National Institute of Technology Rourkela

Synopsis Seminar

Seminar Title : Numerical and Analytical Study of the Impact of Droplets on Substrates of Various Topologies

Speaker : Prakasha Chandra Sahoo (Rollno : 519me1012)

Supervisor : Prof. Jnana Ranjan Senapati

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Abstract : The phenomenon of droplet impact, commonly observed in everyday scenarios such as rain falling on surfaces, ink droplets spreading, or coffee stains, has garnered significant attention across diverse scientific and technological fields like medicine, aerospace, electronics, energy, and materials. This dissertation primarily focuses on numerical simulation and analytical prediction of the collision of droplets on solid substrates with various topologies. Finite volume-based axisymmetric simulations are carried out by employing the volume of fluid (VOF) method to predict complex hydrodynamic behaviors. Firstly, a thin cylinder is considered a solid stationary target, and the droplet deforms continuously during impact. Various crucial stages like free fall, hitting, cap formation, encapsulation, uncovering, and detachment are observed by considering several influencing parameters: Weber number *(We)*, contact angle *&theta*, Ohnesorge number *(Oh)*, Bond number *(Bo)*, and diameter ratio *DcDo*. The findings show that the maximum deformation factor increases with the increasing *We* and reducing contact angle. An analytical model has been formulated to elucidate the maximum deformation factor, which shows excellent agreement with the numerical results. Furthermore, a correlation was developed to predict maximal deformation factors in terms of *&theta*, D_c/D_o, *We*, and *Oh*, which operates exceptionally well within ±1% of the computational data. Subsequently, the water droplet impingement and spreading dynamics around a small right-angled circular cone suspended in the air have been studied numerically. Herein, an increase in *We* shorten the droplet&rsquos interaction duration with the substrate for a particular value of *&theta*, *Oh*, and *DcDo*. Moreover, the interaction time reduces drastically with an increase in *Oh* when *&theta*, *We*, and *DcDo* remain constant. Work is also carried out to characterize the liquid drop impingement and pinch-off mechanism on a hemispherical substrate. The analysis of temporal and maximum deformation factors is delineated by considering pertinent parameters. A scattered regime map on *Oh-We* plane is included for different *DhDo* and contact angles to address the distinguished zones. Further, the impingement mechanism of a liquid droplet on a solid torus surface is demonstrated using numerical simulations and an analytical approach. The key findings indicate that the developed central film gets ruptured at the early stage when the torus diameter ratio *DtDo* is lower because a relatively thin film is developed. Concomitantly, the very tiny drops get pinched off at *DtDo*= 0.83, whereas the detached drops are relatively large-sized in the case of lower *DtDo*= 0.16 due to the higher drainage rate of liquid mass through the hole at lower *DtDo*. It has been seen that the 1st pinch-off is faster with the continual upsurge of *We* for a specific value of *DtDo* and ��. Efforts are also made to understand the binary head-on collision of equal-sized vertically aligned drops on the thin cylindrical substrate. A larger value of *&betaf,max* is achieved at a higher *We* for a constant *&theta*, *DcDo*, and *Oh*. The ring drop is pinched off from the parent merged drop when the value of *DcDo* is lower at a higher value of *We*. A theoretical model has also been developed to determine the maximum deformation factor. It is also attempted to elucidate the mechanism of collision and drainage of liquid mass around the spherical substrate suspended within the hollow cylinder using Gerris open-source code by employing VOF methodology. The pattern of the interfacial morphology of droplet collision and drainage mechanism is presented using numerical contours. It has been observed that quantifying the drainage of liquid volume passes through the passage, denoted as *Q*=QQo*, is an increasing pattern of *QQo* with continuous progress of time stamp for all cases of sphere diameter ratio *Ds&fraslDo* for a fixed value of *We*. Moreover, it is studied computationally to characterize the morphological and hydrodynamic behavior of hollow droplet impingement onto a cylindrical substrate. The dynamics of the droplets have been visualized with the help of pressure contour and velocity vector.

Keywords: Droplet impact, VOF method, Maximum deformation factor, Weber number, Contact angle, Ohnesorge number, Interaction time.