Deliverable report

Deliverable No:	D2.4
Dissemination level:	Confidential (CO)
Title:	Reactor Design for the Hydroformylation Process
Date:	08/10/2020
Version:	FINAL
Author(s):	Thorsten Rösler (MPI), Sebastian Püschel (MPI), Andreas Vorholt (MPI)
Reviewed by:	Manuel Selinsek (Ineratec), Sanna Tuomi (VTT)
Approved by:	Benedikt Heuser (FEV)

Grant Agreement Number:	817612
Project Type:	H2020-LC-SC3-RES-21-2018-development of next generation biofuels and alternative renewable fuel technologies for road transport
Project acronym:	REDIFUEL
Project title:	Robust and Efficient processes and technologies for Drop In renewable FUELs for road transport
Project start date:	01/10/2018
Project website:	www.redifuel.eu
Technical coordination	FEV (DE) (www.fev.com)
Project management	Uniresearch (NL) (http://www.uniresearch.com)

Executive Summary

The hydroformylation step is one of the key steps in the REDIFUEL project. Via hydroformylation, C_5-C_{10} olefins from the Fischer-Tropsch process will be converted into alcohols. The alcohols derived from the hydroformylation step will make up about 30 % of the final fuel blend and improve the emission characteristics during combustion.

In previous reports, a catalytic system was developed for the conversion of olefins into aldehydes (D2.1). Subsequently, a catalyst recycling concept was developed (D2.3). To recycle the homogeneous rhodium catalyst, it is immobilized in a second polar liquid phase (water) which separates from the non-polar substrates and products. To apply this type of liquid/liquid biphasic system, a reactor has several requirements to fulfil. To ensure high reaction rates, it is especially important to bring those two phases in close contact with each other during the reaction. The reaction rate in a biphasic reaction directly correlates to the interfacial area created during the reaction. The biggest asset to ensure a high interfacial area is the reactor. Hence, the design and choice of the reactor has a strong impact on activity and selectivity in the case of liquid/liquid biphasic reaction systems.

In literature, several reactor concepts have been used for biphasic systems. Among them, the Jet-Loop reactor and the Continuously-Stirred-Tank-Reactor (CSTR) have been studied extensively. Because of the high Space-Time-Yield and the low investment costs, the CSTR reactor was chosen as the most feasible candidate in this case. A CSTR reactor was designed which suits the special needs of this reaction. The design of the reactor was held flexible to be able to adjust to changing reaction conditions. Two different reactor vessels can be used with the same reactor cap: a 200 mL window reactor and a 300 mL stainless steel reactor. While the window reactor will be used for experiments in which the visual inspection is important, the 300 mL reactor will be used for high throughput continuous experiments. Special attention was given to the stirrer. The stirrer is the main tool to create high dispersion during the reaction. A stirrer engine, which allows for stirrer speeds up to 2000 rpm, is used. This allows for a very high energy input during the reaction. By 3D printing, several different stirrer geometries are accessible and can be adjusted to perfectly fit the actual needs depending on the liquid phase fraction and the reactor dimensions. Together with the stirrer speed this allows for a perfect control over the interfacial area which will be created during the reaction.

The reactor was installed into a miniplant setup. In the miniplant setup, a second vessel (settler) allows for a continuous separation of the two phases after the reaction. The products will be withdrawn from the upper organic phase while the water/catalyst phase is recycled back into the reactor. The miniplant setup is currently being tested in continuous operation.

Acknowledgement

H2020-LC-SC3-RES-21-2018-DEVELOPMENT OF NEXT GENERATION BIOFUELS AND ALTERNATIVE RENEWABLE FUEL TECHNOLOGIES FOR ROAD TRANSPORT

Acknowledgement:
The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

Project partners:
1 - FEV – FEV EUROPE GMBH - DE
2 - MPI – MAX-PLANCK-GESELLSCHAFT ZUR FORDERUNG DER WISSENSCHAFTENEV - DE
3 - CSIC – AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS - ES
4 - VTT – Teknologian tutkimuskeskus VTT Oy - FI
5 - RWTH – RHEINISCH-WESTFAELISCHE TECHNISCHE HOCHSCHULE AACHEN - DE
6 - OWI – Science for Fuels gGmbH - DE
7 - VUB – VRIJE UNIVERSITEIT BRUSSEL- BE
8 - NESTE – NESTE OYJ – FI
9 – MOL - MOL HUNGARIAN OIL AND GAS PLC - HU
10 – INER - INERATEC GMBH - DE
11 – T4F - TEC4FUELS - DE
12 – UNR - UNIRESEARCH BV – NL

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 817612