Chapter 6

Conclusions

An Aspen Plus model of the GTL process was created and heat and power integration was done on the model. High quality natural gas (95% methane) was used as feedstock. Autothermal reforming (ATR) was considered the best option for reforming and the Slurry Bed Reactor (SBR) for the Fischer–Tropsch synthesis. It was seen from a total GTL reaction stoichiometry that the process is a net exporter of energy (with near adiabatic operation of the ATR for a specific Schulz–Flory alpha value of 0.95). Maximum carbon efficiency could also be obtained without separating CO_2 directly after the reformer, but rather recycling the tailgas externally from the work–up to the reformer. This tailgas consists mostly of CO_2.

The heat integration was focused on recovering heat from the Fischer-Tropsch reactor, from the reformer and from the purge stream (necessitated by the external recycle - see figure 5.6). Maximum carbon ATR feed preheating was done within a heat exchanger between the carbon feed and the ATR product stream. It was assumed that no sooting would occur and that such a heat exchanger was possible for estimating optimum heat recovery from the ATR (thus idealistic). Steam used as feed to the ATR was generated with excess ATR product heat and saturated steam was generated with SBR reaction heat. Any surplus steam generated was used in a steam turbine to generate electricity to be used in the GTL process. The work–up tailgas that was not recycled to the ATR, was combusted in a combined cycle process to generate electricity for use in the process. The amount of steam generated and thus electricity generated depends on the ATR temperature.

The effect of different ATR temperatures were investigated with the following constraints:

- The H_2:CO syngas ratio (product of ATR) was kept constant at 2.15 to maintain a Schulz–Flory alpha value of 0.95 in the SBR.

- The maximum amount of work–up tailgas was externally recycled to the reformer while maintaining the H_2:CO syngas ratio at 2.15.
- Minimum steam and oxygen feeds were used in the ATR to maintain the H_2:CO ratio of 2.15 and the specified ATR temperature.

It was shown in this work that lower ATR temperatures compared to typical commercial ATR temperatures can increase the carbon efficiency of an integrated GTL process without significantly increasing the methane slip (taking the assumptions into consideration). The reason for this being that more tailgas recycling is possible at lower temperatures, i.e. more CO_2 can be processed in the reformer while maintaining the desired H_2:CO ratio in the reformer product. While the lower ATR temperature results in an increase in methane slip, the CO_2 recycle helps to reduce the methane slip up to a point where the H_2:CO syngas ratio cannot be maintained. The lower ATR temperature also implicates that lower O_2/C and H_2O/C feed ratios to the ATR are required.

Target exergy analysis was used as an optimization tool for finding the optimum ATR temperature of 975°C. This optimum ATR temperature considers the trade–off between methane slip, carbon efficiency and energy utilization. At the optimum ATR temperature of 975°C the methane slip is 2.7% (still within an acceptable range), the improvement in carbon efficiency is 7% compared to the carbon efficiency at 1100°C and the total exergy loss is 26% lower than the total exergy loss at 1100°C. At the optimum temperature the energy is utilized in such a manner that the maximum exergy is stored in the final product (i.e. liquid hydrocarbons) and not in utilities (i.e. electricity) produced by the process.

The integrated GTL layout in this study was just the first iteration in a process of finding the optimum integrated GTL layout. The exergy analysis showed that the largest contributors to internal exergy loss are the feed/product preparation sections and the ATR reaction section. Further improvements in a follow–up study of these sections could result in further optimization. The exergy analysis will also assist a cost benefit analysis in a follow–up study to motivate the integration investment costs.

Chapter 7

Recommendations

The recommendations that result from this study:

- Incorporate selectivity into Fischer–Tropsch reactor model to implement trade–off between between a decrease in selectivity and an increase in reaction rate for a higher H_2:CO ratio in the syngas.
- Improve feed/product preparation process sections and also the ATR reaction section to decrease internal exergy losses.
- Use pinch analysis together with exergy analysis to optimise use of heat in GTL process.
- Do a cost analysis for trade–off between profits gained in energy savings and product yield vs. investment costs for start–up equipment.
- Design procedures for process synthesis, exergy and pinch analysis integration.
- Compare the results of the exergy analysis to the results of a cost analysis.