Modeling and Simulation of the Rapid and Automated Measurement of Biofuel Blending in a Microfluidic Device Under Pressure Driven Flow Using COMSOL Multiphysics®

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Abstract

Introduction: As the fossil fuels are depleting with time, the concerns and research work in the area of renewable energy is growing; thereby providing ample scope for the production and utilization of biofuels. Due to different fuel-combustion properties, the blends of biofuel with conventional fuels can be used as an automobile fuel. Today a device is required to monitor the composition of the fuel in automobiles which is easily deployable, robust, user-and-equipment friendly, in-situ, and inexpensive. It is well observed that the fuel mixture directly affects the lubricating properties of the fuel and therefore directly affecting the engine performance. As the lubricating properties are simply related to the different physical properties, developing a sensor, based on such physical properties, can provide a reliable and effective solution to detect and monitor the fuel blending. This work describes the development of a y-shaped micro-device (Figure 1) which is able to perform various fluidic operations by observing and analyzing different physical properties and their variation. These devices are fabricated using well-established micro-fabrication techniques which are inexpensive on mass-production, and can potentially be integrated with the existing microcontrollers in the automobiles. The test results of various samples with different blending ratios clearly distinguish the diesel blending with different quantities of bio-diesel. Such microfluidic devices have prospects for various other viscosities based sensing and monitoring, such as, fuel adulteration, hemoglobin detection, food adulteration etc.

Use of COMSOL: COMSOL Multiphysics® was used to study the viscosity based flow inside the micro-fluidic device. Designing of a polymer microfluidic device to work as micro-viscometer to detect the bio-fuel blending was done based on the results obtained using the software. In this model, the parametric solver is used to solve Hagen Poiseuille flow equation for the two different fluids that flow inside the channel. To analyze the interface shift, when dynamic viscosity of the sample fluid is changed with respect to the immiscible reference fluid, the simulation tool was used.

Results: The design aims to maintain a laminar flow field when the two streams, A and B, are

united and thus prevent uncontrolled convective mixing (Figure 2). The transport of species between streams A and B should take place only by diffusion in order that species with low diffusion coefficients stay in their respective streams. The comparison of the simulation and experimental results clearly showed that as the test sample of different viscosity is selected there is an interface shift i.e. the test sample with higher viscosity tends to take broader path in the common channel thereby pushing the less viscous reference fluid.

Conclusion: Using this device once can do real-time detection and monitoring of bio-fuel blend-ratio and adulteration of automobile fuels. In the future scope it can also be modified for other applications like food adulteration and hemoglobin detection in blood. The final product is a Microfluidic device capable of real-time detection and monitoring of bio-fuel blend-ratio and adulteration of automobile fuels.

Figures used in the abstract

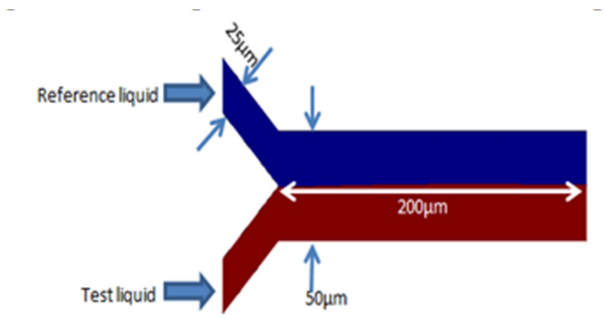

Figure 1: Y shaped Microfluidic Device Geometry Design

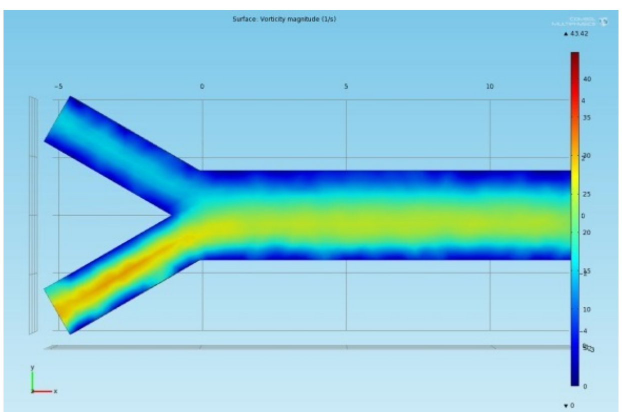

Figure 2: Flow velocity field