Ultrasonic and hydrodynamic biodiesel synthesis-energetic considerations for continuous reactor

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Biodiesel continues to be a viable proposition as a renewable energy source and an alternative to fossil-based fuels. Even though the ultrasonically assisted transesterification process is well known [1], the use of ultrasound can simplify the process producing biodiesel which fall within the limits of the quality standard. The improvements were due to higher mass transfer between the two non-miscible reactants via the formation and collapse of asymmetric cavitation bubbles [2]. The main drawback to the upscaling of this type of process is the potential limitation to reactor volume, lab scale process cannot be scaled up linearly to higher volume due to impossibility to reproduce the same acoustic pattern using larger volumes and more powerful ultrasonic devices. This aspect can be solved by using a continuous reactor assisted by ultrasound, well characterized at lab scale, followed by numbering up technique for industrial scale or a hydrocavitation reactor, much easier to expand to larger scale. For such ultrasonic reactors the most important feature is the very short residence time so that even at a small volume of the reactor it is possible to use a high flow rate of reactants to allow a high production rate. To these features should be added the minimal energy consumption within the process.

Our work has focused on a study of biodiesel production using continuous flow systems assisted by acoustic cavitation (ultrasonic or hydrodynamic). In the case of the acoustic cavitation reactors two types of generators were used: US probe system (www.sonics.com) and MMM-Clamp on (www.mpi-ultrasonics.com). In both cases the reactors were thermostated. In the case of hydrodynamic cavitation, a specifically designed reactor was used (built by the SME *SC Progen IMPEX SRL (www.progen.ro)*. These processes are compared in terms of fatty acid methyl ester concentration at the outlet of reactors and specific energy consumption.

The advantages and limitations of each type of equipment were highlighted:

- The US probe device ensures the most efficient stirring (and therefore better mass transfer) during the reaction (no premixing is required), the optimum power density has been determined to achieve biodiesel quality standard at the minimum energy consumption, having the lowest specific energy consumption.
- MMM-clamp on, due to the larger surface of ultrasound energy transfer to the reaction medium, cannot provide good enough stirring (not producing enough cavitation bubbles when the reaction mixture passes throughout reactor), a pre-mixer is needed. However, this type of equipment can be raised to larger scale slightly easier than the US probe device;
- The hydrocavitation reactor is best suited for scale-up. The design of such a reactor should be carefully chosen to ensure the uniformity of treatment. For our reactor, the minimum required FAME concentration, as stated by accepted standards was not obtained. This type of reactor can be used when the quality restrictions for biodiesel are lower.

The target end user for biodiesel production unit is a small or medium farm where such equipment could provide enough fuel for agricultural machinery which will use green fuel produced on site.

References

1. Stavarache, C., et al., *Chemistry Letters*, 2003. **32**(8): p. 716-717.
2. Maeda, Y., et al., *Method for producing fatty acid alcohol ester*, in *US Patent 6,884,900*. 2005.