Influence of Elevated Pressure on Impingement of a Droplet Upon a Hot Surface

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Abstract

Introduction

The conditions of drop impact at high wall temperatures and high ambient pressures are relevant for spray impact onto a wall inside internal combustion engines or in air-blast atomizers for gas turbines. The ambient pressure has a significant influence on the evaporation rate of an impacting drop because it changes the saturated vapor temperature of the fluid. Therefore, it affects the boiling temperature, the Leidenfrost temperature, the thickness of the vapor layer, and thus the dynamics, the outcome, the heat transfer rates and the parameters of the secondary spray at certain temperatures.

In the present investigation we consider a specialized and simplified case of a single spherical droplet of water descending a short distance in air and impinging onto a hot flat metal target. Evaporation during flight and subsequent condensation during evaporation of the droplet upon the target are neglected. Although simplified, this case is suitable for applications such as high power cooling.

Experimental method

This study focuses on the qualitative effect of elevated ambient pressure on water droplets with a diameter of 2.4 mm, which accelerate 30 mm, under the influence of gravity, and impact onto a heated surface. A flat aluminum target was heated up to 400 °C (673.15 K) in order to cover nucleate boiling, transition and rebound impact regimes at 1 bar. The experiment is placed in a pressure chamber filled with air pressures upto 24 bar. This is done to simulate conditions comparable to those of combustion chambers in modern engines. Observations of impact dynamics are made with a high-speed camera at 4000 fps and a high-speed LED stroboscope with flash duration of 300 to 400 ns.. Figure 1 shows the visualization examples of impacting droplets.

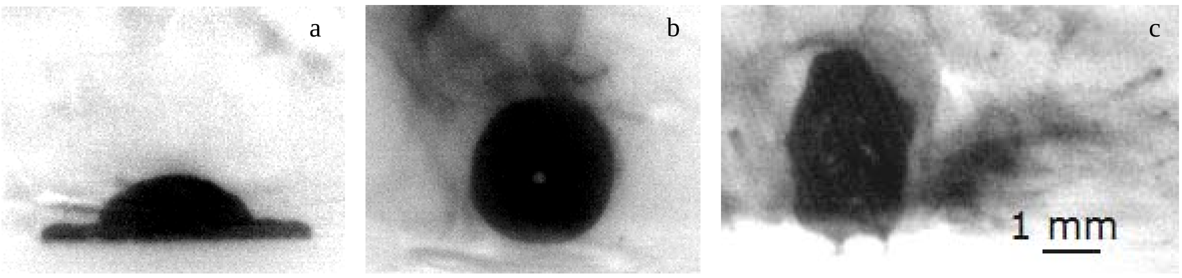

Figure 1. Impact of water droplets onto a heated plate: a: wetting; b: in-flight evaporation; c: satellite droplets.

Results and Discussion

The lifetime of a droplet changes according to both the surface temperature and the pressure in the impact regimes. The regime limits shift according to the saturated vapor pressure. The breakup is observed to generate accelerated secondary droplets in the transition boiling regime. A clear bouncing is observed, when the temperature of the target is above the Leidenfrost point. State-of-the-art boiling theory with nucleation site density for bulk liquids projected at the corresponding contact area explains the initiation of boiling in the droplet. Departure from nucleate boiling is not yet understood, a significant difference in the target superheat at different pressures, compared to a nucleation model, is observed.

Conclusions

The observed behavior of the evaporating droplets is dependent on the conditions upon the surface of the hot plate, especially in the transition region between the boiling and the Leidenfrost temperatures. Understanding of these phenomena provides the opportunity to design a heat exchanger interface equipped with coatings or structures to achieve enhanced performance.

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