FEA OF A PHOTON ABSORBER BASED ON CONCEPT OF VOLUMETRIC ABSORPTION

MEDSI 2016
MECHANICAL ENGINEERING DESIGN OF SYNCHROTRON RADIATION EQUIPMENT AND INSTRUMENTATION

K. J. Suthar* and P. Den Hartog
Mechanical Engineering and Design, Advanced Photon Source Engineering Support Division, Argonne National Laboratory, USA

ABSTRACT

A crotch absorber is an important device in stopping part of the synchrotron radiation. Designing of the crotch absorber requires careful consideration due to high temperature and steep thermal gradient that is generating via surface absorption of synchrotron radiation. Volumetric absorption of synchrotron X-rays is one of the efficient way of removing heat while maintaining low temperature and low thermal gradient compared to other surface absorption devices. The volumetric absorption also helps to reduce the photon stimulated gas desorption, adverse change in vacuum, and local structural softening at a minimum level. This paper discusses multiphysics analysis of a crotch absorber for APSU project via full-coupling of heat-transfer, and structural mechanics. The simulation results are discussed in detail.

MOTIVATION

- Beryllium (Be) can act as a transparent media, while copper tubes that are placed in the Be body can absorb the photon beam. This technique has a few advantages:
- The overall temperature and the thermal gradient will be lower than the copper body design.
- The maximum temperature rise will not occur on the intercept surface that will further reduce the outgassing at the surface.
- The scattering due to reflected photon can be reduced.
- Heat transfer will be efficient due to proximity of the cooling water circulation.
- Enables the heat removal by conduction and therefore, local structural softening will be reduced due to the presence of the transparent material.
- The overall thermal deformation will be reduced.

THEORY

Incident photon beam loses energy when interacts with material. The change in incident beam's energy can be estimated by following equation. Here y, and z are transverse direction while x is direction along the beam path.

$$I(x,y,z) = I_0(y,z)\cdot e^{-n\cdot\sigma\cdot x}$$

$I(y, z)$ = the initial intensity, SynRad output
n = the number of atoms/cm^3
σ = a proportionality constant
dx = the incremental thickness of material from surface into the body of the absorber

- The combination of number of atoms/cm^3 and the proportionality constant is the linear attenuation coefficient (μ). Therefore, the equation becomes

$$I(x,y,z) = I_0(y,z)\cdot e^{-\mu\cdot x}$$

- The linear attenuation coefficient (μ) describes the fraction of a photon beam that is absorbed or scattered within the per unit thickness of the absorber.
- Using the transmitted intensity equation above and linear attenuation coefficients, the FEA calculations were performed.

RESULTS AND DISCUSSION

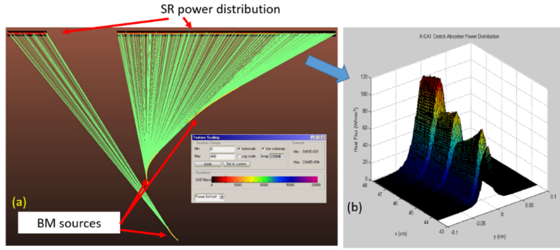

Figure 1: Power profile distribution (a) SynRad trajectories and power profile for B crotch absorber for ASPU project (b) power distribution and profile

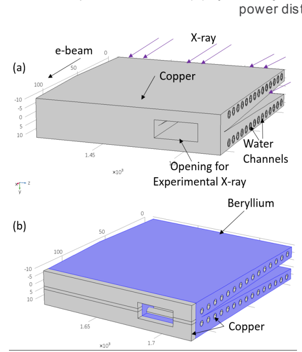

Figure 2: APSU crotch absorber (a) copper body design (b) Beryllium and copper design

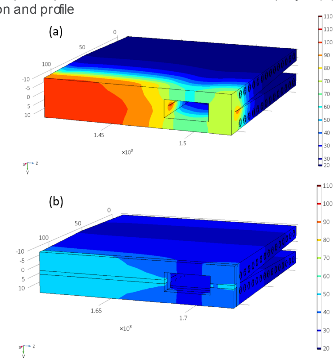

Figure 3: (a) Temperature distribution of Cu body design (b) temperature distribution of Be and Cu body design.

RESULTS

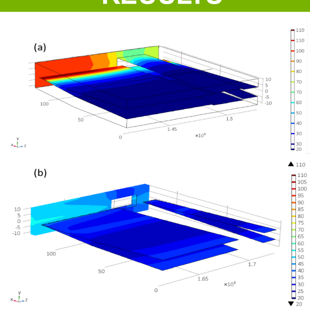

Figure 4: Temperature profile of X-ray intercepting surface (a) All-Cu body design (b) VA design.

CONCLUSION

- The conceptual design and analysis of the volumetric absorption showed improvements over the baseline design in temperature rise and distributions.
- Temperature rise in VA design was 56°C, which is 50°C lower than the base line design results. Moreover, the thermal gradient distribution indicates that the VA design spreads out the heat and produces relatively flat profile.
- The temperature rises towards the vacuum showed even smaller temperature rise which is about 45°C. Thus, lower temperature towards vacuum would be beneficial in reduction of the outgassing rate.

REFERENCES

[1]. Pavlinsky, G.V., *Fundamentals of X-ray Physics*. 2008: Cambridge International Science Pub.
[2]. CXRO. *Optical constants.* 2016 [cited 2016 9/6/2016]; calculator]. Available from: http://henke.lbl.gov/optical_constants/.
[3]. Matweb LLC. *Material property database.* 2016 [cited 2016 9/6/2016]; Available from: http://www.matweb.com/

ACKNOWLEDGEMENT

This research used resources of the Advanced Photon Source, a U.S. Department of Energy (DOE) Office of Science User Facility operated for the DOE Office of Science by Argonne National Laboratory under Contract No. DE-AC02-06CH11357. Authors would like to thank Benjamin Stillwell and Dr. Branislav Brajuskovic for important discussion and Jason Carter for providing SynRAD calculated power profile respectively.

* Corresponding Author: suthar@anl.gov