Technische Universität Braunschweig

MUSEN

Direct Numerical Simulation (DNS) of Drop Dynamics

Lecture of

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The numerical prediction of two-phase flows is generally difficult. Normally a lot of simplifications and assumptions have to be made. On the other hand, a lot of two-phase flow phenomena are present in our daily life and in a lot of technical processes. In many of these processes single droplets or interactions of droplets are of great interest (e.g. injection, interaction and evaporation of fuel droplets in a rocket or car engine or a gas turbine combustion chamber, clouds formation, rain droplets, air pollution, sprays in medical applications,…). The ITLR in Stuttgart has developed over the past 20 years a CFD code named FS3D (Free Surface 3D), which is able to predict droplet interactions, droplet evaporation as well as jet desintegration by using direct numerical simulation (DNS). The computational resources needed for this approach are high, so that the code is run normally on the supercomputers in Stuttgart. Grid sizes of about several billion cells have been used already successfully.

For the numerical simulations of basic droplet processes, the in-house 3D-CFD program FS3D (Free Surface 3D) has been used. This code solves the Navier-Stokes equations for incompressible flows with free surfaces. The equations are solved without a model by Direct Numerical Simulation (DNS), which requires a high resolution of the computational domain to capture the small length scales of the two-phase flow. The governing equations are conservation of momentum, mass and energy. In two-phase flows additional information about the interface position between the disperse and continuous phase are needed. In FS3D a volume-tracking method, well known as the Volume-of-Fluid (VOF) method, is used. In the VOF-method an additional transport equation for the volume fraction f (VOF variable) of the dispersed phase is solved. To ensure a sharp interface and to suppress numerical dissipation of the disperse phase in each step, the interface is reconstructed with the PLIC-method (Piecewise linear interface reconstruction computation). After the reconstruction of the interface, the disperse phase is transported on the basis of its reconstructed distribution. The spatial discretization is realized by a structured Finite Volume scheme on a staggered grid. In each phase the discretization is second-orderaccurate. Due to high gradients across the interface a limiter is used to prevent the formation of oscillations and spurious solutions. The program is fully parallelized and adapted to high speed computing.

In this lecture several different applications of FS3D will be shown. The examples range from droplet-droplet, droplet-film, droplet-wall collisions, droplets with phase change to primary jet break-up of shear thinning fluids applications.