TRANSIENT LIQUID CRYSTAL TECHNIQUE SOLVING FOR MULTIPLE THERMAL PARAMETERS FROM A SINGLE DATA SET

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ABSTRACT

Liquid crystal paints have been proven useful in determining local temperatures in a variety of transient and steady state experiments. The technique presented allows for the solution of multiple thermal parameters from a single transient liquid crystal experiment.

Heat transfer coefficients must be based on a reference temperature. Depending on the situation, this temperature may be derived from multiple input temperatures such as in the case of film cooling. The film cooling effectiveness ($\theta$), is defined as a ratio of the mainstream, coolant, and wall temperatures of the system. Likewise, in jet impingement heat transfer the heat transfer coefficient reference temperature can be defined as the local adiabatic wall temperature of the fluid. In both situations, two thermal parameters are unknown.

The test rig used in the current jet impingement study is shown in the following schematic.

Previous researchers have run two transient tests using different narrow band liquid crystals to solve for the two points of the time-wall temperature history of each point. This results in two data points used to solve for the two unknown thermal parameters with the minimum amount of data required.

The technique presented utilizes a wideband Hallcrest SPN20C20W liquid crystal paint, to provide temperature play between 20°C and 40°C. The gas temperature is stepped up at the start of the test using a 20 micron diameter wire mesh heater before the test section. The mesh heater due to its low thermal capacitance reaches the step temperature change in fewer than 33 milliseconds. Using a Sony CCD camera, video of the transient test is recorded at 15 frames per second. The Hue component of color from each video frame is then converted to a temperature at each pixel using the liquid crystal calibration curve.

Since heat transfer coefficient and adiabatic wall temperature are the two thermal parameters necessary for the test, only two points are required. However, using all data points allows for an over constrained system of equations and decreases the uncertainty. The time-temperature history of each pixel is then fit to the 1-D semi-infinite transient heat conduction equation using a least sum of the squared approach.

Although two thermal parameters were extracted for the jet impingement study, theoretically the number of thermal parameters possible is only limited by the number of data points collected.
Below is an example of the resulting local Nusselt number distribution for baseline jet impingement geometry at a Reynolds number of 40,000.

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REFERENCES