

Chapter 7: Conclusions and recommendations

7.1. Conclusions

A general characterisation of the coal used for this study was conducted. A suitable impregnation method was selected to impregnate large coal particles and the influence of impregnation in terms of catalyst loading and catalyst distribution was studied. The influence of catalyst addition on steam gasification reactivity was investigated by conducting steam reactivity experiments in a large particle TGA. The results for the above-mentioned analyses and experiments were presented and discussed in the preceding sections. The following conclusions can be drawn from the results obtained during this investigation

7.1.1. Coal characterisation

Based on the results obtained from the proximate analysis, it can be concluded that the washed coal used for this study has a relatively low ash content (12.6 wt.%, air-dried basis) when compared to other South African ROM coals. XRF analysis indicated that the mineral matter in the coal largely consists of Si_2O_3 and Al_2O_3 , with a low K_2O content of 0.53 wt.%, which is typical for South African coals. The coal was characterised as a grade B coal, according to the gross calorific value of 26.6 MJ/kg (air-dried basis).

7.1.2. Impregnation

The pH of the impregnation solution decreased and stabilised after 21 days, and no significant trend was observed with regards to particle size. The size and structure of the 20 mm and 30 mm particles were altered during impregnation, and these particle sizes were not used for reactivity experiments. The maximum catalyst loadings obtainable for the large particles, with the excess solution impregnation method, were found to be between 0.68 wt.% and 0.83 wt.%, which is relatively low. XRF and ISE were used to determine the catalyst loading, and it was concluded that both of these methods showed an increase in catalyst loading with a decrease in particle size. The difference in catalyst loading results for these two methods can be attributed to the occurrence of experimental errors during the preparation of the diluted samples. Therefore, it was concluded that XRF is more accurate in analysing the catalyst loading. SEM images illustrated that the impregnation of large coal particles results in the formation of cracks, which may assist in the distribution of catalyst throughout the particles. From the EDS analysis it was concluded that the majority of the

catalyst is concentrated around the outer surface of the particle, and this observation is consistent with literature. Volume analysis conducted with tomography scans indicated that the mineral vol.% increased with a decrease in particle size, and these observations are similar to what was found for catalyst loading.

7.1.3. Steam reactivity experiments

From the reactivity results obtained for the raw and catalysed particles, it is concluded that the addition of K_2CO_3 increased the steam gasification rate. The reaction rate was found to be temperature sensitive, and independent of particle size. These observations conclude that gasification experiments were performed in the chemical reaction control regime. Evaluation of the reactivities, k (h^{-1}), indicated that an increase in temperature resulted in increased reactivities. It was found that the addition of K_2CO_3 only slightly reduces the activation energy, and the values were in accordance with published results. The catalytic effect on the char surface was investigated with a light microscope and SEM. It was observed that the addition of the catalyst appeared to reduce the agglomeration effect of char. It remains unclear whether the enhancement of reaction rate is entirely attributed to a catalytic effect, or whether transformation of the char structure due to catalyst addition also has an effect.

7.2. Recommendations

The following recommendations are proposed based on the results and findings obtained from this investigation, in order to assist future studies in the field of large particle catalytic steam gasification:

- Optimisation of the impregnation method should be studied, in order to effectively impregnate particles larger than 10 mm. It could be beneficial to have reactivity results for larger particles impregnated with a specific catalyst, in order to compare it with the results obtained for the 5 mm and 10 mm particles.
- Physical mixing should be investigated as a possible catalyst addition method to be used for larger coal particles.
- The influence of catalyst solution concentration on the catalyst loading should be studied, in order to determine if the catalyst loading obtained for large coal particles is significantly influenced by the concentration of the impregnation solution.

- The influence of the excess solution impregnation method on the coal pore structure should be investigated, using gas adsorption analyses and mercury porosimetry.
- In order to reduce the influence of varying devolatilisation temperatures on char formation, all coal samples should be charred uniformly before gasification commences.
- Future studies should focus on the char morphology to determine the catalytic effect on char composition. This will give insight into the exact role of the catalyst, and whether or not the catalyst results in the formation of other catalytically active compounds.
- A suitable modelling tool should be used to study and predict the inorganic behaviour and changes in mineral matter composition due to catalyst addition. The results may validate that the catalytic influence on the chemical composition and ash fusion temperature (AFT) can reduce the slagging tendency of the ash.
- Advanced characterisation, such as Fourier transform infrared spectroscopy (FTIR), solid-state nuclear magnetic resonance (SS-NMR), free swelling index (FSI) etc., should be conducted on the raw and catalysed coal to quantify the structural changes as a result of catalyst addition. This will give insight into the reduction of agglomeration and swelling due to the addition of a catalyst, and can assist in eliminating swelling and agglomeration on an industrial scale.