DROPLET IMPACTION ON A HOT STAINLESS STEEL SURFACE

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Abstract

The project is concerned with the experimental study of droplet impaction and heat transfer on a hot surface. It is considered to be relevant to spray cooling and other fields where droplet impaction occurs, such as fuel injection and fire extinguishing systems.

The work is based on a novel experimental approach for producing near monosize sprays of droplets by means of a rotating cup enclosed by a cylinder which has a small aperture. A Phase Doppler Anemometer (PDA) has been used to simultaneously measure the droplet sizes and velocities. The droplet streams have volume median diameters between 80 μm and 140 μm and mean velocities between 12.4 ms^{-1} and 26.6 ms^{-1}. Mass flux of impacting droplets is in the range 0.32 $kgm^{-2}s^{-1}$ to 0.84 $kgm^{-2}s^{-1}$. The volume of satellite droplets formed is very small and reduced at low water flow rates. The smaller droplets disperse more rapidly, so that their proportion in the centre of the spray decreases with the distance from the rotary cup. Higher droplet speeds are achieved at the expense of decrease in droplet size when increasing the cup speed, however lower droplet velocities can also be achieved by increasing the distance from the cup.

For utilising these sprays in droplet impaction heat transfer, a 3 mm diameter heated target system was designed and constructed, using electrical heating with overall heat flux measured by thermocouples. A total of 39 impaction conditions are used to analyse the effect of spray parameters on steady state heat flux at surface temperatures 140 °C – 400 °C. It is noted that the effect of increasing droplet velocity is not always to increase the heat flux, so that above a certain velocity value further increase in droplet velocity causes the heat flux to decrease.

Visualisations are performed for analysing the impaction behaviour of droplets at different impact Weber numbers and surface temperatures. These use a high speed video system at 27000 frames/s. Particular attention was focused on droplets impacting with Weber numbers greater than 200, as these have not been covered significantly in previous studies. Visualisation cannot be achieved at impaction velocities greater than 20 ms^{-1} due to the limitations of the framing rate and image resolution. The results are summarised as a family of qualitative models of impaction, which depend upon Weber

number and surface temperature. These models are novel and more detailed than in previous work and cover wider ranges of impact Weber numbers. Correlation equations are developed and presented for droplet numbers and angle of flight as functions of droplet Weber number and surface temperature. The reatomized droplet sizes and velocities are difficult to determine quantitatively from the visualisations and thus the PDA technique is also applied. Based on droplet velocities, a filtration procedure is developed for separately characterising impacting and reatomized droplets. The results show the difficulty in interpreting data from a small measurement volume near the surface, in order to provide unbiased information on all reatomized droplets produced by the impacting droplets. However, in the *film* and *transition* boiling regimes, the size of reatomized droplets is insensitive to surface temperature. It increases with primary droplet size and reduces with velocity, for a given Weber number.

The heat transfer and visualisation results show that, whilst Weber number and surface temperature determine the observed mode of droplet impaction behaviour, a further parameter must be involved in determining heat transfer. This parameter is considered to be related to the ratio of surface contact time and "heat-up" time of impacting droplets, however further tests and analysis are required in order to confirm this phenomenon.