

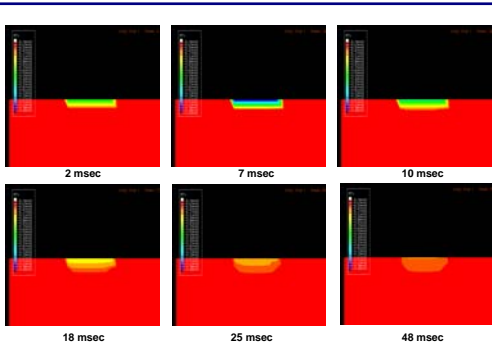
Interactions of droplets with hot solid surfaces

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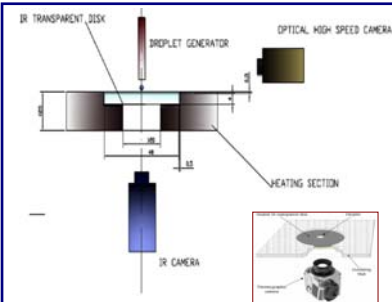
In some postulated PWR accidents water droplets entrained in steam will flow through the core and will be the main means available for core cooling. Just how much heat will a droplet extract when it impinges on overheated nuclear fuel? Under what conditions will it bounce off, and when will it wet the wall? This project is addressing these topics, by a combination of experiment and modelling.

Experimental studies

Experiments will shortly begin aiming to reveal the spatial and temporal variation of the temperature of a hot solid due to its interaction with a tiny (say 120 microns), near-saturation water droplet, by employing an infrared spectroscopic method. The time of the interaction is expected to be of the order of msec and the variation in temperature of the order of a few degrees. This will enable us to determine the local heat transfer coefficient that characterises the phenomenon and associate it with the droplet size, the droplet impingement velocity, the temperature of the hot surface as well as the degree of subcooling of the droplet. Initial numerical experiments using ABACUS have been performed in order to assist in optimising the experimental setup.

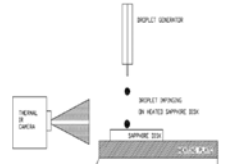


Numerical simulation of the a 4 mm droplet impinging on a 400°C Inconel surface (original experiment performed by Chen and Hsu (1995). The sudden temperature drop as well as the rapid recovery very close to its initial value are obvious. Final temperature drop approx 25 °C. Here, the transient, 2D phenomenon is shown. Overall time of run is 50msecs. Times shown are after the droplet impact.

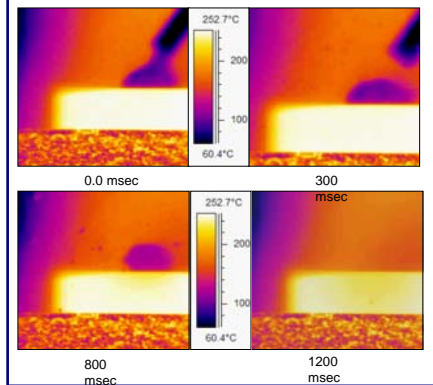


Experimental set-up. The IR transparent disk (coated with aluminium) will be heated up to 500°C by means of a miniature heating ring. The IR thermal camera will be placed below the heated disk in order to record the temperature variations. The water droplets to be used will be varying in size from a few microns to 1mm. A high resolution camera will be used. At the same time, photographic observations will be conducted with an optical high speed camera.

Initial experiments have employed the **FLIR SC3000 EPSRC Thermal Camera**. A sapphire disk was heated by means of a heating plate up to 252.7°C. A 4mm water droplet was

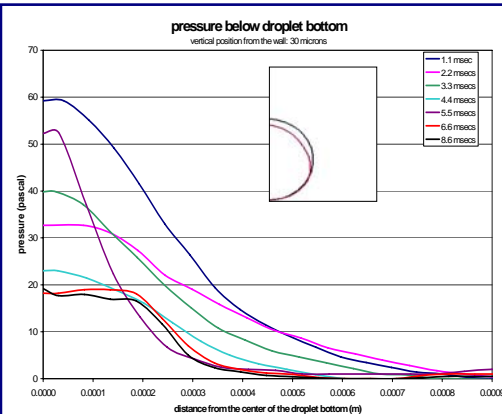


released onto the hot surface. Despite the short time of the presence of the droplet on the surface (approx 800msecs) and the absence of wetting, the hot sapphire was cooled significantly (overall temperature drop was approx 30°C). The following images were obtained. The formation of a vapour layer between the droplet and the hot surface is quite obvious.



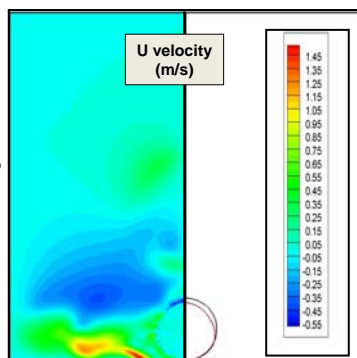
Computational studies

We are studying computationally the interaction of water droplets with a hot fuel rod. Simulations of a single evaporating droplet impacting on a hot wall (wall temperature above the Leidenfrost temperature), in the presence of superheated steam, are being performed with a finite volume code solving the Navier-Stokes equations for incompressible viscous fluid flow. The one-fluid formulation is used and the Level Set method is employed for the tracking of the interface between the two phases.



Simulated pressure profile at different times after 0.9mm radius droplet release on the hot surface ($T_{wall}=400^{\circ}\text{C}$). The pressure drops gradually as the droplet comes closer to the wall after oscillating. Then, the evaporation rate acquires a constant value. So does the pressure. A uniform evaporation rate of $0.1513 \text{ mm}^3 \text{ of liq/s}$ was applied all around the droplet surface when the droplet bottom had stopped oscillating and the vapour layer thickness in that equilibrium state was found to be 30 microns (2D axisymmetric case). Under these conditions, Wachters et al.,(1966) have measured 28,9 microns for the same equilibrium evaporation rate ($0.1513 \text{ mm}^3 \text{ of liq/s}$).

As studied by Wachters et al., (1966), the evaporation rate from the sides of droplet resting upon a vapour cushion is significantly smaller than the evaporation rate at the bottom of the droplet when large (over 1mm diameter) droplets are considered. In the case of small (sub-millimetric) droplets, those two evaporation rates are comparable. It is therefore sensible to use a uniform evaporation rate for the whole droplet surface. The bottom of a small droplet is expected to be closer to spherical gradually flattening as the droplet oscillations die out and the droplet comes to a hydrodynamic equilibrium with the surrounding saturated atmosphere. Previous computational work on this subject has always employed a separate model for the vapour layer sustaining the droplet. The current project is simulating the whole interaction of the droplet with the hot wall, without adopting any additional models for the vapour flow below the droplet. Below, the velocity fields obtained from an initial simulation are presented.



Droplet resting on a vapour cushion
Velocity fields

