Binary water droplet collision study under conditions typical for nuclear reactors

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Abstract

During the course of a hypothetical severe accident in a Pressurized Water Reactor (PWR), hydrogen can be produced by the core oxidation and distributed into the whole containment. In order to avoid the risk of detonation, spray systems can inject water at the top of the containment to ensure a mixing of the atmosphere, to reduce the total pressure, to cool down the containment walls, and to wash-out the eventual suspended fission products. The efficiency of the spray system depends on the evolution of the droplet size distribution in the containment, in particular because of possible droplet coalescence.

This presentation is concerned with the various outcomes of binary droplet collisions. According to the literature, five collision regimes can be pointed out: coalescence with minor deformation, bouncing, coalescence with major deformation, reflexive deformation and stretching separation. In most studies, the collision process is characterized by three parameters: the Weber number We, the impact parameter I and the diameter ratio Δ that are used to determine the transition curves between all binary collision outcomes. Qian and Law (1997) showed that droplet collision behaviour depends on ambient conditions like pressure, temperature, relative humidity and gas properties as density or viscosity. However, no data exist for the conditions typical of a hypothetical nuclear reactor accident. The purpose of the present work is thus to extend the previous results on water droplet coalescence by studying a wider range of parameters typical of reactor conditions and to propose correlations for the given conditions.

An experimental set-up, which will be described in the full-length paper, has been developed at IRSN to study binary water droplet collision. Water droplets from 200 and 700 μm diameter are used. Droplet velocities are between 1 to 19 m.s-1, and droplet collision angles between 10° and 95°. Experiments allow us to characterize the behaviour of water droplet collisions for We from 10 to 2800 and for Δ from 0.5 to 1, taking into account the huge difference between droplet characteristics at the top of the reactor containment. The set-up is enclosed in a vessel in order to allow the change in some gas mixture conditions (injection of helium for a safe simulation of an ambient air-hydrogen mixture, gas heating, etc.). Results under atmospheric pressure and ambient temperature conditions are presented. They are analyzed in terms of a new "symmetric Weber number" and of the Ohnesorge number.

Keywords: collision, coalescence, bouncing, droplet, water, Weber, density, viscosity, Ohnesorge, Knudsen

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