

CAVITATION AS A NOVEL TOOL FOR PROCESS INTENSIFICATION OF BIODIESEL SYNTHESIS

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Various products derived from vegetable oils have been proposed as an alternative fuel for diesel engines. Today “bio-diesel” is the term applied to the esters of simple alkyl fatty acids used as an alternative to petroleum based diesel fuels. Importance of biodiesel in the recent context increases due to increasing petroleum prices; limited fossil fuel reserves and environmental benefits of biodiesel (decrease in acid rain and emission of CO₂, SO_x and unburnt hydrocarbons during the combustion process). Due to these factors, and due to its easy biodegradability, production of biodiesel is considered as an advantage over that of fossil fuels. The conventional techniques for the synthesis of biodiesel refer to a catalysed chemical reaction involving vegetable oil and an alcohol to yield acid alkali esters and glycerol. Usually waste vegetable oils as against virgin vegetable oil have been used for the synthesis with an aim to reduce the cost of production (Zhang *et al.*, 2003). The conventional techniques typically utilize temperatures in the range of 70 to 200°C, pressures in the range of 6 to 10 atm and reaction times of up to 70 hours for achieving conversions in the range of 90 to 95% based on the type of raw material used (usually mixtures of fatty acids obtained as waste). The present work aims at using cavitation as an alternative technique for the synthesis of biodiesel. Cavitation results in conditions of very high local temperatures and pressures at the same time releasing free radicals which intensifies many chemical reactions (Gogate *et al.* 2003).

Esterification of Fatty acid (FA) odour cut (C₈-C₁₀) with methanol in the presence of concentrated H₂SO₄ as a catalyst has been studied in hydrodynamic cavitation reactor as well

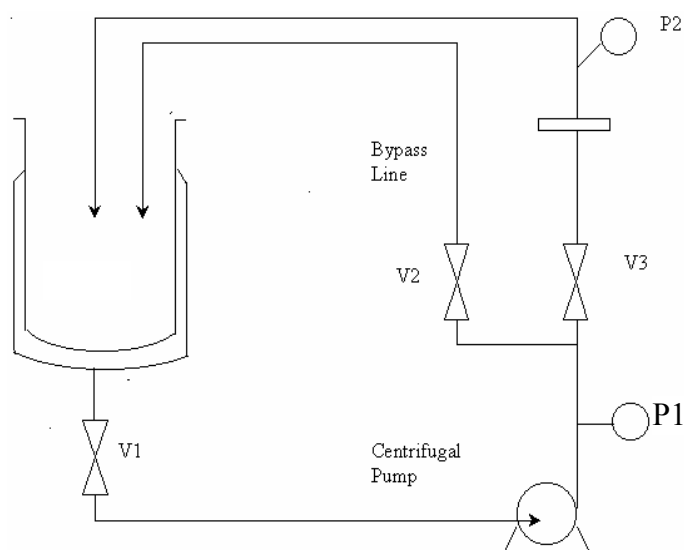


Figure 1: Schematic representation of the experimental setup for hydrodynamic cavitation reactor

as in the sonochemical reactor. The hydrodynamic cavitation reactor consists of a reservoir or a collecting tank with (10 lit) capacity that is connected to the multistage centrifugal pump with power rating of 1.5 kw. A schematic representation of the setup has been shown in the figure 1. The pipe connected to the discharge side of the pump branches into main and bypass lines. The main line has the facility to incorporate different orifice plate to generate cavitation of different intensities and characteristics. The main line and bypass line having the throttling valves and pressure

gauges for the adjusting the pressure. The operating temperature of the reactor was maintained by circulating water within the jacket surrounding the tank as the energy dissipated by the pump can increase the temperature of the mixture. The sonochemical reactor used in the present work is a conventional cleaning tank type reactor equipped with 3 transducers at the bottom of the tank in triangular pitch and operates at an irradiating frequency of 20 kHz and power dissipation of 120kW. Few experiments have also been carried out with other acid/alcohol combination viz. coconut fatty acids with methanol and ethanol and FA odour cut with fatty alcohols with an aim of investigating the efficacy of cavitation for giving the desired yields and also to quantify the degree of process intensification that can be achieved using the same.

The different reaction operating parameters such as molar ratio of acid to alcohol, catalyst quantity have been optimized under acoustic as well as hydrodynamic cavitating conditions in addition to the optimization of the geometry of the orifice plate in the case of hydrodynamic cavitation reactors. It has been observed that ambient operating conditions of temperature and pressure and reaction times of less than 3 hours, for all the different combinations of acid/alcohol studied in the present work, was sufficient for giving more than 90% conversion. This clearly establishes the efficacy of cavitation as an excellent way to achieve process intensification of the bio-diesel synthesis process. To cite a specific illustration as regards to the degree of process intensification achieved in the present work, with an operating ratio of FA cut (waste fatty acids) to methanol as 1:10, 0.1% by weight loading of the catalyst and at operating temperature of 30⁰C, 92% conversion was achieved using hydrodynamic cavitation in only 90 minutes of reaction time whereas conventional method for the esterification of waste cooking oil using methanol required about 69h to obtain more than 90% oil conversion to methyl esters at 65⁰C operating temperature and a molar ratio of methanol to oil as 30:1 (Freedman *et al.*, 1986).

Comparison of energy efficiencies of hydrodynamic cavitation reactors with sonochemical reactors indicated that hydrodynamic cavitation is more energy efficient as compared to acoustic cavitation. Depending on the type of acid/alcohol combination used in the present work the energy efficiency for hydrodynamic cavitation varied in the range of 1×10^{-4} to 2×10^{-4} g/J whereas for acoustic cavitation it was order of magnitude lower i.e. in the range of 5×10^{-6} to 2×10^{-5} g/J. The obtained results are quite similar to those obtained in our earlier works for cell disruption, hydrolysis of fatty acids and degradation of colored dye effluents (Save *et al.* 1997, Pandit & Joshi, 1993 and Sivakumar & Pandit, 2002) clearly establishing the superiority of the hydrodynamic mode for generation of cavities.

The present work has clearly illustrated the efficacy of cavitation as a novel tool for process intensification of synthesis of bio-diesel which has been looked at an affordable alternative to conventional petroleum based fuels.

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