Using Manifold Feedstocks for Ultrasonic Transesterification of Biodiesel

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Biodiesel Transesterification Process & Ultrasonic Mixing Effects

Biodiesel can be produced by the transesterification of triglycerides with methanol (rarely ethanol). Further, base catalysts or acid catalysts are needed transform oil or fat into fatty acid methyl ester (FAMEs).

The reaction equilibriums below show the overall and stepwise reactions of biodiesel transesterification:

$$TG + 3CH_3OH \underset{}{\overset{catalyst}{\rightleftharpoons}} GL + 3FAME$$

The stepwise reactions are:

$$TG + CH_3OH \rightleftharpoons DG + FAME \quad (1)$$

$$DG + CH_3OH \rightleftharpoons MG + FAME \quad (2)$$

$$MG + CH_3OH \rightleftharpoons GL + FAME \quad (3)$$

Excess methanol and catalyst (e.g. KOH) are significant cost factors in biodiesel production. Hielscher ultrasonic reactors add cavitational shear to the mixing process. Ultrasonic cavitation generated in liquid creates locally extreme effects, such as liquid jets of up to 1000km/h, pressures of up to 2000atm and temperatures of up to 4500 °C. By these extreme conditions, very fine emulsions and dispersions can be produced. For biodiesel processing, the significantly smaller methanol droplets result in improved methanol and catalyst utilization. Therefore, less methanol and catalyst are required. In addition to that, the cavitation influences the reaction kinetics, leading to faster and more complete transesterification. Ultrasound can reduce the processing time from one to four hours needed in batch processing to less than 30 seconds. Also, it reduces separation time from approx. up to 10 hours, down to one.

The conventional biodiesel process proceeds in the batch. Ultrasonic biodiesel processing allows a continuous inline production. By that, ultrasonication can achieve a biodiesel yield in excess of 99%. Furthermore, the ultrasonic inline mixing reduces the number and volume of tanks used for conventional batch processing. This improves capital utilization. Jeff Longo from Genuine Bio-Fuel, Inc. (Indiatown, FL, USA) – Florida's leader in biodiesel technology - uses several ultrasonic units and confirms the outstanding efficiency of ultrasound for a high quality biodiesel production: "At Genuine Bio-Fuel Inc. the Hielscher UIP1000hd ultrasonic processors enables us to produce high quality ASTM biodiesel from various feedstocks. This unit reduces our costs and improves the process performance."

Various Feedstocks for Ultrasonic Biodiesel Production

Feedstock is an important factor for efficient and cost-effective biodiesel production, especially if oils and fats become scarce resources. The possibility of using various feedstocks allows the biodiesel producer to secure its oil supply to reasonable conditions.

The most commonly used feedstock in the biodiesel production is (virgin) straight vegetable oil (SVO) or waste vegetable oil (WVO). Especially, waste cooking oil (e.g. from restaurants, fast food chains etc.) is cheap if biodiesel manufacturers can get their hands on it. But waste oils present a demanding challenge for the transesterification process as they contain contaminants such as water and food residues, which have to be filtered out. Also processing costs for waste oils and grease are higher per gallon than that of straight vegetable oils. This results from the high content of free fatty acids in the cheap and poor feedstock as in waste oils the FFA molecules are separated from the glycerol molecules.
Next to the most widely used vegetable oils, obtained from rapeseed, canola and soy, also peanut, coconut, palm, sunflower seed, jatropha or algae are used as feedstock.

Animal fats, including tallow, lard, yellow grease, chicken fat and by-products of omega-3- fatty acids from fish oil are a potential, not yet widely used, feedstock for the biodiesel production. Especially fats, obtained directly in the slaughterhouse (hot and cold fats) are of special interest, as in freshly slaughtered animal bodies there are absolutely no free fatty acids (FFAs), so the result of ultrasonically assisted transesterification is crystal-clear biodiesel (clear as water). Also the by-product glycerin appears crystal-clear. This makes cold and hot fats from the slaughterhouse an ideal feedstock, that full potential is still not yet fully recovered by industrial biodiesel manufacturers. But as feedstock for the biodiesel production is always in great demand, the recovery of these slaughterhouse fats becomes more and more known.

One example for the successful ultrasonic conversion of slaughterhouse fats is a Californian slaughterhouse that produces by that it covers its own energetic requirements.

Hielscher's powerful UIP1500 ultrasonic processor (1500 watts) with flow cell for biodiesel processing

Regarding the different free fatty acid (FFA) content depending on the type and quality of the feedstock, it is important to have the possibility to adjust the production parameters. Using an ultrasonic inline reactor, it gives the operator the ability to resize the processing parameters, such as the flow rate, the intensity of ultrasonic irradiation (amplitude), pressure, and the temperature.

Hielscher Ultrasonic Processing Equipment

All processes tested in bench-top size can be scaled-up linear. Hielscher's ultrasonic processors are made to deliver high performance. They are reliable, robust, and easy to clean as well as easy to install and to operate. By the wide range of different processors' sizes (500W, 1000W, 1500W, 2000W, 4000W, 10000W, 16000W) and the possibility to install them as clusters, there is virtually no limit that restraint the production capacity.

Considering rising energy prices, the energy efficiency of processing equipment is of high importance. This means, that it is important, that the equipment does not lose much energy in the conversion of electricity into mechanical output. Hielscher ultrasonic processors have and outstanding efficiency of >85%. This reduces your electricity costs and gives you more processing performance. To meet industrial processing requirements takes more than just power. Hielscher industrial ultrasonic devices are built for continuous operation in demanding environments. In worldwide installations, Hielscher ultrasonic systems face outdoor installation, dusty air, sprayed liquids or rough handling.

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