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Life sciences explore vibrations with lasers

Nanostructures colour butterflies and stones

Light gives industry the measure of flow

Optics helps industry to understand fluid flows

Manufacturers are discovering that optical methods developed to carry out advanced research also offer solutions to long-standing problems in process control, steam generation and safety. **John Bell** reports.

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Tomography: Bodo Ruck and colleagues at the University of Karlsruhe synchronize the scans of a laser sheet with a video camera running at rates of up to 200 frames per second to produce three-dimensional tomographic impressions of phenomena in fast liquid flows. The images combine frames of approximately 20 light sheets to illustrate the development of a 23 mm long free jet as it flows from left to right and expands from 3 to 9 mm under the influence of a crossflow.

Anaytical methods such as particle image velocimetry and laser tomography are becoming more sophisticated in measuring fluid flows at ever higher velocities, at greater temperatures and in more hostile places. However, as some researchers develop these techniques further, others apply them in their existing forms to solve a range of industry's mundane but costly problems.

These optical tools all share a unique quality: light measures without physical contact. Researchers exploit this property to measure what goes on inside the turbines of jet engines of aircraft, for example (*OLE* December 1997 p28). Others use it to measure how a stirrer mixes paint; to produce infrared images that reveal how water cools red-hot steel; and to analyse two-phase flows of toxic and explosive substances.

For example, delegates at the recent conference on optical methods in fluid dynamics in London heard how thermography at Italy's Bologna University shows that cooling a hot surface with a splash of water is not as simple as it seems.

Impurities in the water, droplet size, the angle at which a droplet hits the surface, the thickness of the water films and the materials' thermal conductivity all affect how quickly a surface loses heat.

Cost savings

Maria Roberta Randi told the conference that she expected the infrared images of water falling onto hot, non-porous surfaces to help to cut the cost of spray cooling in the metal industries, reduce energy consumption in steam generation, and maintain turbine blade temperature better, for example.

Her group is looking at how droplets of 10 to 50 µl cool materials such as glass-like Macor, stainless steel and aluminium – materials that show low, medium and high thermal conductivity respectively. Macor has the extra benefits of emitting lots of infrared and withstanding great thermal stress.

The basic experiment is simple, but it must produce large amounts of data on relatively small physical changes. It involves placing droplets of deionized and distilled water onto a hot surface, at a temperature of 380 to 460 K, then filming the result. A syringe that can measure volumes to an accuracy of ±1% releases the drops from a height of 1 cm.

"Droplets on steel or Macor take different times to evaporate depending on whether they boil," said Randi. "Times with steel consistently decrease, with both boiling and non-boiling droplets, as the initial surface temperature rises. This is not observed with Macor.

"The effect seems to relate not only to the different thermal conductivities of the surfaces but also to the initial volume of the droplet. For example, the evaporation times of 10 µl boiling and non-boiling droplets on Macor are remarkably close despite solid temperature differences of about 40 K"

The research also showed that droplets remove most heat from Macor just before they evaporate. Thermography also shows that gases and minerals in water can affect the shape of a droplet as it evaporates and thus its efficiency in cooling the surface. It also appeared that a droplet's contact angle has a minor influence on evaporation rates but that its thickness appears to be a key parameter in governing heat transfer.

Randi said that thermography shows that the temperature of the solid–liquid boundary is never constant or uniform as both boiling and non-boiling droplets evaporate. It is difficult to determine accurately the surface temperature that will initiate boiling or non-boiling evaporation. The group seeking a better >>>