Design and Analysis of Divertor Calorimetry In Alcator C-Mod

I. PAYNE, D. BRUNNER, B. LABOMBARD, J.L. TERRY, PSFC, MIT

**Design Goals & Overall Concept**
- Build an array of calorimeters to characterize the energy deposited on the tiles by the plasma.
- Use IR camera system to cross check calorimeter measurements.
- Attempt to calculate the time dependent heatflux entering the tile.
- Correlate calorimetry data to plasma parameters to determine how various parameters affect the thermal load on the outer divertor.

**Initial Design Concept**
- Fast Thermocouples for surface temperature measurements
- Ramp tile surface 2 degrees in the toroidal direction to provide clear strike point
- Inner tile thermocouples to provide “back end” for heatflux calculations
- Infrared Camera to serve as a reference and provide higher spatial resolution
- Use existing features to constrain the rotation of the calorimeter and prevent misalignment of the calorimeter surface and the tile surface.

**Calorimeter Optimization**

One of the primary goals is to create a calorimeter that is as close to a perfect calorimeter as possible. In order to measure this difference, and optimize the design, finite element models were run using the ALGOR Fempro software.

The simulation consisted of a 2.5 second square heat pulse of 10 MW/m², and then were allowed to equalize over 60 seconds. The results of the full assembly were then compared to the results of just an isolated molybdenum slug.

In order to get a better comparison of how well the redesign worked the temperature difference between the pure calorimeter and the assembly was taken and divided by the temperature of the pure calorimeter to give the percent error as a function of time.

**IR Camera**
- Can be used to cross check measurements from surface thermocouples and the calorimeters.
- Allows the creation of “virtual” surface thermocouples that are not subject to magnetic effects.
- Virtual sensors can be treated as surface thermocouples.
- IR Camera has a large range of frame rates, from 383fps at 320x256 to 28000 at 64x.

**Calibration**
- The camera outputs in the raw 16bit digital level read from the detector. This digital level needs to be correlated to temperature in order to reinterpolate the temperature of a pixel from its digital level.
- Calibration needs to take place at a large range of temperatures, from room temperature to 800°C.
- Calibration setup needs to include all of the optical components present in the final experimental setup.

**Data Analysis**
- To test the accuracy of the procedure, and the accuracy of the sensors, the total energy deposited on the surface of the sensor is calculated for each sensor type.

For Shot: 1109025068
Calor: 1399000 l/m²-2
STC05: 1248430 J/m²

**Design Challenges**
- 1. During a shot the machine shakes, causing horizontal and vertical translation of the video.
- 2. Each pixel must correlate to a fixed location in space, r, z, and q.

1. Using a procedure similar to the stabilization procedure. A vectorframe, where the r, z, and q coordinates are known for every pixel, is correlated to the stabilized IR video, and thus the location of each pixel can be mapped.

**Conclusions**
- As shown in the above chart, the measurements from the IR camera and the surface thermocouples match very well.
- The Alger Analysis data points were generated by using the heatflux calculated from the surface thermocouple and using that as the input into the Alger model.
- Still need to finish calibration algorithm for the IR camera to allow for virtual IR sensors.
- Working on an image mapping algorithm that will map every IR pixel to r, z, and q-space.
- Need to replace Thermocouples in the calorimeters.