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# Multiphase simulation of droplet dynamics by smoothed particle hydrodynamics method

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## Abstract

In this work, simulating multiphase flows by implementing smoothed particle hydrodynamics (SPH) as a mesh-free method is presented. The formulation is validated on test cases including droplet evolution, droplet coalescence and droplet splashing by taking surface tension force into account while a high density ratio exists between fluids. Results are presented for time variation of each object at variation intervals until equilibrium condition is approached.

Keywords: Interface tracking, surface tension, drop collision, SPH

## Introduction

Surface tension phenomenon is defined as the cohesion force related to the high attraction of fluid molecules such as water which is responsible for the shape of liquids due to the exceeding of the pressure inside the drops surrounded by the air. It plays an important role especially for droplet formation, impact and splashing[1-3] and coalescence of collision of liquid drops[4, 5], etc. Such hydrodynamics appears in our daily life like rain drop formation in atmosphere and also various industrial application like spray coating, spray cooling, inject printing, as well as in the dispersed phase systems such as dense sprays, liquid–liquid extraction, emulsion polymerization[6, 7].

One of the concerns and difficulties in surface tension modeling, especially in simulating multiphase flow problems are related to interfacial flow tracking. An interfacial surface of inseparable fluids in multiphase flow is one of the significant areas in the field of computational fluid dynamics (CFD). This plays considerable role in various engineering applications and natural systems such as air entrainment at ocean surfaces and bubble boiling heat transfer or flows involved in mixing/separation devices, engines, propellers with cavitation, etc. The air phase in these systems can have a large influence on the water flow evolution and on subsequent loads on each structure. Thus it needs to be modeled correctly and carefully to attain a reliable simulation of dynamic motion of flow.

In general, several methods have been proposed and used to capture the interface of multiphase flow. One of the notable methods of fluid dynamics is based on Eulerian description flows such as volume of fluid (VOF) [8], level set (LS) methods [9] and the Lattice Boltzmann Method(LBM) [10]. Another category is related to the Lagrangian points such as molecular dynamics (MD)[11] and smoothed particle hydrodynamics (SPH)[12, 13].

Smoothed particle Hydrodynamics is one of the most useful meshfree methods for various fields such as oceanography and computational fluid dynamics. It was introduced and developed by Gingold and Monaghan[13]. Besides, recently the range of employing SPH method is expanded in numerous problems such as simulating interface and free surface flow which is one of the advantages of SPH[14-16] for multiphase problems[17-19] and fluid-structure interaction modeling[20, 21]. In addition, SPH method is a good candidate for modeling complex multiphase problems as the Lagrangian nature of this method facilitates the tracking of multiphase interfaces. Moreover, this approach is one of the appropriate numerical simulation methods for surface-tension-driven interfacial flows[22]. In recent years there has been making a lot of effort for interfacial problems with smoothed particle hydrodynamics [18, 23, 24]. Based on such advantages and credits of SPH method, it will be employed for the present simulation of interfacial flow of drop dynamics.

There are two commonly approaches for applying the incompressibility condition in the governing flow equations; namely the incompressible SPH (ISPH), and the weakly compressible SPH (WCSPH) methods and recently several works compared ISPH against WCSPH for various simulations [25-27]. In this study, attempt will be made consider the WCSPH method based on equation of state determining pressure distribution of fluids by calculating density which is a much faster and reliable way instead of implementing the