Interfacial phenomena

Where the action is

When things get small, all of the action happens at the interfaces—where liquid meets solid or liquid meets air. When we sweat, evaporation at the air-water interface cools our skin. Nature employs interfaces for plant transpiration and sap movement in trees. Interfaces are put to good use in a multitude of devices and tools as well. From seemingly ordinary items such as house paint and duct tape to highly advanced hydrogen fuel cells, the action of interfacial phenomena is ubiquitous.

Jeff Allen established the Microfluidics & Interfacial Transport Lab (MnIT) to study and advance the understanding of interfacial phenomena, particularly gas-liquid interfaces where capillary forces are important. “Capillary force typically implies that the system is small; less than a millimeter,” Allen explains. “However, capillary scale really means that surface tension forces are more important than gravitational forces at a gas-liquid interface. There are two ways to make surface tension important relative to gravity. The first is to shrink the size and the second is to shrink gravity. So capillary scale can also mean low-gravity or extraterrestrial.”

In the MnIT lab, Allen and his team are studying evaporation and condensation in low gravity. “NASA, as well as all other space agencies, would like to recycle waste water in space. The easiest method is to evaporate water out of the waste stream and condense the purified water where it can be used. This works well on Earth because gravity can be used to keep the liquid film in place while evaporating. Unfortunately, it's not easy to keep a liquid layer stable while evaporating in space. Capillary forces become important when gravitational forces are reduced. The combination of capillary forces, internal convection, and evaporation results in destabilization of the liquid film.”

The team is also investigating how water moves through the small channels that distribute hydrogen and air in fuel cells. “We are examining exactly how water percolates through fuel cell electrodes, typically teflonated carbon paper. The channels are small enough that capillary forces are very important." In order to carry out these studies, the team is developing advanced high-speed microscopy techniques. “Everything is small and moves fast.”

Fuel cells hold great promise for the future automobile. “Our inability to properly manage the water produced in a fuel cell results in its rapid degradation,” adds Allen. “Currently the best method for optimizing fuel cell electrodes for water management is a tough and expensive trial-and-error process. Our research enables fuel cell optimization and performance predictions to be completed before building and testing a full-size fuel cell stack—something we hope will help bring reliable, durable automotive fuel cells to consumers in the near future.”

Pictured: An example of microfluidics and interfacial effects. The spider’s specialized gland is, in effect, a microfluidic chemical reactor that creates a composite ‘silk’ fiber. Dew drops stay attached in spherical form because at their small size, capillary forces are much stronger than gravity.

Jeff Allen
Mechanical Engineering-
Engineering Mechanics