DESIGN CONCEPT OF THE VACUUM SYSTEM FOR THE 3 GEV TAIWAN PHOTON SOURCE

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Abstract

The design concept of the vacuum system for the electron storage ring of the Taiwan Photon Source (TPS), 518.4 m in circumference, is described. The vacuum system for the synchrotron light source not only meets the specifications of an electron beam energy of 3 GeV and a beam current at 400 mA but also provides a safety factor of 1.7 (~ 500 mA) at 3.3 GeV at the upper bound. The vacuum system for the storage ring is built with consideration of the following features: (1) Large aluminum bending chambers to simplify the ultra-high vacuum (UHV) structure; (2) Absorbers located as far from the source as possible to reduce the heat load and associated yield of photon stimulated desorption (PSD) as well as the photoelectron; (3) Vacuum pumps located in the antechamber and closed to the absorbers to increase the localized pumping efficiency and to minimize the impedance of beam ducts; (4) Quantity of flanges and bellows is significantly reduced. Configuration of the pumps, results of the simulation for the pressure and thermal stress, and the criteria of the design will be discussed.

INTRODUCTIONS

The latest lattice design for the Taiwan Photon Source (TPS) has been proposed to meet the requirements of beam energy at 3 to 3.3 GeV, beam current at 400 mA, and the emittance < 2 nmrad [1]. The electron storage ring, with a circumference of 518.4 m, has 6-fold super period of DBA structure with 24 unit cells in total. Design concept for the vacuum chambers is based on a simple structure that reduces the quantity of components inside the chamber and the consequent surface outgassing rate and the impedance from the chamber wall. Aluminum (Al) vacuum chambers are considered for the electron storage ring for its properties of higher thermal conductivity and easier machining. A large size bending (B-) chamber associated with the antechamber structure has been proposed [2] to meet the design criteria, and the features of the B-chambers as well as the configuration of pumps will be described in this paper.

VACUUM CHAMBERS

Structures of the chambers

One sextant super-period comprises B-Chambers of eight types, B1 ~ B8, so the storage ring has in total 48 B-chambers. Figure 1 presents the assemblies of one unit cell (1/24 of storage ring) of two B-chambers coexisting with the magnets. The B-chambers are designed to accommodate the spaces among the adjacent magnets of dipole, quadrupole (Q-) and sextupole (S-). The drawing for a typical B-chamber is shown in fig. 2. The typical length of each B-chambers is about 4 ~ 5 m. The chamber is made of two halves of Al plates welded peripherally by TIG method after the serial processes of CNC machining and the chemical cleaning. The backside of one half-chamber is machined according to the shapes of poles and coils for the Q- and S- magnets along the beam duct while the inside is machined the channels for the electron beam and the photon ports. Fig. 3(a) and 3(b) illustrate the cross section views of the B-chamber and the Q- and S-magnets, respectively. The inner cross section of the electron beam duct is elliptical shape of 32 mm in height and 70 mm in width. The open gap between the beam duct and the antechamber is kept 10 mm. The clearance between the magnets and the B-chambers is 3 mm in general.

Figure 1: Layout of two B-chambers coexisting with the magnets in a unit cell.

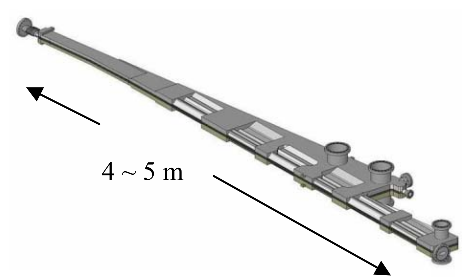
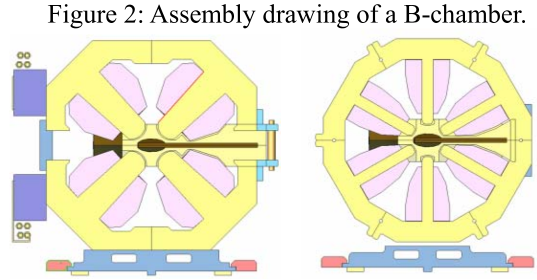


Figure 2: Assembly drawing of a B-chamber.



(a) (b)

Figure 3: Cross section views of a B-chamber with a Q-magnet (a), and a S-magnet (b).

Features of large size Al B-chamber

The B-chamber is designed as a long triangular chamber with an antechamber on the near side of the electron-beam duct. Local photon absorbers are installed inside the antechamber and located near the downstream side; they absorb some of the photon beam without extracting the beam line. The absorbers are located as far from the light source as practicable, to diminish the power density of the heat load. Vacuum pumps with a high pumping speed are located near the photon absorbers to evacuate emitted gas due to photon-stimulated desorption (PSD) and to decrease the amount of gaseous flow back to the beam channel. On the other hand, more spaces are available for locating the pumps in the antechambers rather than in the beam ducts. Impedance of the beam duct is lower since the quantities of pumping holes, flanges, and bellows, are saved as few as possible.

Finite Element Analysis

The deformation of the B-chamber due to evacuation is concerned and simulated with the ANSYS program. The result for the B1 chamber, made of A6061T5 Al, is shown in figure 4. The maximum deformation, shown in red color, addresses 0.131 mm near the Q- and S- magnets, but < 0.1 mm in the beam duct. In this case, the thickness of the Al plates is 50 mm for each halves.

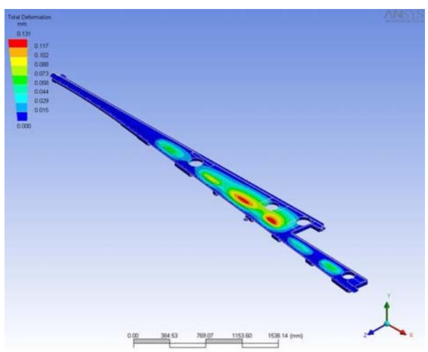
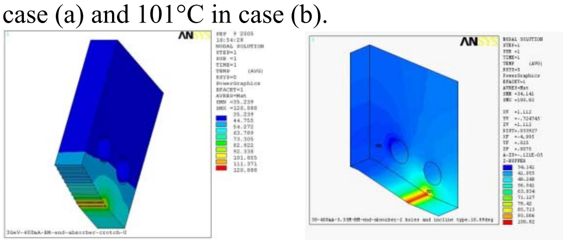


Figure 4: Simulation of the deformation on the lower half of B1 chamber due to the evacuation.

The thermal distribution on the downstream Al absorber with interior drilled cooling channels is simulated by the ANSYS program as well. The maximum power density of the synchrotron light, 3 GeV and 400 mA, irradiated on the surface of the absorber located at 3.3 m far is 22 W/mm^2. The flow rate of cooling water inside the drilled channels is 5 L/min. Simulation results for two types of absorbers with (a) saw-tooth structure of 0.4 mm in step-height and 2 mm in width for each step, and (b) incline surface with gracing angle of 10.9° are shown in fig. 5(a) and 5(b), respectively. The maximum temperature at the hot spot, shown in red color, is 121°C in case (a) and 101°C in case (b).



(a) (b)

Figure 5: Simulation of the thermal distribution on the downstream Al absorber with interior cooling in cases of irradiation surfaces with (a) saw-tooth structure, and with (b) incline surface.

VACUUM PRESSURE

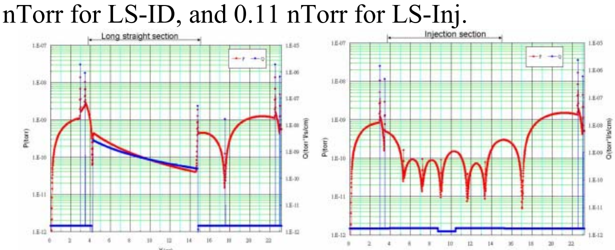
Gas Load

In a dynamical vacuum system, such as the storage ring, two major outgassing sources including the thermal desorption and photon stimulated desorption (PSD) are considered. All the interior area of the vacuum chambers is considered as the source of thermal desorption with the rate of 1×10^{-13} Torr·L/s·cm^2, which is obtained after a vacuum baking at 150°C for 1 day [3]. The rate of PSD is determined by the characteristics of surface of chamber walls or photon absorbers subject the irradiation of synchrotron light. The yield of PSD (η), represented by molecules/electron, is considered as the gas molecules generated by the photoelectrons from the chamber wall irradiated by the photons [4].

Pressure Simulations

Configurations of the pumps for the TPS vacuum systems can be simulated by the computer programs. Two codes are employed to simulate the pressure profiles of the vacuum systems, one is called "iteration method" for one dimensional simulation for the straight sections and the other is called "Monte Carlo method" for two dimensional simulations for the bending sections.

The iterative method utilizes the continuity principle of the gas law [5]. It is useful for the vacuum systems with a simple structure such as the straight sections. Two simulations on the pressure distribution have been done for the long straight sections containing the long flat beam ducts for the Undulator (LS-ID), with typical length of 4.5 m and inner height of 13 mm, and for the injection section (LS-Inj) containing many kinds of discrete chambers for the injection and diagnostic elements, are shown in fig. 6(a) and 6(b) respectively. The pumps of non-evaporable getter (NEG) strips with speed of 3 L/s·cm are considered for the LS-ID, while 5 sets of the types of either lumped NEG or the sputtering ionization pump (SIP) with speed of 400 L/s are selected for the LS-Inj. The averaged pressure obtained at $\eta = 5\times10^{-5}$ molecules/electron is 0.12 nTorr for LS-ID, and 0.11 nTorr for LS-Inj.



(a) (b)

Figure 6: Pressure profiles for the sections of LS-ID (a) and of LS-Inj (b). The outgassing rate and the pressure are illustrated by blue lines and red lines, respectively.

The Monte Carlo method is more suitable than the iterative method for a vacuum system with complex conductance, such as the B-chambers. The approach employed herein can calculate the time evolution of the pressure profile by tracing sample particles at various times [6]. For triangular B-chambers, photon absorbers are located inside the antechamber at a distance of 3 ~ 4 m from the source. Figure 7 presents the pressure profile of the B1-chamber installed three 400 L/s vacuum pumps, obtained by the Monte Carlo method, at a desorption coefficient of $\eta = 1\times10^{-5}$ molecules/electron. The maximum pressure is 1.9 nTorr and the average pressure can reach a value < 1.0 nTorr.

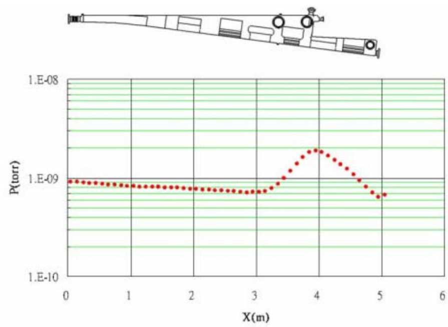


Figure 7: Pressure profile for the B1-chamber. Three 400 L/s pumps are represented by the three circles in the drawing of the triangular shape B1-chamber.

CONCLUSIONS

Conceptual design for the 3 GeV TPS vacuum systems made of aluminum alloys is evaluated. The large size B-chambers contain several benefits including the reduction of impedance for the beam duct, high efficient local pumping structures, localized absorbers far from the source, and simplest interior structure in the part of antechamber. Design for the absorbers in some of B-chamber is to be improved for reduction of the surface temperature.

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