Influence of Surface Roughness in Spray/Wall interaction phenomena

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Abstract

This paper presents an experimental study of the liquid spray impact onto rigid walls with different surface roughness. The average dimensionless surface roughness related to the average impacting droplet diameter varied in the range between 0.04 and 1. The surface roughness has negligible influence on the normal component of the mean velocity ratio (ua/ub) of ejected to impinging spray. In contrast, the ratio of tangential component of the mean velocity (va/vb) decreases significantly with surface roughness.

Introduction

The importance of surface roughness in droplet/wall interaction has been investigated by numerous researches; Weiss (1993), Mundo et al. (1995), Mundo et al. (1998), Stow and Hadfield (1981), Cossali et al. (1997), Range and Feuillebois (1998). The outcome of the impacting droplets onto a rigid surface depend not only on the kinematics and fluid properties of the impacting droplets, but also on the ratio of the surface roughness compared to the droplet diameter; Mundo et al. (1995), Kalantari and Tropea (2007a,b). Mundo et al. (1995) used two rotating discs with different surface roughness ($\bar{\varepsilon}/d_0$~ 0 or 1) to study the effect of surface roughness in droplet/wall interaction ($\bar{\varepsilon}$ is the average surface roughness in μm and d0 is the impacting droplet diameter). Their results indicate that in the case of a rough surface, the droplet size distributions vary only slightly with increasing K value (K=We·Oh-0.4; We and Oh are impact Weber number and droplet Ohnesorge number respectively, defined by Wenb=ρu2d0/σ and Oh=μ/√(ρσd0), where u is the normal velocity component before impact, ρ is liquid density, μ is liquid viscosity and σ is the surface tension) and non-dimensional surface roughness determines the distribution of droplet size. In their experiments, a splash corona could not be observed for the rough surface and the disintegration of the droplet appears to be more immediate.

Materials and Methods

The spray was created using different full cone nozzles from Spraying System Co., operated at pressures between 3 and 7 bars. Both flow rate and pressure during the experiments were variable and measured. Different stainless steel targets with diameter of 15 mm (D= 15 mm) and different surface roughness have been used in this study, using the end face of the cylinders. To characterise the spray, a dual-mode phase Doppler instrument from Dantec Dynamics was used, comprising a transmitting optics with a 400 mm focal length, a receiving optics with a 310 mm focal length, and an “A” type mask at a 34° scattering angle.Praesent scelerisque purus eu libero malesuada vel eleifend nisi consequat.

Results and Discussion

Based on the results obtained in this study, the surface roughness has negligible influence on the normal component of the mean velocity ratio (ua/ub) of ejected to impinging spray (Fig. 1a). In contrast, the ratio of tangential component of the mean velocity (va/vb) decreases significantly with surface roughness (Fig. 1b). The ratio (ua/ub) falls in the range 0.13 < (-ua/ub) < 0.3 for Wenb>12, which is consistent with the results obtained by Kalantari and Tropea (2007a). The average drop size ratio (secondary to impacting drop size) consistently increases with increasing surface roughness as shown in Fig. 2a. Results obtained in this study indicate that the total secondary-to-incident mass ratio is also increased with increasing surface roughness, see Fig. 2b.

The surface roughness influences strongly the direction of the secondary droplet motion. In the case of a rough surface, the reflection angle becomes smaller with respect to the wall normal. This can be explained by dissipation of the tangential momentum due to the surface roughness, as shown in Fig. 1b; see also Kalantari and Tropea (2007); Bai et al. (2002). One sketch illustrating such an effect is shown in Fig. 3.

More details of this study and the correlations will be given in the full paper.

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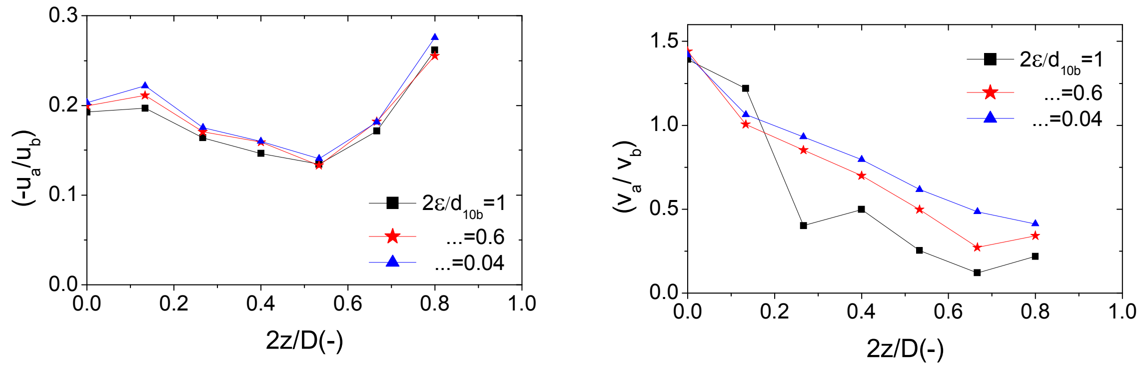

Figure 1. Mean velocity ratio of ejected to impinging droplets as a function of non-dimensional target position for different target surface roughness: (a) normal component, (b) tangential component

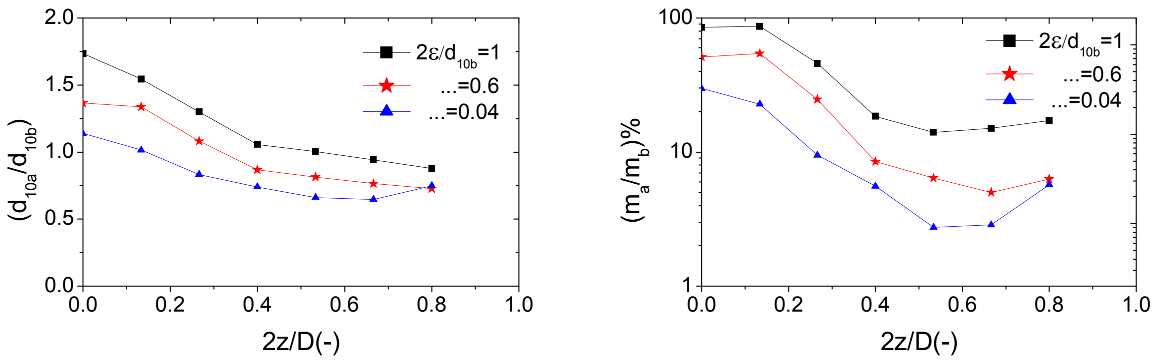

Figure 2. The average secondary to impacting: a) drop size ratio and b) mass ratio, as a function of non-dimensional target position for different target surface roughness

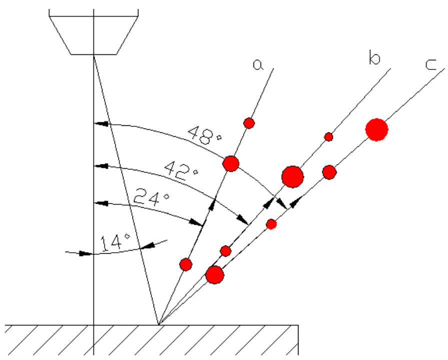

Figure 3. Mean direction of the secondary droplet in the case of smooth and rough surfaces $\bar{\varepsilon}/d_0$ (a: = 1, b: …= 0.6, and c: …= 0.04)