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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Introduction: The fuel mixture directly affects the lubricating properties of the fuel and therefore adversely varying 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. The development of a micro-fluidic device using a MEMS techniques is inexpensive on mass-production, and can potentially be integrated with the existing microcontrollers in the automobiles.

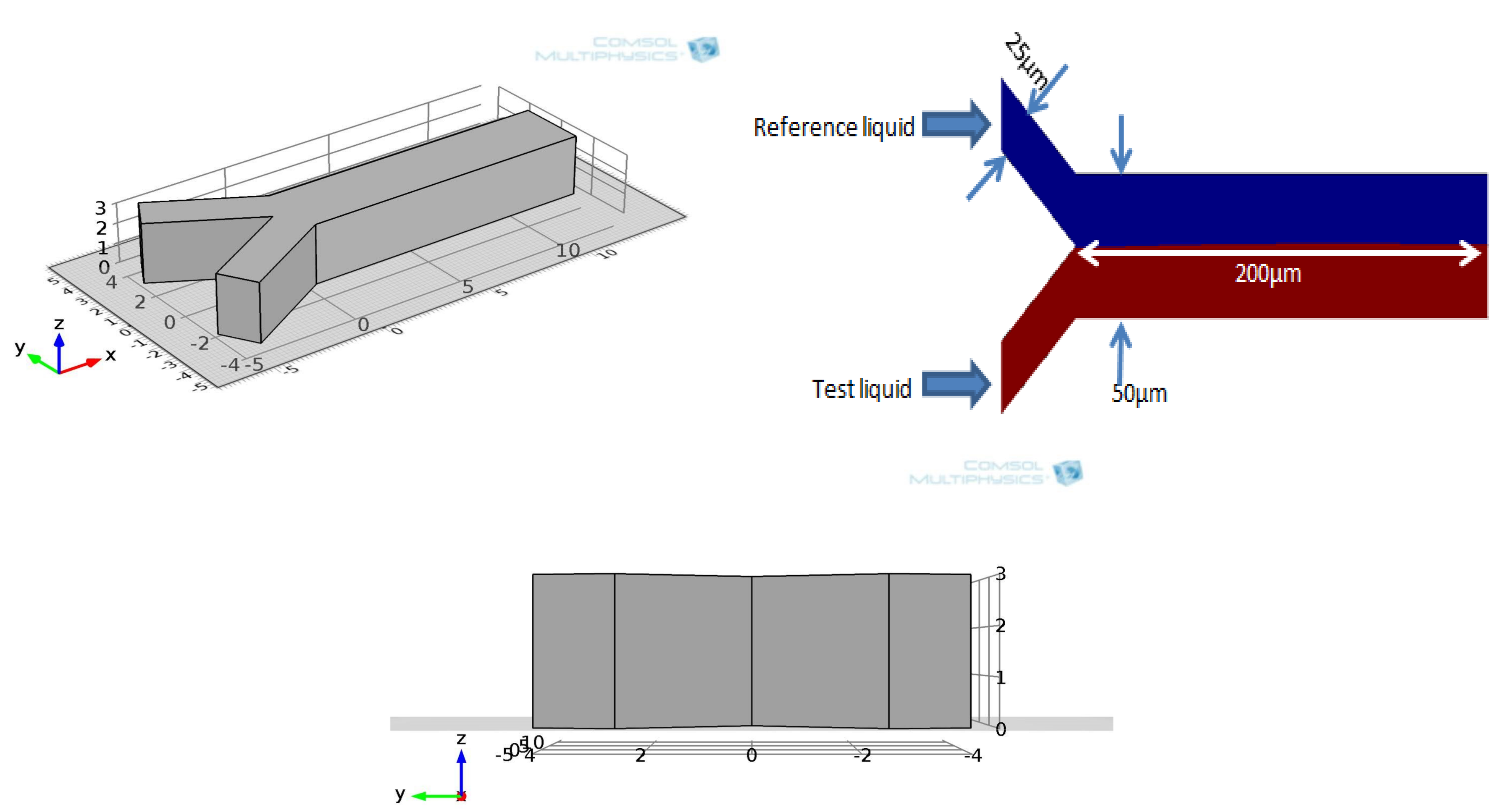

Figure 1. 3D, XY and YZ Geometry of Y-Shaped Microfluidic Device

Computational Methods: The Hagen Poiseuille flow equation given below is the basis of determining the viscosity. Here w is the width of the channel in mm, ΔP is the difference in pressure between the inlet and outlet in Pascals, v_m is the fluid velocity inside the channel and L is the length of the channel.

$$\mu = \frac{w^2 \Delta P}{2 v_m L} \quad (1) \qquad \mu \propto w^2 \quad (2)$$

For solving the Navier Stokes equation and the convention-diffusion physics the mesh applied to the channel is extremely fine with a maximum element size of 0.359 mm and the minimum element size of 0.00359 mm. The mesh is made to flow through the channel with an element growth rate of 1.3.

Results: Reliable and feasible limits and boundary conditions have to be implemented during the mask-design and fabrication. Design of a mask in L-Edit/ AutoCAD is done precisely and then generation of the master pattern on Silicon / glass is performed.

The micro-viscometer is tested in suitable viscosity ranges. Samples are taken in various ratios of adulteration by using automobile fuels with known adulterants and various blending ratios of biofuels with conventional fuels (bio-diesel with diesel and bio-ethanol with petrol). Viscosity of different samples is measured using micro-viscometer.

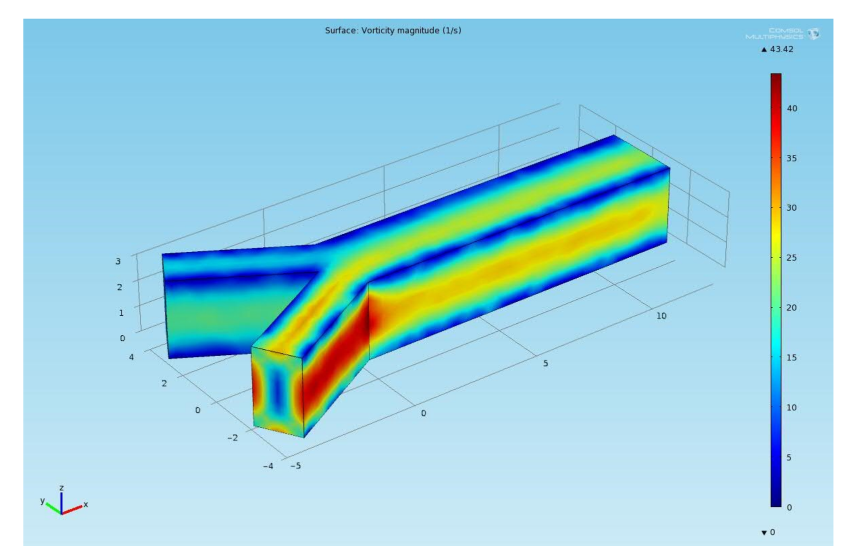

Figure 2. 3D View of the Velocity Field for the Flow

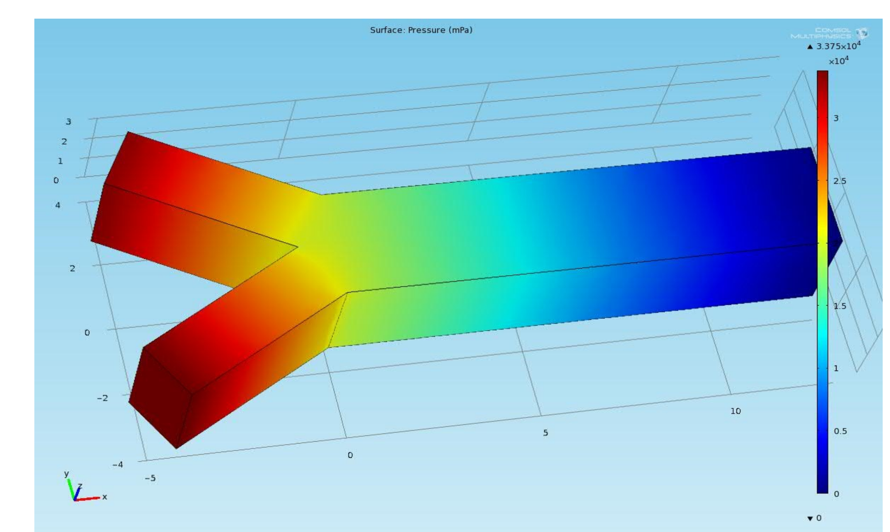

Figure 3. Pressure distribution on the channel walls

Based on the dependence of viscosity and density, it will be possible to extend this proposed method to check adulteration of other edible items, such as, edible oil and milk. Also, the technology can be used in the applications where viscosity is the defining factor, such as, sensing hemoglobin in blood.

% Channel Fraction of Sample	Bio-diesel Viscosity (cSt)
41.60	4.49
44.60	5.39
47.90	8.49
50.00	13.63
51.33	17.40
54.86	27.67

Table 1.

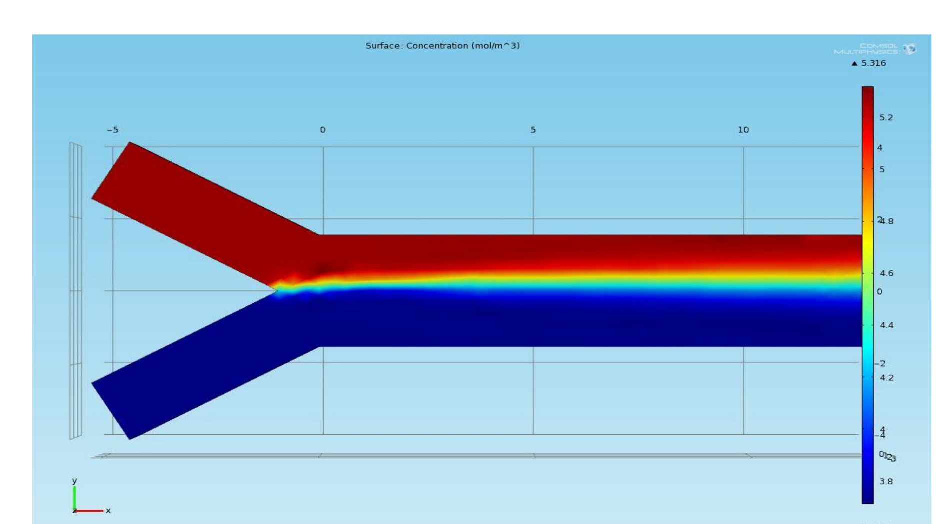

Figure 4. Interface shift between Glycerin and Biodiesel B40

Conclusion: Real-time detection and monitoring of bio-fuel blend-ratio and adulterated automobile fuels by a reproducible micro-fabrication process in a cost-and-time efficient manner. System level integration of the device with the existing microcontroller of automobiles will be explored. Development of a prototype is in progress to be set up inside an Automobile for real-time testing of fuel poured into the fuel tank.

References:

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