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DESIGN AND CALCULATION OF VACUUM SYSTEM FOR WALS STORAGE RING*

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Abstract

Wuhan Advanced Light Source (WALS) is a fourth-generation synchrotron radiation facility with 1.5 GeV designed energy and 500 mA beam current. The storage ring vacuum system has to be designed in such a way which is compatible with a multi-bend achromat (MBA) compact lattice. the new technology of non-evaporable getter (NEG) coating was used, which is more and more popular in accelerator equipment.

The design of the whole vacuum chamber and the necessary calculations were posted in the paper. The results indicated that the design of the vacuum system can meet the design requirement.

INTRODUCTION

Wuhan Advanced Light Source (WALS) is a fourth-generation synchrotron radiation facility with 1.5 GeV designed energy and 500 mA beam current. The storage ring vacuum system has to be designed in such way which is compatible with a multi-bend achromat (MBA) compact lattice. The emittance of WALS is less than 230 pm·rad, which can provide high brilliance lights to experimental stations. To achieve these objectives, the aperture of the various types of the vacuum chambers to be much smaller and more compact than that of the 3rd generation light source, which is complexity of the design of vacuum chamber [1].

The general requirements for vacuum chamber have to be considered for the cost, performance, and required maintenance, these factors will lead to a design by which the details of the chamber construction various according to local spatial constraints and synchrotron radiation (SR) loading [2].

In this paper, the design of the whole vacuum chamber is introduced, the vacuum distribution results calculated by PTMC and the SR heat loads calculated by FEM indicated that the design of the vacuum system is reasonable.

THE OBJECTIVES AND THE LAYOUT OF THE WALS VACUUM SYSTEM

The parameters of the storage ring in WALS are show in Table 1. The Ring circumference is 180 m with 8 cells. Thus, the length of each cell is 22.5 m, contains 6.8 meters of insertion devices. The internal aperture of vacuum chamber is 32 mm (except Super-bend combination magnet section). Each cell contains 12 BPMs, including 7 BPM with bellows in each side, connected with vacuum chamber through knife flanges, and other 5 BPMs directly soldered to the vacuum vessels. The layout of the cell is show in Fig. 1.

Table 1: Parameters of the Storage Ring

Parameter	Value
Beam energy [GeV]	1.5
Current [A]	0.5
Ring circumference [m]	180
Max. magnet field strength [T]	3.5
Total synchronous radiation power [kW]	54.35
Photon desorption coefficient [molecules/photon]	2×10^{-6}
Linear photon airborne [Pa×L/s×m]	2.66×10^{-5}
Static pressure [Pa]	$<5\times10^{-8}$
Dynamic pressure [Pa]	$<2\times10^{-7}$
Vacuum box beam aperture [mm×mm][H×V]	Ø 32 (standard vacuum box) 12×30 (SuperBend combination magnet vacuum box)

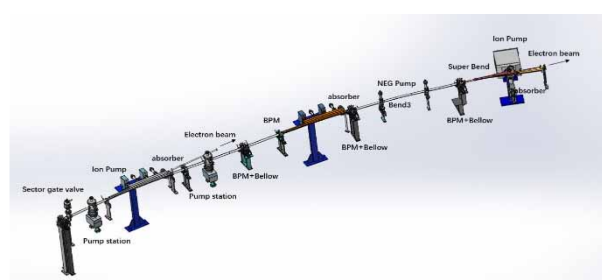

Figure 1: Layout of the 1/2 cell of WALS vacuum system.

According to the overall design requirements, the vacuum system should meet the requirements of static vacuum less than 5×10^{-8} Pa and dynamic vacuum less than 2×10^{-7} Pa. Due to the small aperture of the vacuum chamber, traditional methods with lumped pumping station can

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hardly meet the ultra-high vacuum (UHV) requirements [3].

To achieve the UHV requirement, the new technology of non-evaporable getter (NEG) coating was used, which is more and more popular in accelerator equipment [4].

NEG coating acts as a diffusion barrier between vacuum chamber material and vacuum resulting in a reduction of the electron, photon and ion stimulated desorption yields. It also provides distributed pumping along vacuum chamber. Thus, the specified UHV pressure level could be met with a reduced number and a size of external pumps.

CALCULATION RESULTS OF THE VACUUM LOADS

Synrad and Moflow code were used to simulate the vacuum behaviour of a whole storage ring cell. The Synrad was used to calculated the desorbed of the gas load of the chamber walls. And the data were exported into Moflow to calculated the vacuum distribution. The reflection of the walls were considered. The photon stimulated desorption yields of the material varies according to the dose of the beam, shown in Fig.2.

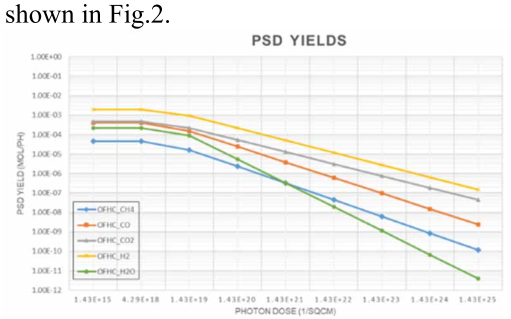

Figure 2: PSD yield with Beam dose.

The pumping speeds of the discrete pumps and the sticking probability of the NEG coating should be provided for each different gas.

Figure 3 shows the individual gas partial pressure vs. distance along the beam after 100 Ah beam dose with both active and saturated NEG coating. It can be seen that the target pressure of 5×10^{-7} Pa at 500 mA is achieved after a beam dose of 100 Ah in the case of fully active NEG coating.

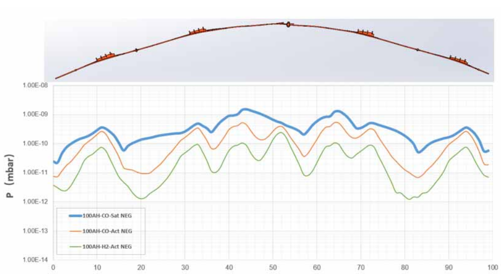

Figure 3: The individual gas partial pressure vs. distance along the beam after 100 Ah beam dose with different NEG condition.

SR LOADS AND PHOTON ABSORBERS

Considering the distribution of synchrotron radiation power, the form of centralized absorption and distributed absorption were adopted in WALS. The high-heat-load absorbers were used in the place where the radiation power is large. And in the place where the radiation power is small, the pipe wall welding water pipe is used for cooling. Shown in Fig. 4.

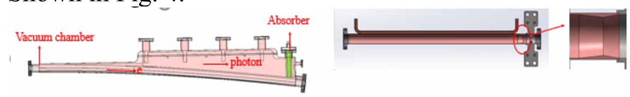

Figure 4: Assembly relationship of absorber and welded tube.

For the high-heat-load absorbers, we compared 3different materials: OFHC, Gild-cop Al-15, and Cu-Cr-Zr alloys, the results show in Table 2. Cu-Cr-Zr has good thermal conductivity, high softening temperature, good weldability, and high mechanical strength and is considerably less expensive which is widely available in all sizes form many suppliers.

Table 2: Properties Comparison of Several Copper Alloys

Properties	OFHC	Gildcop Al-15	Cu-Cr-Zr alloys
Thermal conductivity (W/m/K)	391	365	335
Density (g/cm^3)	8.9	8.9	8.9
Coefficient of Thermal Expansion (µm/m/K)	17.7	16.6	17.0
Melting point (°C)	1083	1083	1083
Poisson's ratio	0.323	0.326	0.32
Elastic Modulus (GPa)	115	130	123
Yield Strength (MPa)	344~381	470~580	350~550

Synrad was used to predict photon heat loading onto the vessel walls caused by the bending magnets for the current lattice, assuming a beam current of 500 mA + 10% margin. Dipole field strengths and arc positions were created using data provided by Accelerator Physics. Fully sticking surfaces were used with no reflection. Synrad used a nominal cell size of 100 cells/cm for the calculation of absorbed power. The calculated photon distribution is shown in Fig. 5. Heat loads were exported into ANSYS for thermal calculations, the results are show in Figs. 6-8.

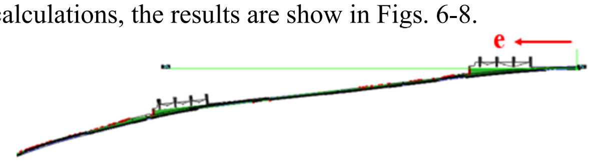

Figure 5: Photon distribution calculated via Synrad software.

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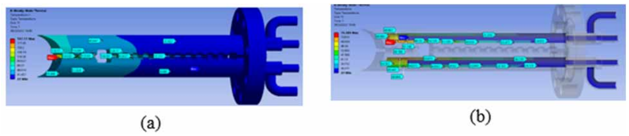

Figure 6: Temperature distribution: (a) absorber body (b) flow path.

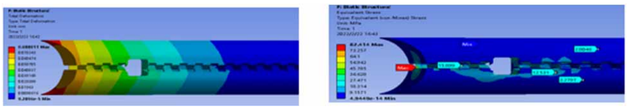
Figure 7: Strain and stress caused by temperature.

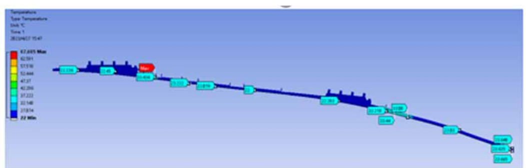
Figure 8: Temperature distribution of vacuum chambers.

The synchrotron radiation load calculated by Synrad was imported into Ansys. The maximum temperature of the absorber body is 197 °C which is far from the melting point of the material. The maximum temperature of the flow path is 79 °C, below the boiling point of the water. The maximum strain is below 0.1mm, and the maximum stress is about 82.4 MPa, far from the yield strength of the Cu-Cr-Zr alloys.

CONCLUSION

The status of the vacuum systems for the WALS vacuum system has been reviewed. The vacuum and SR absorber calculation has been posted in this paper. The results indicated that the design of the chamber and the absorber can meet the design requirement.

REFERENCES

[1] P. He *et al.*, "Progress in the Design and Related Studies on the High Energy Photon Source", *Physics Procedia*, vol. 84, pp. 40-46, 2016. doi:10.1016/j.phpro.2016.11.008

[2] P. F. Tavares *et al.*, "The MAX IV storage ring project", *J. Synchrotron Radiat.*, vol. 21, pp. 862-77, 2014. doi:10.1107/S1600577514011503

[3] M. Grabski and E. Al-Dmour, "Commissioning and operation status of the MAX IV 3 GeV storage ring vacuum system", *J. Synchrotron Radiat.*, vol. 28, pp. 718–731, 2021. doi:10.1107/S1600577521002599

[4] O. Seify *et al.*, "Optimisation of the RGA location in the evaluation of NEG coating pumping properties", *Vacuum*, vol. 165, pp. 207-214, 2019. doi:10.1016/j.vacuum.2019.04.006