**Introduction**

With the increased power and frequency of LCLS II, components in direct contact with the X-ray beam are more susceptible to thermal deformation. As a result, two analyses on Zerodur disk mirror were made to understand and map out the heat distribution. The goal of this project is to use one analysis to predict the laser damage testing results and the other analysis to predict how the heat distribution behaves with a cooling component.

Keywords: LCLS II, thermal deformation, heat distribution, ANSYS, mirror.

**Background**

According to Lin's SLAC Seminar in 2015, high temperatures and temperature variations can cause the disk mirrors to experience several thermal stress issues compromising the performance of the mirror. In order to model the disk failure, it is assumed that the temperature indicates failure.

**Numerical Results**

There are several ways to decrease the temperature of the disk without changing the material. Last year's intern, Jiya, worked on one method which is to use convection from water to cool the mirror. Through many calculations, he concluded a full-side cooling would optimize the cooling. The following equations are Jiya's findings for a two-dimensional full-side cooling disk, which is then modeled in MATLAB:

\[ \alpha_n R = \frac{h R f_0(\alpha_n R)}{k J_1(\alpha_n R)} \]

Equation 1*: This equation describes the alpha constant (\(\alpha_n\)) necessary to solve equation 2. I solved this using the symbolic toolbox and vpasolve function.

\[ T(r, z) = T_f + \sum_{n=1}^{\infty} \frac{p_l w_{lm}^2}{8kR J_1(\alpha_n R)} \left[ \frac{e^{-\alpha_n z} + e^{-\alpha_n(2H-z)}}{1 - e^{-2\alpha_n H}} \right] \]

Equation 2*: This bessel function describes the temperature change in two-dimensions, \(r\) (radius) and \(z\) (depth). \(P_l\) (beam power), \(w_{lm}\) (beam width), \(k\) (thermal conductivity), \(h\) (heat transfer coefficient), \(T_f\) (cooling temperature of fluid), \(R\) (radius of disk), and \(H\) (depth of disk) are constants in the equation. I used a loop to calculate the summation.

**Results with ANSYS**

To analyze a three-dimensional object on ANSYS, a model is first created in a CAD software. For this project, I created two models on Solid Edge. The first is a disk the diameter of the x-ray beam. The second model is a donut-shaped disk the size of the disk being tested with a hole the size of the first disk. I mated the first disk into the second to create a disk, which is then ready to import into ANSYS. It was imperative to create a smaller disk because it created an area I could select for the heat flow of the beam in ANSYS.

**Conclusions**

For the analysis with ANSYS, I expected a large temperature range, however the maximum temperature was a much higher than anticipated. This is because the beam is described as a constant heat flow across the beam diameter. Realistically, the beam is described as a Gaussian distribution. Further work will include the Gaussian distribution as well as a transient thermal analysis.

For the analysis with MATLAB, the analysis was a challenge to model. Equation 1 had many solutions for \(\alpha_n\) which altered Equation 2 to have oscillating characteristics. Through many alterations of the code, I found there is one true \(\alpha_n\) solution that gives the expected heat distribution. The code is not perfect because the beam appears very wide and the maximum temperature is very high for a cooled disk.

**Acknowledgments**

Use of the Linac Coherent Light Source (LCLS), SLAC National Accelerator Laboratory, is supported by the U.S. Department of Energy, Office of Science, Office of Basic Energy Sciences under Contract No. DE-AC02-76SF00515.

*Jiya Janowitz, SLAC Mathematical Proof, 2017
*Lin Zhang, SLAC Seminar, 2015

Date: 08/11/2017