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Inertial Spreading of Drop on Porous Surfaces

Authors : Shilpa Sahoo, Michel Louge, Anthony Reeves, Olivier Desjardins, Susan Daniel, Sadik Omowunmi

Abstract : The microgravity on the International Space Station (ISS) was exploited to study the imbibition of water into a network of hydrophilic cylindrical capillaries on time and length scales long enough to observe details hitherto inaccessible under Earth gravity. When a drop touches a porous medium, it spreads as if laid on a composite surface. The surface first behaves as a hydrophobic material, as liquid must penetrate pores filled with air. When contact is established, some of the liquid is drawn into pores by a capillarity that is resisted by viscous forces growing with length of the imbibed region. This process always begins with an inertial regime that is complicated by possible contact pinning. To study imbibition on Earth, time and distance must be shrunk to mitigate gravity-induced distortion. These small scales make it impossible to observe the inertial and pinning processes in detail. Instead, in the International Space Station (ISS), astronaut Luca Parmitano slowly extruded water spheres until they touched any of nine capillary plates. The 12mm diameter droplets were large enough for high-speed GX1050C video cameras on top and side to visualize details near individual capillaries, and long enough to observe dynamics of the entire imbibition process. To investigate the role of contact pinning, a text matrix was produced which consisted nine kinds of porous capillary plates made of gold-coated brass treated with Self-Assembled Monolayers (SAM) that fixed advancing and receding contact angles to known values. In the ISS, long-term microgravity allowed unambiguous observations of the role of contact line pinning during the inertial phase of imbibition. The high-speed videos of spreading and imbibition on the porous plates were analyzed using computer vision software to calculate the radius of the droplet contact patch with the plate and height of the droplet vs time. These observations are compared with numerical simulations and with data that we obtained at the ESA ZARM free-fall tower in Bremen with a unique mechanism producing relatively large water spheres and similarity in the results were observed. The data obtained from the ISS can be used as a benchmark for further numerical simulations in the field.

Keywords : droplet imbibition, hydrophilic surface, inertial phase, porous medium
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