Numerical simulation of the biomass gasification in an industrial-scale entrained flow reactor for Hydrogen-rich syngas generation

Introduction

To combat global warming the use of alternate energy sources has become inevitable. Among the alternate energy sources, biomass-derived energy has a promising future due to its carbon neutrality, abundance, effective conversion technologies, production, storage, transport and marketing flexibility etc. compared to the other renewables (Ansari et al., 2021; Uzoejinwa et al., 2018; Wang et al., 2021). It has the potential to make up to 60 per cent of global renewable energy usage, while the global biomass energy demand is projected to be 108 EJ by 2030 (*Nakada: Global Bioenergy Supply and Demand Projections:... - Google Scholar*, n.d.). Biomass gasification, which is the partial oxidation of the feedstock in the presence of oxygen less than the stoichiometric ratio at a temperature of more than 600 ^{0}C, yields producer gas along with liquid oil and solid char. Although entrained flow gasification is dominant (> 70 per cent of gasifiers) and established technology for large-scale coal gasification, the entrained flow gasification of biomass is understudied. The present study explores the scope of using biomass as gasification feedstock for syngas (CO+H_2) generation at an industrial-scale gasifier.

Method and validation

A 3-D model of an industrial-scale coal gasifier is utilised for the modelling. The geometry and mesh (0.42 M Tet mesh) are presented in Figure 1. The details of the modelling are presented in Table 1.

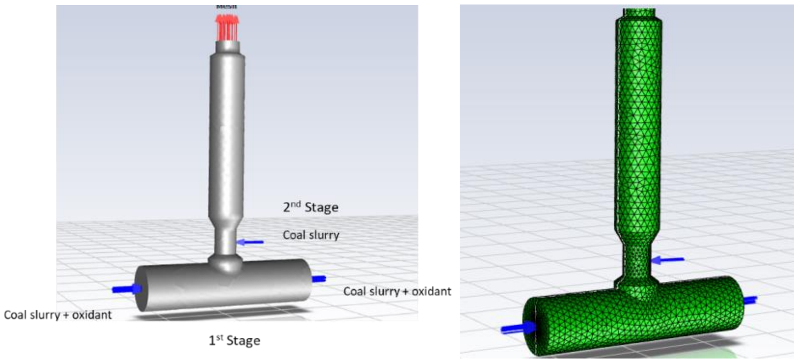

Figure 1 Geometry and mesh

Table 1 Model details

Software	Ansys Fluent 2020 R2
Computational method	Control volume formulation for the fluid phase Discrete element method for the fuel particle phase
Turbulence model	K-ϵ standard
Combustion modelling	Species transport, finite rate/eddy dissipation model
Pressure-velocity coupling	SIMPLE

A finite rate/eddy dissipation species transport model is deployed for the corresponding reaction modelling, as presented in Table 2.

Table 2 Reaction kinetics

Reactants	Products	A	E_a (J/kmol)
Vol + O_2	CO_2 + H_2O + N_2	2.119e+11	2.027e+08
CO + O_2	CO_2	2.2e+12	1.67e+08
H_2 + O_2	H_2O	9.87e+08	2.7e+08

$CO + H_2O$	$CO_2 + H_2$	275	8.38e+07
$C + O_2$	CO	0.052	6.1e+07
$C + CO_2$	CO	0.0732	1.125e+08
$C + H_2O$	$CO + H_2$	0.0782	1.15e+08

The producer gas yield is validated against the experimental data ((PDF) CAPE-OPEN Integration for Advanced Process Engineering Co-Simulation, n.d.) for coal gasification (Figure 2). The composition of the gases should be used for indicative purposes.

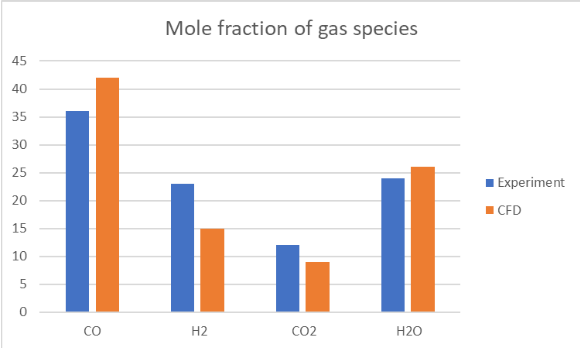

Figure 2 Validation of CFD with experiment: coal gasification

The similar method is deployed to estimate biomass gasification yield. The used biomass is Eucalyptus wood particles of 300 microns size. The biomass feed rate of 10 kg/s, ER 0.4 and steam to fuel mass ratio of 0.5 are deployed for the simulation.

Table 3 Yield composition for biomass gasification

Species	Oxidant gasification Mol fraction (dry N_2 free) %	Oxy-stream gasification Mol fraction (dry N_2 free) %
CO	18.5	14.3
H_2	10.33	15.4
CO_2	33.5	36

Preliminary results and conclusion

The preliminary results indicate generation of syngas (CO 18.5 mol%, H_2 10.33 mol%) with a 432 ton/day biomass feeding capability in the reactor (Table 3). The oxy-stream gasification with stream to fuel mass ratio of 0.5 yields syngas composition of CO 14.3 mol% and H_2 15.4 mol%. The stream to fuel ratio, fuel feed rate, particle size etc. can be varied to optimize the syngas yield. Also, considering the emphasis on hydrogen as a future fuel, oxy-stream gasification can be a desirable option to generate hydrogen-rich fuel from biomass.

References

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