Transportation fuels from biomass fast pyrolysis, catalytic hydrodeoxygenation, and catalytic fast hydropyrolysis - DTU Orbit (11/02/2019)

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This review presents and discusses the progress in combining fast pyrolysis and catalytic hydrodeoxygenation (HDO) to produce liquid fuel from solid, lignocellulosic biomass. Fast pyrolysis of biomass is a well-developed technology for bio-oil production at mass yields up to ~75%, but a high oxygen content of 35–50 wt% strongly limits its potential as transportation fuel. Catalytic HDO can be used to upgrade fast pyrolysis bio-oil, as oxygenates react with hydrogen to produce a stable hydrocarbon fuel and water, which is removed by separation. Research on HDO has been carried out for more than 30 years with increasing intensity over the past decades. Several catalytic systems have been tested, and we conclude that single stage HDO of condensed bio-oil is unsuited for commercial scale bio-oil upgrading, as the coking and polymerization, which occurs upon re-heating of the bio-oil, rapidly deactivates the catalyst and plugs the reactor. Dual or multiple stage HDO has shown more promising results, as the most reactive oxygenates can be stabilized at low temperature prior to deep HDO for full deoxygenation. Catalytic fast hydropyrolysis, which combines fast pyrolysis with catalytic HDO in a single reactor, eliminates the need for reheating condensed bio-oil, lowers side reactions, and produces a stable oil with oxygen content, H/C ratio, and heating value comparable to fossil fuels. We address several challenges, which must be overcome for continuous catalytic fast hydropyrolysis to become commercially viable, with the most urgent issues being: (i) optimization of operating conditions (temperature, H2 pressure, and residence time) and catalyst formulation to maximize oil yield and minimize cracking, coke formation, and catalyst deactivation, (ii) development of an improved process design and reactor configuration to allow for continuous operation including pressurized biomass feeding, fast entrainment and collection of char, which is catalytically active for side reactions, efficient condensation of the produced oil, and utilization and/or integration of by-products (non-condensable gasses and char), and (iii) long-term tests with respect to catalyst stability and possible pathways for regeneration. By reviewing past and current research from fast pyrolysis and catalytic HDO, we target a discussion of the combined processes, including direct catalytic fast hydropyrolysis. By critically evaluating their potential and challenges, we finally conclude, which future steps are necessary for these processes to become industrially feasible.

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