Biodiesel from the Kitchen?!

Investigation of Heterogeneous Solid-Catalysed Transesterification from vegetable oil for biodiesel production in an Oscillatory Baffled Reactor (OBR)

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Background

In commerical biodiesel production, homogeneous alkaline catalyst route is used to convert vegetable oils into biodiesel via transesterification. However, low quality glycerol and side reactions are the downside of it. Thus, a different approach was investigated. Solid catalysts can be used to overcome these problems. One of the promising solid catalysts is commercial solid calium oxide (CaO) according to various studies. It is also environmentally friendly, cheap and simple to prepare.

Oscillatory Baffled Reactor **(OBR)** [Fig.2] is a plain tube reactor with baffles inserted periodically. OBR uses oscillations provided by a pump or piston to produce vortices forming furrows at each inter-baffle zones along the tube. It is a highly efficient plug flow reactor as its mixing intensity can be controlled by changing oscillating conditions.

A number of researches focus on optimising operating conditions in a sitrred tank reactor **(STR)** or fixed bed reactor. In this study, solid CaO catalyst will be used in an OBR to investigate the potential of OBR and heterogeneous solid-catalysed transesterification in order to enhance current biodiesel production.

Objectives

- Investigate effects of varying experimental parameters on OBR
- Compare potenitals of OBR and conventional STR

Methodology

Transesterification of rapeseed oil and methanol was carried out in the STR [Fig.1] at mixing rate of 170 rpm using magnetic stirrer and meso-scale OBR (10 ml volume) at 6:1 molar ratio of oil to methanol, 60°C reaction temperature and 3 weight (wt.) % of CaO catalyst where the weight was based on oil with mixing conditions of 4 mm 8 Hz. Both of the reactors were in batch mode.

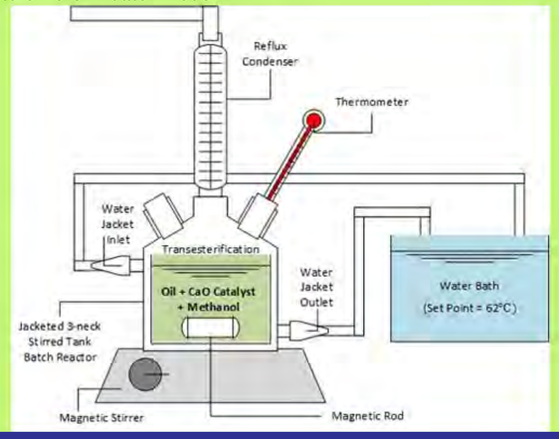

Fig.1: Experimental set up of STR, where water bath provided heat for the reactor and was set to be 62°C to account for heat loss.

Experimental parameters affecting potential of OBR were then investigated (i.e. Mixing conditions and CaO catalyst concentration). The mixing conditions used were 5mm 6Hz and 8mm 4Hz. The catalyst concentrations used were 1, 3 and 5 wt. %. The experimental set up can be seen in Fig.2.

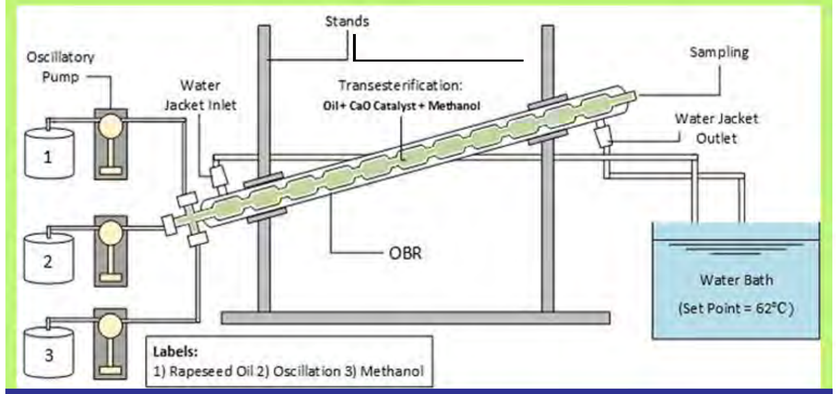

Fig. 2: Experimental set up of OBR, where water bath provided heat same as STR. The CaO catalyst was pre-suspended in methanol for 30 mins.

Samples of the product were collected at certain reaction times to analyse for Fatty Acid Methyl Ester (FAME) or biodiesel yield produced from the tranesterification reaction. The analysis of the FAME yield used was based on internal standard method where a standard biodiesel was used to compare against the samples collected in Gas Chromatography (GC).

Results & Discussion

After 1 hr of reaction, the yield of biodiesel in the OBR is 76% compared to 27% in the STR [See Fig.3]. Thus, it shows that the reaction time to convert vegetable oil into biodiesel is halfed in the OBR due to better mixing. Both reactors can reach approximately 80% FAME yield after 2 hrs of reaction time.

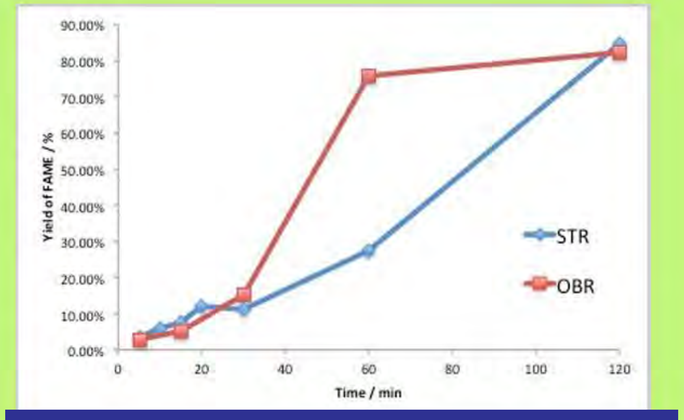

Fig. 3: FAME yield in STR (170 rpm mixing rate) and OBR (8mm 4Hz) at 6:1 molar ratio of oil to methanol and 60°C temperature.

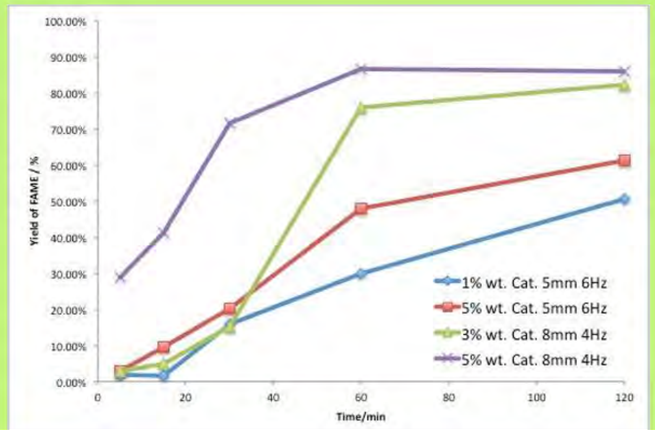

Fig. 4: Effects of mixing and catalyst concentration on FAME yield in the OBR at 6:1 molar ratio of oil to methanol and 60°C temperature

From Fig. 4, increasing either mixing condition or catalyst concentration increases FAME yield. The highest yield was 86% at mixing conditions of 8 mm 4 Hz and 5 wt. % catalyst.

Summary

– Oscillatory flow mixing in the OBR enhances mass transfer rate leading to shorten reaction time compared to STR.
– Higher mixing condition or catalyst concentration increases the yield of biodiesel obtained from OBR.

Research Impacts

- This research has proven that vegetable oil can be effectively converted to biodiesel via OBR using solid catalyst which solve current problems in commercial biodiesel production.
- Production rate of biodiesel will be faster if the OBR technology is applied.
- If the biodiesel consumption increases, use of petro-diesel will decrease leading to lower carbon dioxide (CO_2) emission.

Acknowledgement

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References: Reay D., Ramshaw C. and Harvey A., 2013. Process Intensification: Engineering for Efficiency, Sustainability and Flexibility. 2nd ed. Oxford: Elsevier.