H2CAP - Hydrogen assisted catalytic biomass pyrolysis for green fuels

Stummann, Magnus Zingler; Høj, Martin; Gabrielsen, Jostein; Jensen, Peter Arendt; Jensen, Anker Degn

Publication date:
2017

Document Version
Peer reviewed version

Link back to DTU Orbit

Citation (APA):

General rights
Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.
H₂CAP - Hydrogen assisted catalytic biomass pyrolysis for green fuels

Magnus Zingler Stummann¹, Martin Høj¹, Jostein Gabrielsen², Peter Arendt Jensen¹, Anker Degn Jensen¹

¹ DTU Chemical Engineering, Technical University of Denmark, 2800 Kgs. Lyngby (Denmark)
² Haldor Topsøe A/S, 2800 Kgs. Lyngby (Denmark)

1 INTRODUCTION AND PURPOSE

Fast pyrolysis of biomass produces a high yield of bio-oil through well-established technologies [1]. To utilize this oil as liquid fuel the oxygen content must be reduced from 15-30 wt.% down to <1 wt.% which increases heating value and stability and decreases acidity [1]. Upgrading bio-oil by catalytic hydrodeoxygenation (HDO) is challenged by severe polymerization and coking upon heating the oil. Alternatively, performing fast pyrolysis in high-pressure hydrogen atmosphere in a fluid bed reactor with a HDO catalyst as bed medium, could immediately stabilize reactive pyrolysis vapors [2]. An additional vapor phase HDO reactor could ensure removal of oxygen down to <1 wt%, resulting in separate hydrocarbon oil and water phases being recovered. A schematic diagram for such a process is shown in Figure 1. A simplified bench scale setup of this process has been constructed at DTU Chemical Engineering. With a capacity of 100 to 300 g/h solid biomass, the aim is to provide a proof-of-concept for the continuous conversion of solid biomass to low oxygen, fuel-grade bio-oil.

![Diagram of H₂CAP process](image)

Figure 1: Simplified H₂CAP process diagram including fluid bed catalytic hydropyrolysis (20 to 40 bar and 350 to 500°C), char separation, temperature adjustment, vapor phase HDO reactor (20 to 40 bar and 300 to 400°C), cooling, condensation and liquid separation. These parts have been constructed at DTU Chemical Engineering. Additionally, steam reforming and water gas shift (WGS) of non-condensable gasses to H₂ and CO₂ and wind-powered electrolysis of water to H₂ is envisioned.

2 RESULTS

Experiments were performed with 50 g of CoMo/MgAl₂O₄ catalyst in the fluid bed reactor and 173 g of Ni-Mo/Al₂O₃ catalyst in the HDO reactor. The catalysts were sulfided before experiments. Hydropyrolysis of beech wood was performed at 25 bar with gas composition 470 ppm H₂S, 6 % N₂ balance H₂. A photograph of the condensed liquids from Exp. #1 and the yields obtained from Exp. #1 to #4 are shown in Figure 2.

![Photograph of recovered liquids](image)

Figure 2: Photograph of the recovered liquids from Exp. #1, oil is top phase in bottle 1 and bottle 2, only oil in bottle 3. Yields of char, C₁-C₃ hydrocarbons, CO + CO₂, condensed aqueous phase and condensed oil with potentially condensable oil (C₄+) in gas phase on dry, ash free basis for Exp. #1 to #4. The mass balance sum to 100, 98, 100 and 101 % respectively.

These very first results show that the process performs excellently as intended. The products are phase separated aqueous and hydrocarbon fractions. The low viscosity, free-flowing oil with <1 wt.% oxygen is very different from conventional wood pyrolysis oil. The best oil yield obtained is 22.2 wt.% of the wood, corresponding to approximately 39 % carbon atom yield and an energy yield of approximately 53 %. The liquid yield may be further improved by choice of catalysts and reaction conditions, which is the focus of ongoing work.

3 INNOVATION AND RELEVANCE

This study confirms that catalytic hydropyrolysis with hydrodeoxygenation is an attractive route for biomass to liquid fuels. The reaction conditions employed are significantly milder than gasification, potentially resulting in lower capital and operating costs, and the energy yield is significantly better than 2nd generation bio-ethanol.

References