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# Investigations on the Droplet Impact onto a Spherical Surface with a High Density Ratio Multi-Relaxation Time Lattice-Boltzmann Model

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**Abstract.** In the current study, a two-dimensional multi-relaxation time (MRT) lattice Boltzmann model which can tolerate high density ratios and low viscosity is employed to simulate the liquid droplet impact onto a curved target. The temporal variation of the film thickness at the north pole of the target surface is investigated. Three different temporal phases of the dynamics behavior, namely, the initial drop deformation phase, the inertia dominated phase and the viscosity dominated phase are reproduced and studied. The effect of the Reynolds number, Weber number and Galilei number on the film flow dynamics is investigated. In addition, the dynamic behavior of the droplet impact onto the side of the curved target is shown, and the effect of the contact angle, the Reynolds number and the Weber number are investigated.

**AMS subject classifications**: 76T10

**Key words**: Multiphase flow, MRT Lattice Boltzmann, high-density-ratio, droplet impact, film thickness, dynamic behavior.

## 1 Introduction

Many engineering process operations involve the droplet impingement onto solid surface, such as spray cooling, spray painting and coating, diesel and automotive injection, catalytic reaction process in fixed bed reactors and more recently in microfabrication and

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microchannels. Therefore, understanding the fluid dynamics of droplet impaction onto solid surfaces is important for the design and improvement of the above industrial processes.

Rein [1] and Yarin [2] presented comprehensive reviews on the experimental and theoretical studies of the droplet impact dynamics onto the solid surface. Systematic studies have been carried out by Rioboo et al. [3]. Six possible outcomes of drop impact on a dry wall were revealed, namely deposition, prompt splash, corona splash, receding break-up, partial rebound and complete rebound. The influence of droplet size, impact velocity, droplet viscosity, surface tension of the droplet, the surface roughness amplitude and the surface wettability characteristics on the impingement outcomes have been investigated. Experimental and analytical investigations have been done extensively to study the time evolution of the spread factor and the correlation between the maximum spreading factor and Weber number, Reynolds number, Ohnesorge number [4–8]. The three non-dimensional parameters, Weber number ($We$), Reynolds number ($Re$) and the Ohnesorge number ($Oh$) are defined as

$$We=\frac{\rho_L D_0 U_0^2}{\sigma}, \tag{1.1}$$

$$Re=\frac{\rho_L D_0 U_0}{\mu_L} \tag{1.2}$$

$$Oh=\frac{\mu_L}{\sqrt{D_0\sigma\rho_L}}, \tag{1.3}$$

where $U_0$ is the drop impaction speed, $D_0$ is diameter of the spherical drop prior to impact, $\mu_L$ is the liquid viscosity, $\sigma$ is surface tension of the liquid drop, $\rho_L$ is liquid density.

Most of the existing work has investigated the droplet impacting onto a flat surface. However, very limited research has been focused on the droplet impacting onto a spherical surface. Hung and Yao [9] have carried out experiments on the impaction of water droplets, the diameters of which are 110, 350 and 680 $\mu$m on cylindrical wires. The effect of droplet velocity and the wire sizes were varied parametrically to reveal the impaction characteristics. Hardalupas et al. [10] have conducted experiments on droplets of a water-ethanol-glycerol solution in the size and velocity ranges of $160<D<230$ $\mu$m and $6<U<13$ m/s respectively, impinging on the surface of a solid sphere with $0.8-1.3$ *mm* diameter. The impinged droplet formed a crown which was influenced by surface roughness, droplet kinematic and liquid properties. Bakshi et al. [11] have reported experiments and theory on the impact of a droplet onto a spherical target over a range of Reynolds numbers and target-to-drop size ratios. Three distinct temporal phases of the film dynamics were found, namely the initial drop deformation phase, the inertia dominated phase, and the viscosity dominated phase. The influence of the droplet Reynolds number and the target-to-drop size ratio on the dynamics of the film flow on the surface of the target were conducted.

Since experimental techniques are not adequate to deal with the complex measurement, numerical investigations have drawn increasing attention in simulating complex