the SSRF storage ring

offers effective RF isolation between the electron channel and the antechamber. All unused SR photons will be stopped by the water-cooling absorbers located in the antechamber. The huge gas load induced by SR photons will be pumped by the large TSP pumps discretely located just below the absorbers. The large aperture of the antechamber provides large longitudinal conductance that can raise the efficiency of the pumps. The large cross section is benefit to thermal conduction and temperature uniform during bake out and operation.

Each chamber will be machined from two thick plates of A5083-H321 aluminum alloy and welded at the perimeter. The numerical control machining and TIG welding will be adopted in the fabrication. This kind of fabrication method is very suitable to the vacuum chamber of the third generation light source, which has complex structure, small deformation and high position accuracy requirements.

Different features are designed on the external surface of the chamber to match the shape of different magnets (See Figure 2). The chamber wall near the magnet pole can be designed very thin to reduce the magnet aperture. The span of metal subjected to vacuum load is much large in antechamber type structure. The integral ribbing between magnet pole tips can support the vacuum load from outside. Some support stages are designed in the SR shade region of the absorbers inside the chamber to increase the chamber strength. Enough space in magnet pockets is left to avoid the interference between the chamber and the magnets caused by relative movement during bake out. Conflat® type sealing structure with AL-SS transition material is used for most of the flanges in order to connect with the standard vacuum equipment except the BPM flanges that use Helicoflex® gaskets for high position precision. Helicoil® screws are used inside the screw holes of aluminum chamber to avoid aluminum alloy screw destroyed. Water-cooling channels are designed in the chamber body to ensure the thermal stability in operation. Long welding lip structure is adopted in order to reduce the distortion caused by large heat input in welding. Welding joint on atmosphere side and full penetration are designed to provide possibility of re-welding if any leak should be found.

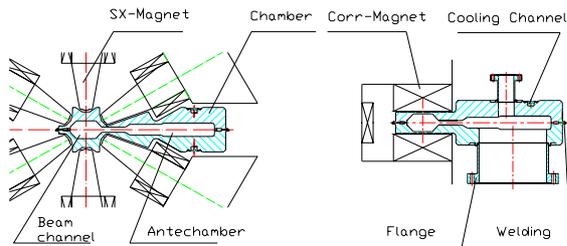


Figure 2: Cross-section of the vacuum chamber

3 FABRICATION

There are four possible problems, which have to be faced in chamber fabrication, i.e. machining distortion, welding distortion, leakage and surface contamination. Basing on the domestic technical conditions and referring the manufacture experiences of other laboratories, technical requirements for the chamber fabrication are issued.

3.1 Machining

The material of the chamber is A5083-H321. The selection of the alloy was based on weldability and dimensional stability during machining. SS316L--A6061-T6 explosion bonded plates are applied to flanges. At the middle region of the 6 m long chamber is a 9° bending section with length about 1.7 m. The thickness of one piece (top or bottom) of the chamber is 50 mm. There are many magnet features on the external surface and two channels on inner surface. Most of the materials on both surfaces will be cut off asymmetrically during machining. The half piece of the chamber is easy to distort. In order to reduce the distortion, the machining procedure was arranged as below: Blank the plate to within 5 mm of perimeter of the part; Machine the cooling-water groove on external surface, then clean the part and weld to form the cooling-water channel; Rough machine the magnet features to within 1 mm of finish surface; Rough machine the inner channel to within 1 mm of finish surface; Release all restraints and keep free for one week, re-clamp and finish machine the outside surface to the final size in two steps; Finish machine the inner surface as above. In order to ensure the size precision between a pair of BPM holes that locate in two chamber pieces respectively, we took the following scheme: First, rough machine the BPM holes in each piece of the chamber; Then assemble the two halves together and fix tightly based on the pine hole; Finally, finish machine both of the BPM holes in one cut. The surfaces which will match the side flange were machined at this time to ensure precise assembly.

All of the machining processes were carried out in a constant temperature workshop. Dedicated milling cutters were designed to fit the complex shape requirements of the chamber. High-speed cutting and spray cooling with water-soluble lubricants were adopted to increase the dimensional precision and reduce the surface roughness. To avoid strange materials that may form extra gas source in vacuum embed the surface of the aluminum chamber, polishing by sandpaper or other materials after the final cutting was forbidden.

Dimensional checking for the chamber parts indicated that the precision of size and location for general parts, magnet features, beam channel and other features all satisfied the design requirements. The inner surface roughness is better than 0.4 μm.

3.2 Surface treatment

After machining, the aluminum alloy surface must be subjected to surface treatment to clean surface contamination such as grease and cutting lubricants, and to form a new surface layer covered by a thin and non-porous Al_2O_3 layer. The following cleaning procedures were applied to the SSRF chamber prototype: (1) Scrub the chamber with ALMECO 18 alkaline solution at room temperature. Wash the surfaces with tape water immediately after the scrubbing. The process is repeated until a continuous and uniform water film is achieved. (2) Scrub the chamber with 3% CITRANOX acid solution at room temperature. (3) Scrub the chamber with ALMECO 18 alkaline solution at 50~60 °C. (4) Final rinsing by flowing distilled water; (5) Dry the cleaned parts naturally.

3.3 Assembly and weld

The inner surfaces were carefully protected from any contamination during operation.

The first step was to weld the flanges to the two halves of the chamber. The two halves of the chamber were assembled together and the flanges were fixed to the chamber body using special designed fixing structure. Some suitable supports were set inside the channel near flanges to form a reverse pre-deformation in order to reduce the sunken deformation. The second step was to weld two halves chamber parts together. The two chamber halves were aligned by inserting a precisely machined cylinder through two BPM holes. The whole vacuum chamber was fixed in position on an 8-m long welding platform using many clean clamps along the external profile. Clearance between welding lips was kept to less than 0.05 mm. The weld started from the center with a tack weld alternately on both sides of the chamber assembly. The welds between the tacks were carried out by the same manner. All of the ports on the assembled chamber were tightly covered with clean aluminum sheet to let Argon gas flow inside the chamber continuously during welding. The chamber was released several times during welding to measure the distortion and decide the following welding sequence to compensate the distortion.

4 MEASUREMENT

4.1 Leakage

A 10 cm long crack was found near the welding line between a flange and its connection pipe. It was caused by mistaking use of filler material. The flange was cut off and the part was cleaned again. Re-welding was performed with correct filler material. After the chamber welding, three leaks which located in the welding seam between the flange connection pipes and chamber body were found in He leak checking. The material in leak region was dug out and re-welded it with filler successfully.

4.2 Dimension measurement

The combined machining and welding error was checked in detail. The flatness of the chamber body is 0.23 mm. In the transverse direction, the maximum combined error is 1.4 mm. The maximum transverse error of a 10-m long chamber for ALS is 3 mm and it could be reduced to 0.3 mm with modest lateral forces applied by the chamber support system[3]. In SPring-8, the maximum transverse error of a straight section is 3 mm and it is not corrected[4]. Some methods should be tried to correct it to less than 1 mm during project construction. The maximum vertical sinkage of the chamber is 0.28 mm under vacuum load and it is less than 0.01 mm in the BPM region.

4.3 Vacuum test

The chamber prototype was vacuum baked to 150 °C for 48 hours. The pressure achieved 2.7×10^{-8} Pa using only ion pumps. The pressure dropped to 4.9×10^{-9} Pa in 4 hours after sublimation of a 1300 l/s TSP. The main residual gas was hydrogen that was about 90% of the total pressure. No contamination evidence was found from the RGA spectrum. The surface outgassing rate was 4.1×10^{-10} Pa.m³/s/m² obtained by the orifice method. The test results show that the material selection, the structure design, the surface state and the sealing performance are all satisfactory.

5 CONCLUSION

A complete process from design to test for the prototype of SSRF storage ring vacuum chamber has been performed. Machining techniques have produced very complex chamber with good dimensional accuracy and acceptable vacuum properties. A lot of problems were exposed in this period. Many effects have been taken to solve corresponding problems. The R & D of the chamber has proved that the great aluminum alloy UHV chamber for electron storage ring can be manufactured on domestic technology.

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