Chapter 7

Conclusions and scope for future work

7.1. Conclusions

Energy is one of the most important inputs for the development and economic growth, but a large proportion of the population living in developing countries like India does not have access to modern forms of energy. A reliable, affordable and clean energy supply is of major importance for remote and rural area. Off-grid electrification can provide a more reliable supply and has a great potential to supply power to remote and rural areas. In this context, use of lignite as a fuel (as opposed to traditional use of biomass fuel) in downdraft gasifier coupled with engine-generator is considered a very promising clean energy option for remote electrification. Towards this concept, the present study was aimed at investigating the potential of lignite as a fuel for downdraft gasifier and to evaluate the effect of the particle size on gasifier performance. The study also involved co-gasification of lignite and wood waste and development of stoichiometric equilibrium model for co-gasification process.
The following conclusions are drawn from lignite gasification study:

1. It is feasible to gasify lignite in downdraft gasifier despite the fact that lignite contains high ash and moderate moisture.
2. The operation of downdraft gasifier is sensitive to particle size and performance of gasifier is greatly influenced by particle size.
3. Clinker formation is common phenomena as lignite contains high ash. Various sized clinkers were formed during gasification of selected particle size. However, larger clinkers were found with smaller sizes of lignite whereas smaller clinkers were produced during gasification of medium and larger lignite sizes. Larger size of clinker caused flow problem in throat section and subsequently choked the throat which resulted in to an unstable gasifier operation.
4. The 22-25 mm particle size was found most favorable with respect to producer gas properties. The producer gas obtained for 22-25 mm particle size had a more stable composition of 10.27% [H\(_2\)], 18.28% [CO], 12.12% [CO\(_2\)] and 1.71% [CH\(_4\)] with LHV (Lower heating value) of 4.17 MJ/Nm\(^3\) and a gasifier efficiency of 65.78%.

The following conclusions are drawn from co-gasification study of lignite and wood waste:

1. The addition of wood to lignite played a great role in reducing clinker formation. The formation of clinkers were reduced as the percentage of wood waste increased and almost vanished when wood percentage reached to 30%.
2. The temperature of oxidation and reduction zone increased with increase in wood ratio. With increasing wood waste percentage, the H\(_2\) and CO\(_2\) compositions increased while CH\(_4\) composition was not affected.
3. Higher heating value of producer gas increased to 4.75 MJ/Nm\(^3\) from 4.45 MJ/Nm\(^3\) and cold gas efficiency increased to 71.65% from 65.78% as the wood content varied from 0 to 30%.

A stoichiometric equilibrium model is developed for simulating a gasification process of the fuel mixture of lignite and wood waste. The combination of the equations of mass balance, energy balance and equilibrium constant provides an algorithm that is used to estimate the gas compositions. Furthermore, gas heating value and cold gas efficiency is also predicted and compared with experimental results. Through this model, an attempt is made to study the effect of various gasification parameters such as equivalence ratio, moisture content and different
wood-lignite ratio on gas composition. Performance of the co-gasification process of lignite and wood waste is also studied by producer gas heating value and cold gas efficiency.

The following conclusions are drawn from the stoichiometric equilibrium model study:

1. The $\text{H}_2$, $\text{CO}_2$ and $\text{CH}_4$ content decreases with increased amount of air supply for all wood-lignite ratio.
2. The CO content and temperature increases with equivalence ratio for all wood-lignite ratio.
3. The cold gas efficiency increases initially with increase in equivalence ratio and then decreases. The optimum value of cold gas efficiency is obtained at ER = 0.4 for all wood-lignite ratio.
4. The temperature increases as the equivalence ratio increases, however, gas calorific value reduces with increase in temperature.

### 7.2. Scope for future work

Several aspects in the present work still require attention and they are worth mentioning in this section so as to encourage future research:

- The present study involved the effect of particle size of lignite on performance of downdraft gasifier. As a future work, the performance of the producer gas engine coupled with present gasification system could be studies. It would be also of interest to analyze the exhaust gas of producer gas engine. In addition, it would be interesting to carry out wear analysis of various components of producer gas engine.
- One of the main parameters in gasification process is the carbon conversion efficiency. The carbon conversion efficiency may be calculated by measuring all gas constituents containing carbon. In the present study only CO, CO$_2$ and CH$_4$ was measured. The producer gas also contains a small amount of higher order hydrocarbons that would be desirable to measure. It would also be of interest to measure tar, dust, SPM (suspended particulate matter) and water content in the producer gas.
- A catalyst may be used to improve the reactivity of fuel. Effect of various catalyst on gasification process and product gas could be studied as a future work.