Hydrogen production through biomass gasification: A kinetic modelling and process intensification study

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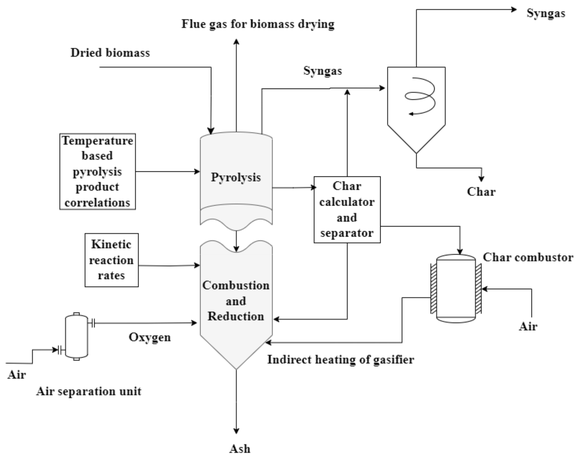
Objectives

- Design of a reference kinetic model in Aspen Plus for hydrogen production through biomass gasification using Pressure Swing Adsorption (PSA) and multistage mechanical compressor for purification and compression [1].
- Demonstrate simulation approach to kinetic modelling of gasifier[2].
- Evaluate process intensification using Electrochemical Hydrogen Pumping (EHP) module for purification and compression in two different design configurations.
- Demonstrate energy flow and improvements in key parameters of the reference model and the process intensification models.

Process Simulation

Feedstock selection with known proximate and ultimate analysis → Design basis for 25 MWe power generation → Empirical correlation for tar formation in pyrolysis[2] → Reaction kinetics[4 5 6] for gasifier, reforming and shift reactions → Sizing to achieve target composition → Syngas cleaning and hydrogen purification using PSA or EHP. → Purified hydrogen

Simulation of Gasifier



Equipment Sizing and Operation Parameter

Block	Length (m)	Multi-tubular	Diameter/Tube diameter if multi-tubular (m)	Number of tubes	Temperature (°C)	Pressure (atm)
Gasifier	8	NO	0.5	-	800	
SMR	4	YES	0.01	100	830	32.2
HTS	5	YES	0.01	1000	350	29.9
LTS	5	YES	0.01	300	200	27.5
Gasifier cold gas efficiency (%)					83	

Method and Assumptions

- Ultimate analysis[7] for wood is used as biomass feedstock.
- Enthalpy reported by Aspen Plus is corrected using method described in[1].
- Air separation unit is not a part of this simulation, electricity requirement for oxygen generation is taken from[3].
- Mechanical compression of hydrogen to 800 bar is done through a five stage compressor with polytropic efficiency of 78%.
- Electricity requirement of EHP is calculated using Nernst equation and efficiency of 80%.

Process Flow Diagrams and Energy Flow Analysis

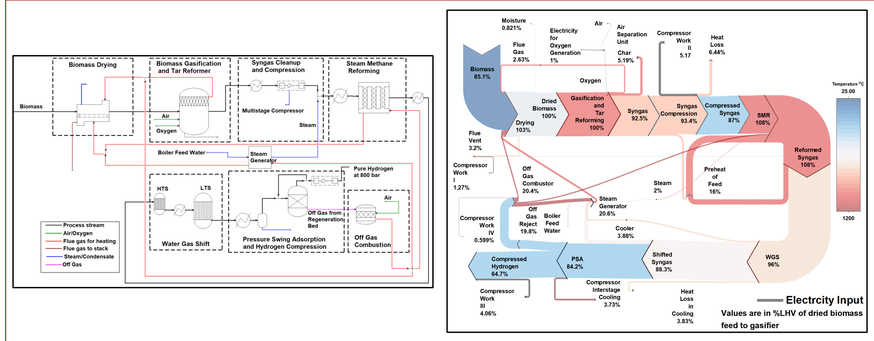


Figure 1: Simulation case for the reference method of hydrogen production through biomass gasification using PSA

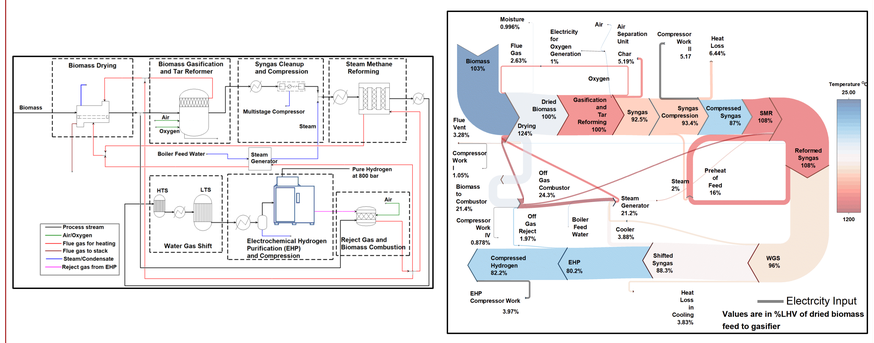


Figure 2: Simulation case for the hydrogen production through biomass gasification using EHP

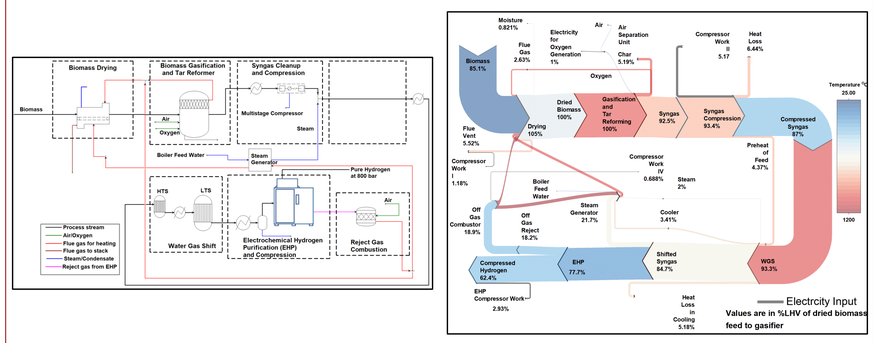
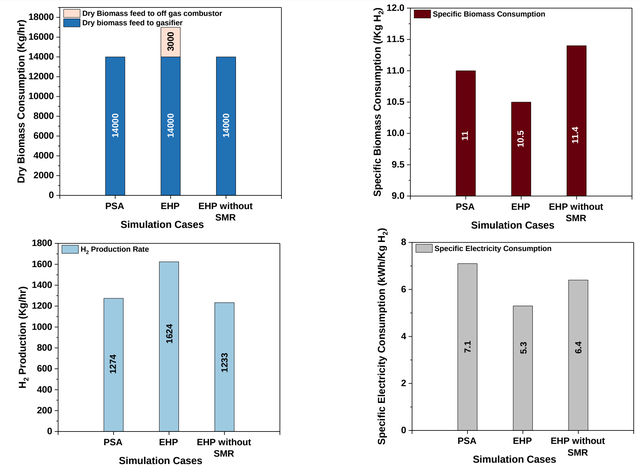


Figure 3: Simulation case for the hydrogen production through biomass gasification using EHP without SMR

Results



Future Work

- Integrate a detailed model for air separation and hydrogen purification based on adsorption.
- Improve gasification kinetic model based on operating data of existing biomass gasifiers.
- Implement EHP model in Aspen Plus with the experimental data.
- Disseminate a comprehensive techno-economic analysis for the proposed configurations.

Acknowledgement

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Key References

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