

MICROFLUIDICS FOR DYNAMIC INTERFACIAL TENSION MEASUREMENT – TOWARDS IMPROVED FUEL-WATER SEPARATION TESTING

Shweta Narayan¹, Davis Moravec², Brad Hauser², Andrew Dallas², Cari Dutcher¹

¹University of Minnesota, ²Donaldson Company, Inc.

Water entrained in diesel fuel often undergoes shear-induced breakup to form microemulsions, with droplets ranging from 10 – 150 μm in diameter. The water droplets are stabilized by the presence of fuel additives, including lubricity improvers, anti-fouling agents, and deposit control chemicals, which act to lower the fuel-water interfacial tension (IFT). Separation of water droplets from fuel is achieved using coalescing filters with woven fiber mats, which capture and coalesce these micron-scale droplets. In general, the lower the IFT, the harder the water is to separate from the fuel, due to drop in the thermodynamic driving force for coalescence. Conventionally, fuel-water dynamic IFT is measured using flat interfaces or large millimeter-sized drops in accordance with ASTM D971 using a Du Noüy ring or equivalent methods such as pendant drop tensiometry, which measures IFT at 30 seconds after droplet formation. In this work, we use microfluidic devices to test the effect of emulsion size on IFT measurements, towards improved fuel-water separation testing. Biphasic microfluidic platforms with continuous fuel phase and discrete water phase can be used to mimic real fuel-water emulsions in a dynamic flow environment. Droplets in the size range 75 – 90 μm are formed using a flow-focusing microfluidic design and deformed in a contraction-expansion geometry. High-speed droplet deformations are imaged and related to material and flow-field parameters using previously established analyses to calculate interfacial tension. A series of 26 geometric contractions enable dynamic IFT measurement, with hundreds of droplets used for analysis. We measure dynamic or time-dependent IFT between water and real and surrogate diesel fuel systems, with various fuel additives. Through microfluidic tensiometry, we find that small micron-sized droplets reach equilibrium IFT orders of magnitude faster than large millimeter-sized drops in conventional testing methods. This implies that in actual application, within the time frame required for droplets to travel from the point of formation in a diesel fuel system to the filter, the IFT would already decay to the equilibrium value. Since ASTM D971 dictates measurement of IFT at 30 seconds after droplet formation, if testing is conducted on large millimeter-sized drops, the measured IFT values would likely be much higher than the IFT observed in real fuel-water systems.