Status of Temperature Calculations with Mathematica

Hovanes Egiyan

"BC-65-m23" Test Summary (Vitaly)

Test Configuration Name	R_{max} (cm)	ϕ_{max} (deg)	Z_{max} (cm)	T_{max} (°C)	T_{cold} (°C)	Maximum power (KW/cm^3)
All Nominal ($\sigma^{(x,y)}_{beam}$ = 1 mm, 4 holes)	0.32	-90	135	90	50	2.9
$\sigma^{(x,y)}_{beam}$ = 1/3 mm	0.32	-90	140	135	55	8
$\sigma^{(x,y)}_{beam}$ = 1.5mm						
90% B-field	0.32	-90	150	88	50	2.5
110% B-field	0.32	-90	120	102	55	7
-1mm shift in Y						
+1mm shift in Y						
-0.5mrad angle in Y	0.32	-90	100	110	50	3.7
+0.5mrad angle in Y	0.65	-90	355	100*	50	2.2
+1mm shift in X						
+0.5mrad angle in X	0.32	245	120	90	50	3
20% radiator thickness	0.32	-90	115	90	50	2.3

Nominal, cylindrical, short in Z	0.32	-90	120	100	50	3.4
Nominal, rectangular, short in Z	0.32	-90	120	95	50	2.9

Summary of Analysis for "BC-65-m23" Tests (Vitaly)

- I continued analyzing Vitaly's FLUKA data with power depositions with different test configurations.
  - I used water temperature T_{water}=40 ^{o}C with cooling holes offset at (x,y)=(±5,±7)cm for these analyses.
  - The resulting temperature at the nominal conditions is T_{max}=90 ^{O}C.
    - This number was observed for both solving the cylindrical data with both rectangular and cylindrical solver.
    - Today's cylindrical and rectangular grid data for systematic checks resulted in T_{max}=100 ^{O}C for cylindrical and T_{max}=95 ^{O}C.
- All test with realistic parameters so far produced temperatures T_{max}<150 ^{O}C in the absorber using cylindrical grid for FLUKA data and cylindrical coordinates for the equation solver.
- There is a discrepancy or improvement with the results from February model calculations that provided T_{max}=245 ^{O}C.
  - The February number was the same for my and Tim's thermal analysis, both using rectangular grid.
  - The discrepancy is likely indicative of the uncertainties for the temperature determination.
- I tried to understand the discrepancy by comparing to the February results.
  - Using rectangular coordinates for cylindrical grid data from FLUKA I calculated the temperature that would be present if the absorber was designed as in February: narrow and with two cooling holes.
    - "Nominal" beam provides T_{max}=180 ^{0}C , while "very narrow" beam provides 270 ^{0}C.
  - Using cylindrical coordinates for cylindrical grid data from FLUKA I calculated the temperature that would be present if the absorber was designed as in February: narrow and with two cooling holes.
    - "Nominal beam" provides T_{max}=135 ^{0}C, "very narrow" beam provides 210^{0}C, "90% B-field" – 120 ^{O}C, "110% B-field" – 140 ^{O}C.
  - The discrepancy is T_{max}=135 ^{0}C / 180 ^{0}C versus T_{max}=245 ^{O}C for nominal settings.
    - Asked Vitaly for 33% higher than nominal B-field with rectangular and cylindrical grids.
- We should design strain reduction features for this model.
- The electron beam and photon beam positions will need to be interlocked.

KLCPS69 Test Summary (Pavel)

Test Configuration Name	Hot Spot Location Section	R_{max} (cm)	ϕ_{max} (deg)	Z_{max} (cm)	T_{max} (°C)	T_{cold} (°C)	Maximum power (KW/cm^3)
All Nominal ($\sigma^{(x,y)}_{beam}$ = 1 mm, 4 holes)	Keyhole	0.04	+90	37	200	55	7
$\sigma^{(x,y)}_{beam}$ = 0.33 mm	Keyhole	0.1	+90	43	250	65	14
$\sigma^{(x,y)}_{beam}$ = 1.5 mm	Keyhole	0.2	+90	8.5	205	55	5
97% B-field	Circular	0.15	+90	58.5	205	60	8
103% B-field	Keyhole	0.1	+90	33	200	55	7
-1mm shift in Y	Keyhole	0.2	+90	8	220	60	7
+1mm shift in Y	Circular	0.1	+90	57	225	60	6.5
-0.5mrad angle in Y	Keyhole	0.2	+90	8.5	220	60	6.5
+0.5mrad angle in Y	Circular	0.15	+90	58	235	60	7
+1mm shift in X	Keyhole	0.5	+70	7.5	245	60	6
+0.5mrad angle in X	Keyhole	0.45	+70	8	250	60	6

All using cylindrical grid data and cylindrical coordinates in the solver

Summary of Analysis for KLCPS69 Tests (Pavel)

- I looked at all the tests that Pavel did with KLCPS69 model to estimate the temperature in the absorber.
  - I used water temperature T_{water}=40 ^{o}C with cooling holes offset at (x,y)=(±7,±7)cm for these analyses.
    - The pipes are a little further away from the hot spot than what I had for Viltay's model.
  - The resulting temperature at the nominal conditions is T_{max}=200 ^{O}C based on the cylindrical grid calculations.
    - Rectangular grid calculations in Mathematica gives T_{max}=230 ^{O}C. Waiting on ANSYS.
  - With a smaller absorber with X-section 5cm x 5cm and by cooling full outside surface of the absorber, I get T_{max}=170 ^{O}C.
- All tests with realistic parameters produce T_{max}<250 ^{O}C in the absorber (cylindrical grid).
  - The highest values are T_{max}=250 ^{O}C for beam with σ = 0.33mm, and with 0.5mrad angled beam in the horizontal direction.
- We should design strain reduction features for this model
  - Assume that the temperature in the absorber will be around 250 ^{O}C.
  - The absorber design should allow for temperatures of 350 ^{O}C.
  - Pavel has five slits there for strain relief, but it is probably will not be sufficient.
  - We need to simulate in FLUKA a version with 1mm slits every 2cm along the beamline.
- The beam should be interlocked such that:
  1. The electron beam position at BPMs before CPS does not move more than 1mm from the nominal
  2. The photon beam position does not shift by more than 5mm at the KPT
     - Need to design and build a device like GlueX Active Collimator.
  3. Temperature at the beginning and the end of the keyhole cavity should be below 250 ^{O}C.
     - We'll need radiation resistant temperature sensors implanted in the absorber.

  ❑ If the conditions above are not satisfied, the beam is shut off by FSD.

Conclusions

- Temperatures in the absorber for all currently available tests from Pavel have been calculated.
  - They all provide maximum temperatures below T_{max}<250 ^{O}C based on cylindrical grid data.
- Although the thermal analyses of all tests from Vitaly are not complete, I have some rough idea what they will be.
  - It looks pretty good, there seem to be some uncertainties.
  - I will continue working on these data.
- Both CPS configurations, in my opinion, will need to have thermal stress reduction scheme for the absorber.
  - This will need to be designed and tested next month.
  - We will need this for the review in August.
  - This will require some effort from Tim.
    - FLUKA-to-ANSYS iterations will need to be done.
- Need to move on to radiation environement, costs/weights, and photon beam quality evaluations.