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INFLUENCE OF MIXING AND COOLING ON AEROSOL FORMATION AND EVOLUTION IN BACKWARD-FACING STEP FLOW

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In many applications formation of aerosols may occur due to sudden phase transition in supersaturated vapor mixtures, e.g., mixing processes, fast expansions or chemical reactions in the gas phase. Formation of aerosols can be a desired or an undesired effect depending on the application. For example, aerosol droplets in commonly available electronic cigarettes are usually formed via rapid evaporation and cooling of supersatured vapors. In industry, aerosol droplets are often used to wash unwanted pollutants from a gas stream in the so-called pollution scrubber systems. In such systems the aerosol may evaporate too fast during the quenching process without having a chance to contact the pollutants. Adversely, the aerosol may evaporate too slowly after the contact, causing captured pollutants to become reentrained into the system. This may cause operational problems in the downstream equipment. In the above cases it is important to have simultaneous control of flow, heat and mass transfer in order to obtain a well-controlled aerosol generation systems.

In order to study the competing heat and mass transfer between the phases we consider a situation in which the phase changes (gas-liquid) happen simultaneously in a setting motivated by desorption in packed columns. In such a setup, the hot gas phase enters the system with a cold liquid being present inside. Due to simultaneous cooling of the hot gas and mixing with the partially evaporated liquid along the interface, the states of the gas and liquid phases change. As long as the vapors are supersatured, droplets are formed in the domain due to homogeneous nucleation. Through condensation or evaporation, the droplets subsequently grow or reduce in size. In addition, in the process of simultaneous mixing and cooling, the newly formed aerosol can coagulate forming larger droplets.

To consider the described situation in practice, we study the flow in a backward-facing step geometry (Fig. 1a). We consider laminar flow conditions at various Reynolds numbers (example of developed flow at $Re = 1500$ is shown in Fig. 1b). The hot saturated vapors at temperature T_m enter the geometry from the inlet (see Fig. 2a) and flow past the step. The vapors are cooled by the presence of wall at lower temperature T_w. We investigate various flow rates at prescribed thermal conditions to study the influence of simultaneous mixing and cooling on the aerosol formation (see Fig. 2b). In addition, we consider a situation in which the hot vapors are mixed with evaporated (comparatively cold) liquid (water) diffusing from the bottom of the geometry (cooling wall). In particular, we concentrate on the partitioning between the gas and liquid (aerosol) phases and control of the aerosol droplet size via the flow and thermal conditions. The influence of evaporated liquid from the wall on aerosol formation is also studied by varying its quantity and temperature of the cooling wall.

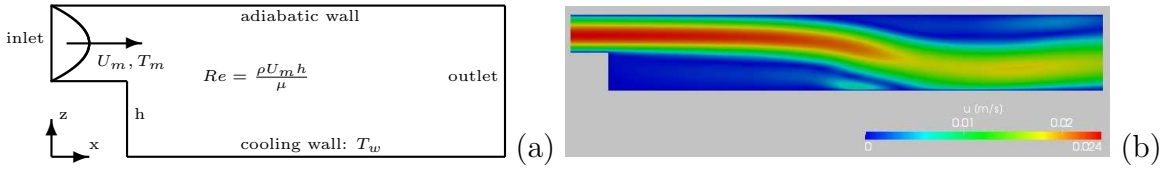

Figure 1: Backward-facing step geometry (a) and developed flow velocity u [m/s] at Reynolds number $Re = 1500$ (b).

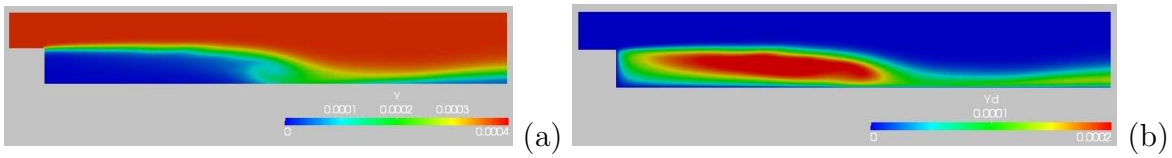

Figure 2: Mass fraction of nucleating species in the gas phase Y (a) and in the liquid (droplet) phase Y_d at developed flow conditions (Re=1500, cooling wall temperature $T_w = 298$ [K], temperature of vapor phase at the inlet $T_m = 363$ [K]) (b).

The aerosol formation and evolution process is captured in the Euler-Euler representation using compressible formulation with a multispecies aerosol model (see [1, 2]). Classical nucleation theory is used for the aerosol formation, while the aerosol is described only with two moments, i.e., the droplet mass concentration and the droplet number concentration, while keeping the geometrical aerosol size distribution fixed in every computational cell.

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