STAINLESS STEEL VACUUM CHAMBER FOR SSRF STORAGE RING

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Abstract

Vacuum chambers with antechambers and made of stainless steel (SS) sheet are developed for Shanghai Synchrotron Radiation Facility (SSRF). The reasons to adopt SS material are mentioned. After R&D of nine prototypes of chambers, many technical problems are solved with special tools and techniques. Tolerances of flatness and straightness and deformations of chambers are controlled within 1mm. Annealing chambers reduces a magnetic permeability at welds from 2.5 to 1.02. Pressure in all chambers is 5×10-9 Pa after vacuum pretesting. Position tolerances of chambers on girders are controlled within 2mm.

INTRODUCTION

Pressure of 1.3 × 10-7 Pa should be achieved in SSRF storage ring with a beam of 300mA and an energy of 3.5GeV. A series of discrete absorbers must locate on antechambers to collimate and absorb synchrotron radiation (SR). Many TSP's and (SIP+NEG) combined pumps are near absorbers. Beam channels of chambers form a thoroughfare for an imaging current and must possess very low impedance and have very low magnetic permeability. Spaces occupied by the vacuum system are restricted severely by magnets, so a complex structure and a high dimension accuracy of chambers are necessary, a manufacture process for them is difficult and interesting.

MATERIAL

Both Al and SS possess excellent performances suitable for chambers of third-generation light sources and are used wildly. Especially, Al has a high thermal conductivity and a low magnetic permeability. We developed an Al chamber prototype 6 meter long for SSRF and got design and manufacture experiences for mass production of Al chambers in 2000[1]. However we made a big decision to quit Al chambers and to adopt SS chambers for SSRF in 2005. There are two reasons for this decision, first the complex manufacture process for Al chambers 400 meter long will take much time, delaying a general scheme of SSRF, second a cross section of a chamber made of SS sheets is really a core of an Al chamber, about half material will be cut and throw away during manufacturing Al chambers, so costs for SS chambers are about 60% for Al chambers, about 1.4 million dollars can be saved for chambers long of 400m. SS316LN are used due to its high intensity and low magnetic permeability after welding.

DESIGN AND ANALYSE

The SSRF storage ring is divided as 20 magnet cells, one cell contains 2 bending magnets called as BM1 and BM2. The chambers in a cell are divided into 7 short segments shown in Fig.1, 6 segments are surrounded by magnets, and 1 segment is in a straight section, being called as BM chambers and QM chambers and SS chambers respectively. A structure of chambers is a typical double-chamber similar with SLS[2]. The cross section of beam channels of BM chambers and QM chambers is same, but is different from SS chambers, as shown in Fig.2. There are smooth transitions between two kinds of cross sections. A beam channel in a BM chamber is built by two bending bars made of OFHC, the bars are fixed on inside walls of the BM chamber, water cooling tubes are inserted into the bars. Installation ports for absorbs and pumps are on antechambers. There are 7 pairs of beam position monitors (BPM) in a cell. Each pair of BPM locates on a SS block, being inserted into QM chambers. BPM blocks are supported to ensure the high position accuracy and stability of BPM's and absorbers and chambers.

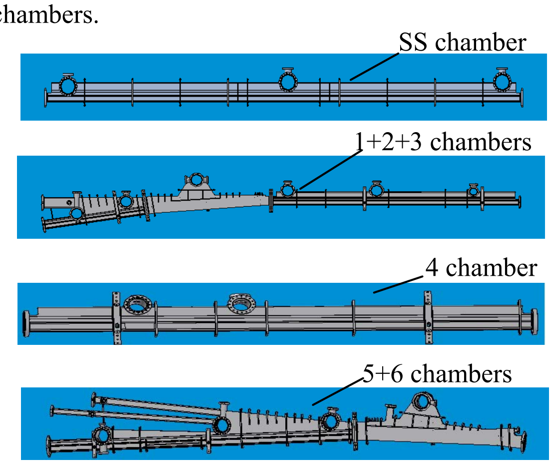

Figure 1: Chambers in a cell.

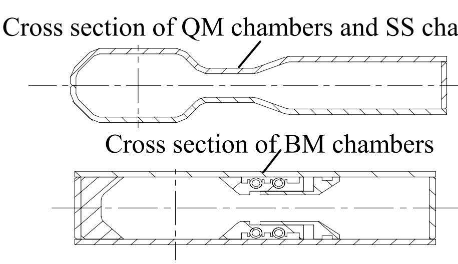

Figure 2: Chamber cross sections.

Installation ports for pumps are far from beam channels due to dense magnets, so the largest width of chambers is 380mm, big deformations of chambers with a wall thickness of 3mm under atmosphere will appear. In order to keep deformations in a specified level, the chambers are reinforced by inner and outside ribs, the inner ribs hide in absorber shadows. The deformations and stresses are analyzed with ANSYS to optimize chamber structure, the largest deformation anywhere will be less than 1mm.

Thermal analyses are made, the SS chambers will be safety if SS chambers are directly hit by SR operating at a current of 5mA, an interlock system must be excited in 1 second if SS chambers are hit by SR operating at a beam of 300mA.

FABRICATION AND INSTALLATION

There are five technical keys for manufacturing chambers, first how do you improve the precision of profiles of QM chambers? second how do you reduce the deformation induced by TIG welding? third how do you reduce the magnetic permeability at welds induced by TIG welding? fourth how do you keep the cleanness inside gaps which are not penetrated by TIG welding? fifth how do you connect short chamber segments as a long chamber segment in a controlled dimension precision? Fortunately all problems are solved through R&D of nine chamber prototypes before mass production of chambers.

After giving up CNC edge bending process at last, the precisions of QM chamber profiles are achieved with a deep-drawing die and a big press machine of 6000 tons. TIG welding is adopted, since we can not find big EBW equipment suitable for our chambers in China, so welds are not penetrated due to adopting a small welding current to reduce chamber deformations. A special automatic welding machine and a special platform rotatable in 360° are made to keep weld quality and to boost welding efficiency. Special inner stopples and outside clamps fix chambers to be welded to restrict movement and deformation induced by welding. Welds lie inside wall of chambers as possible, but outside welds are inevitable. Laser cutting and wire cutting are used several times during whole manufacture process to modify shapes of semi-manufactured chambers. Though it is said that the magnetic permeability of SS316LN material has invariability after welding, the magnetic permeability at welds is increased from 1.01 to 2.5 unluckily. We are forced to build a big vacuum anneal furnace (Φ1100× 3500mm, 900℃) to depress the magnetic permeability at welds. By the way, the internal stress of chambers is relieved, and inner surfaces of chambers, including non penetrated gaps, are cleaned very well, and chambers are degassed. Then the bending OFHC bars are installed into BM chambers. Afterward the short chamber segments are connected as the long chamber segments on a long special platform on which some orientation blocks are ranked to keep the dimension precisions of the long chamber segments. Then the long chamber segments are put on temporary supports, pumps are added, and vacuum pre-testing is done. Then they are hung by a special shelf and are put into opened quadrupole and sextupole magnets and are supported on girders. The alignment and the position adjustment of chambers are made in succession. Finally the long chamber segments are filled with dry N_2 and are opened to air and are connected by RF shield bellows. Large rectangular CF flanges with RF shield rings are adopted, their rectangular knife edges are machined cleverly on CNC lathes.

PERFORMANCE

Dimension tolerances and position tolerances of all chambers are listed in table 1 and table 2

Table 1: Main dimension tolerances of all chambers

Flatness	**Lightness**	**Angle of flange for absorber**	**Angle of rectangular flange**
<0.5mm	<1mm	<0.9mrad	<1.4mrad

Table 2: Main position tolerances of vacuum equipments

	X (mm)	Y (mm)	Z (mm)
Chambers	±2	±1	±1
Absorbers	±1.5	±0.2	±2
Normal BPM	±1	±1	±1
High position BPM	±0.5	±0.5	±0.5

The magnetic permeability at all welds is less than 1.02 after annealing. The dimension tolerance of all long chamber segments is less than 0.5mm. The leak rate of all long chamber segments is less than 10^{-8}Pa.l/s. The ultimate pressure in all long chamber segments is about 5×10^{-9}Pa after vacuum pre-testing. After in site baking all chambers in straight sections and all pumps on the ring, the average ultimate pressure in the ring without an electron beam is 2×10^{-8}Pa. More vacuum information can be seen in a paper presented at EPAC'08[3].

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