Thermal Analysis of Absorbers for the 3 GeV TPS

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Abstract

To minimize the outgas from photon stimulated desorption and the yield of photoelectrons, the crotch absorbers for the TPS electron storage ring will adopt normal incident synchrotron irradiation. The absorbers are directly machined on the downstream part of aluminum bending chambers with cooling channels inside to simplify the structure. A design of ladder-shape crotch absorber for the aluminum chambers is considered to take the heat load from 3-GeV bending magnet light source. A method of finite element analysis is applied to simulate the thermal stress and the thermal distribution for the absorbers. The results will be presented in this paper。

1. Introduction

The new project of 3-GeV Taiwan Photon Source (TPS) storage ring, which has bending dipole of 1.387 Tesla field strength, will be operated at 400 mA beam currents. The bending magnets emit large amount of synchrotron radiation in the storage ring, about 80% of which will not be used and will be intercepted by the crotch absorbers. The crotch absorbers irradiated by the synchrotron radiation will generate considerable quantity of the outgas from photon stimulated desorption and the yield of photoelectrons. This needs huge pumping capacity to remove the outgas.

The quantity of the outgas from photon stimulated desorption and the yield of photoelectrons correlates with the incident angle of synchrotron radiation. To minimize this kinds of outgas and photoelectron, the crotch absorbers will adopt normal incident synchrotron irradiation. The crotch absorbers will be directly machined on the downstream part of the aluminum bending chambers to simplify the structure. From the method of finite element analysis, we found that the maximum temperature is too high even though there is cooling water inside the crotch absorbers. With the special design of the ladder-shape crotch absorber, the maximum temperature is reduced to acceptable one.

The finite element analysis is run with the condition of 3.3 GeV, 350 mA beam current, 31 W/mm^2 power density, at 3.3 m distance from the source and normal incident, using a commercial program ANSYS. With the different types of crotch absorber and the different cooling efficiency, the thermal analyses show that the maximum temperature is reduced from 261℃ to 128℃. The thermal stress is also analysed, the Von Mises is reduced to 72 MPa, which is smaller than the yield strength with a safe factor about 4.

2. Design of the Crotch Absorbers

There were many papers talked about the crotch absorber with the inclined incidence [1-2], but seldom mentioned the normal incidence with the ladder-shape. The bending chamber in the TPS storage ring will be made of aluminum as shown in Fig. 1, consisting of up and down shells and welded through the symmetry plane. Inside the chamber, only the two crotch absorbers are irradiated by the synchrotron radiation. The crotch absorbers are directly machined on the downstream part of the chamber with cooling channels inside. The cross section of the crotch absorbers is ladder-shape (Fig. 2).

The gap between the up and down shells is 10 mm at the front of the crotch absorbers. The internal fins of the water channels are used to enhance the cooling effect. The water channels are about 5 mm from the cooled surfaces. All the crotch absorbers are used for normal incident synchrotron irradiation. The material of the crotch absorbers is the Al 6061.

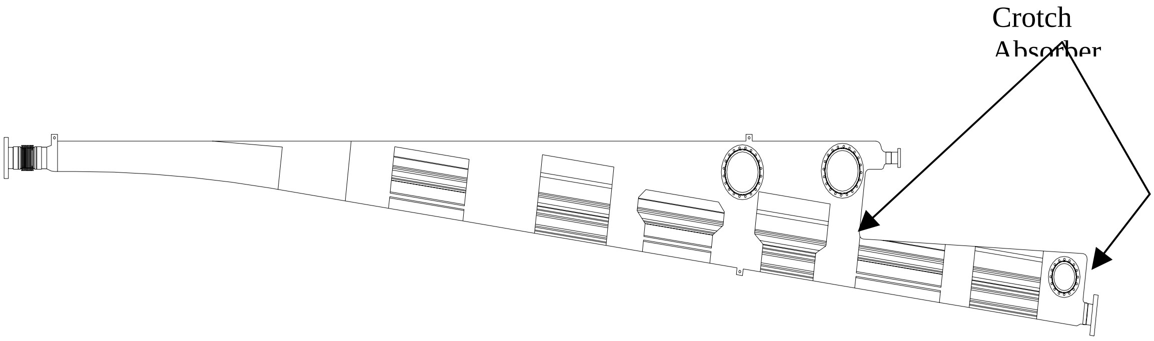

Figure 1. The bending chamber

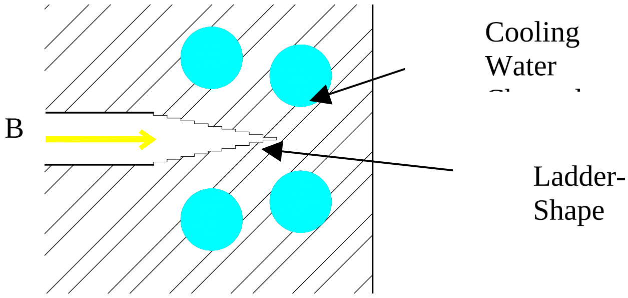

Figure 2. The ladder-shape crotch absorbers in the bending chamber

3. The Finite Element Analysis

The finite element analyses of the crotch absorbers are conducted by the commercial program ANSYS. The material used are the Al6061 (thermal conductivity 176 W/m-℃, yield strength 276 MPa). The power density of the bending magnet is a Gaussian-distribution heat flux in the vertical plane and a constant heat flux in the horizontal plane. The normal power density is 31 W/mm^2 and the normal linear power density is 19 W/mm, at 3.3 m distance from the source. The diameter of the circle water channels is 10 mm. The film convection coefficient of the water channel is 1 W/cm^2-℃.

Fig. 3 shows the maximum temperature of the flat-shape crotch absorber is about 261 ℃. This is too high for the crotch absorber to withstand the heat load. It is impossible to use this flat-shape crotch absorber. We designed another ladder-shape crotch absorber to reduce the maximum temperature. By keeping the height 0.1 mm and changing the width from 2 mm to 0.4 mm, the maximum temperatures are obtained in Fig. 4. It shows that the width should be at least 2 mm wide to have better effect of thermal conduction. By keeping the width 2 mm and changing the height from 0.1 mm to 0.5 mm, the maximum temperatures are obtained in Fig. 5. It shows the height should be as small as possible. Considering the possibility of the machining process and space, the height 0.4 mm and width 2.7 mm is the first choice, but the maximum temperature 143℃ is still too high (see Fig. 6).

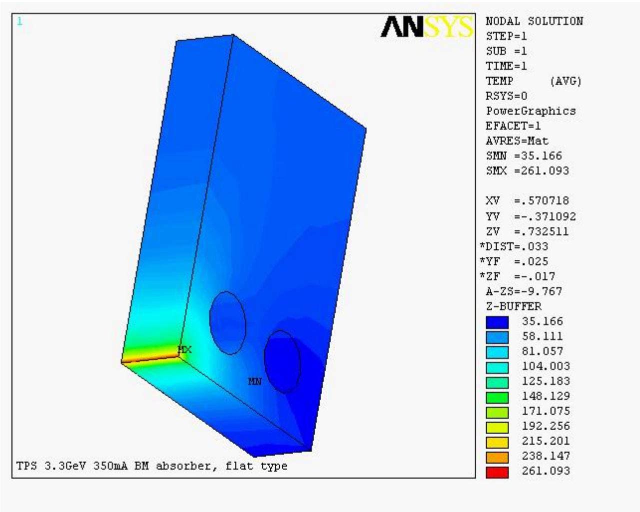

Figure 3. The temperature distribution of the flat-shape crotch absorber.

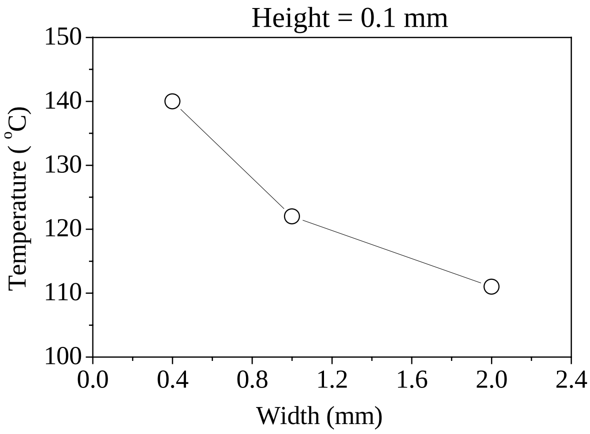

Figure 4. The max. temperature vs. width at the fixed height.

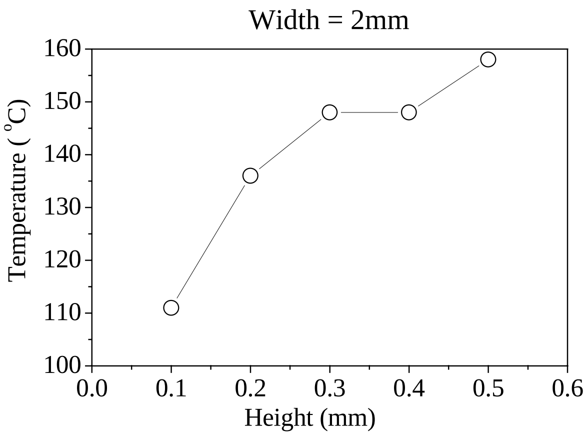

Figure 5. The max. temperature vs. height at the fixed width

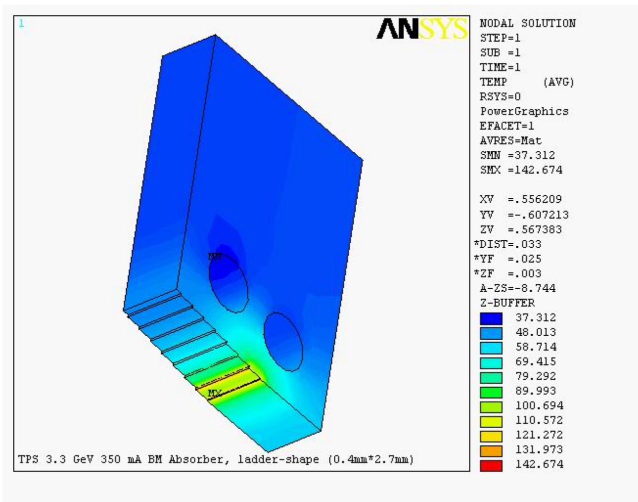

*Figure 6. The temperature distribution of the ladder-shape absorber (0.4mm*2.7mm)*

The cooling channels were changed from circle channels to fins-type channels to simulate the temperature distribution. The number of fin was increased from one fin to three fins, and found it needed at least three fins to decrease the maximum temperature. By adding the cooling surfaces with three fins, the maximum temperature is reduced to 128℃ (Fig. 7). The thermal stress is also calculated in this condition, the Von Mises stress is 72 MPa smaller than the yield strength.

The increase of the film convection coefficient was also studied to find the better cooling effect. Fig. 8 shows it is better to keep the coefficient larger than 1 W/cm^2-℃. We also found there is not much gain to increase the film convection coefficient from 1 to 3 W/cm^2-℃. The spring coils will be put into the cooling channels to increase the film convection coefficient. This is just to guarantee the film convection coefficient in the safe regime, even if the water flow is suddenly dropped.

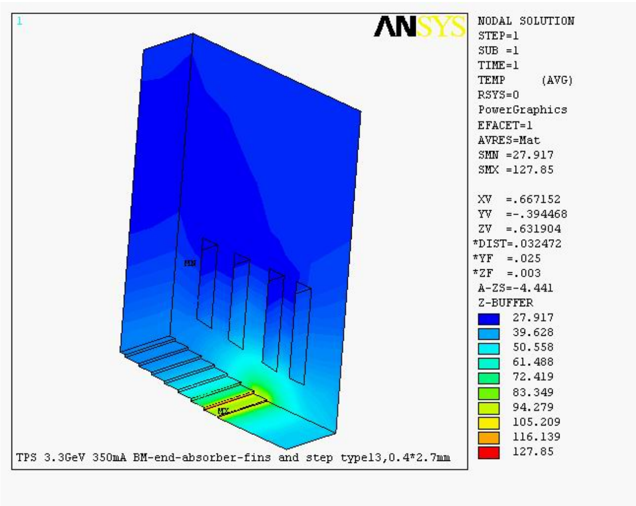

*Figure 7. The temperature distribution of the ladder-shape absorber (0.4mm*2.7mm) with cooling fins*

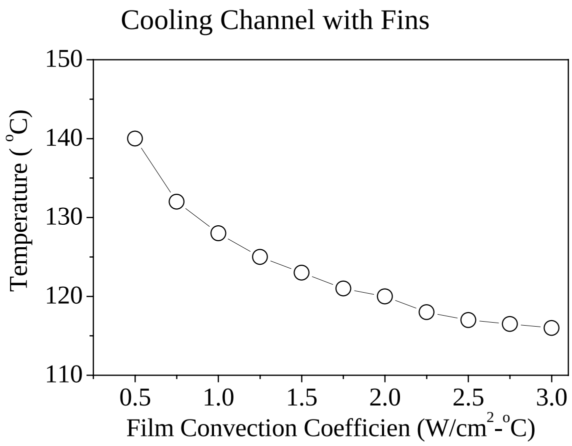

Figure 8. The film convection coefficient vs. the max. temperature variation

4. Conclusions

The TPS crotch absorbers of the bending magnets was analysed by the software ANSYS. The maximum Von Mises stress is safe enough. The maximum temperature 128℃ is quite high. From the operating experience of the TLS storage ring, this maximum temperature is still acceptable. But the temperature is still too high to have another additional source like the SWLS, IASW and wiggler source, which increase the heat on crotch absorber.

5. Acknowledge

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6. References

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