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University of Bahrain
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Department of Chemical Engineering

EXPERIMENTAL AND CFD SIMULATION STUDIES OF BIODIESEL PRODUCTION IN AN IN-HOUSE TESLA SHAPED MICROREACTOR

Abstract

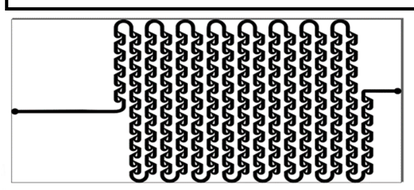
This project aims to examine the validity of the biodiesel production results obtained from a built-in CFD simulation model of a microreactor to those established experimentally. Thus, an in-house tesla-shaped microreactor was designed and accordingly fabricated on a PMMA sheet using CNC milling machine and finally laminated using a polyurethane sheet and commercial double-sided tape. A 2-D CFD simulation model was constructed in COMSOL Multiphysics software (v.5.6). The microreactor performance in the model was examined through quantifying the % yield in the reaction engineering interface and through the application of the laminar flow interface. To validate the simulation model, biodiesel was produced in the fabricated microreactor from WCO via the transesterification reaction at different operating temperatures and alcohol to oil molar ratios. Qualitative comparison that assesses the trends and statistical tests were conducted to confirm that the simulation results are adequately comparable to the experimental and other previous literature results, thus validating the simulation. The validated model can then be utilized by chemists and engineers for studying and developing the production performance of biodiesel in microreactors efficiently.

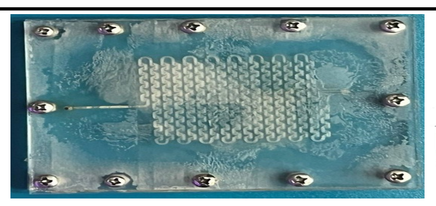
Objective and Motivation

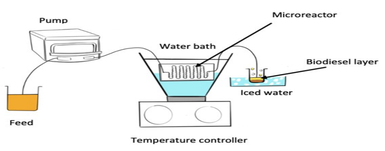
One of the limitations to which biodiesel is not largely used to replace fossil fuels until now is its production system which is very time consuming and relatively very expensive. Thus, various studies are now being done to test the microreactor application for biodiesel production due to its huge potential of substituting fossil fuels in the upcoming future. Therefore, a viable solution that allows testing microreactors promptly and in the least costly manner is pursued by validating a (CFD) simulation system using COMSOL Multiphysics to an experimental microreactor transesterification setup. This project encourages engineers working in the microfluidic technology sector to effortlessly produce potential designs that can be scaled and implemented to produce biodiesel in high yields.

Design and Implementation

A comparative study yielded in the employment of Polymethyl PMMA as the material of construction for the microreactor. The microreactor was designed to test two tesla dimensions in consideration, on having a width of 600 microns and the other having 800 microns. Two Tesla shaped microreactor inlets were considered, one inlet design and three inlet design. These designs were tested through two fabrication techniques, CO_2 laser cutting and CNC mechanical micro-cutting. The CNC milling machine was ultimately chosen for producing the microchannels due to the under comings of the laser cutter. The sealing of the microreactor is compromised of medical-grade water-proof tape (polyurethane sheet), double sided tape, and bolted together with twelve screws. The Transesterification reaction was implemented on the fabricated microreactor. A pump was used to pump the fluid at low flowrates via butterfly tube. The samples collected were then centrifuged for separation, heated for evaporation, and finally fed to the GC-MS for analysis.

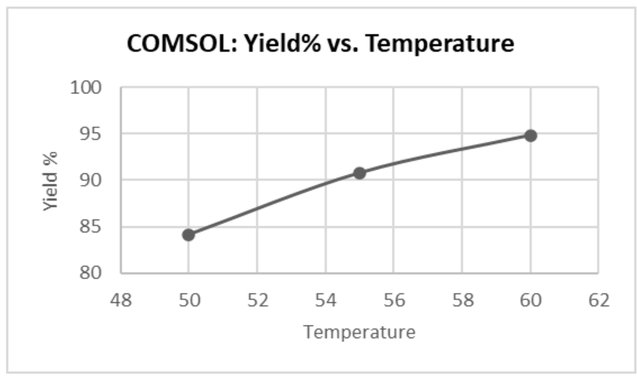


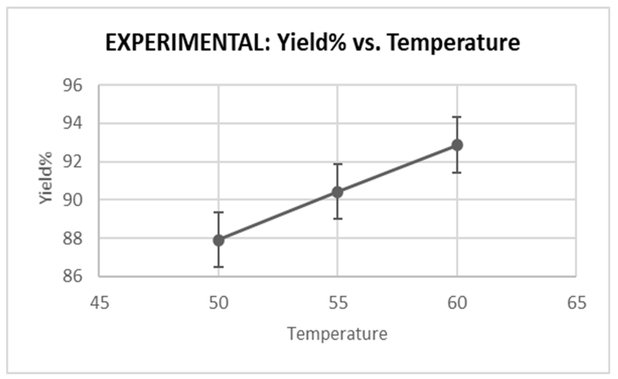


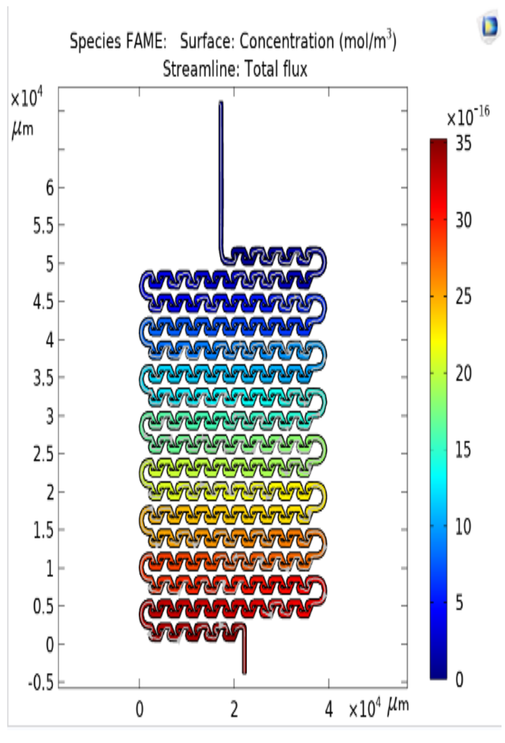


Results

The simulated % yields were found to be 84.13%, 90.79% and 94.85%, and those found experimentally were 86.86%, 89.64% and 92.87% for a molar ratio of 12:1 and at operating temperature of 50°C, 55°C and 60°, correspondingly. Such results are associated with a deviation of 2.73%, 1.15% and 1.98% respectively. On the other hand, with 12:1, 9:1 and 6:1 alcohol to oil ratios and at 60 °C, the % yield from the CFD simulation were found to be 69.89%, 93.67% and 94.85% was compared to the experimental % yield values of 88.71%, 90.34% and 92.87%, in that order. Such results correspond to deviation of 1.98%, 3.33%, and 18.18%, respectively.

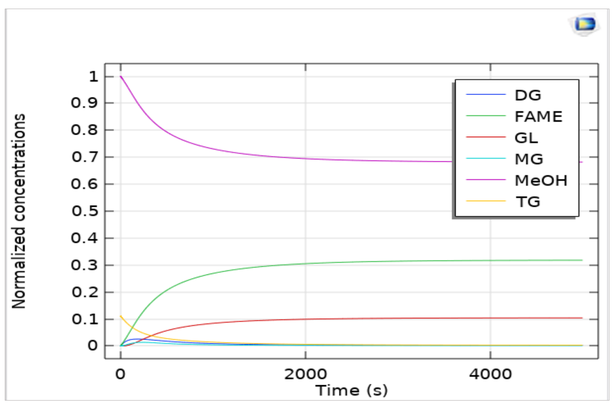






Conclusion

To conclude, the main project's objectives were fulfilled by first successfully designing and fabricating an in-house tesla shaped microreactor using CNC milling machine. The microreactor was made from PMMA and laminated with polyurethane material sheets. Biodiesel was then synthesized from WCO via transesterification reaction at 5 different runs; each at which a certain condition was varied. A CFD simulation model using COMSOL Multiphysics was successfully built for the experimentally tested process and at similar operating conditions then compared with the resulting experimental results. Qualitative comparison and statistical tests were conducted and adequately confirmed that the simulation results are comparable to the experimental and other previous literature results, thus validating the simulation.



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