# CHAPTER IV
# CONCLUSION AND RECCOMENDATION

## 5.1 Conclusion

The processes are improved by Pinch-Exergy methodology namely shaft work targeting and ExPAnD method. These methodologies are very useful for design in early stage. For shaft work targeting, reducing the area between hot and cold lead to reduce work loss due to heat transfer. From ECCs of base case, we can see the room for improvement by manipulating cold stream to reduce area result in shaft work saving of 248.60 kW. Saving of shaft work is increased by changing process stream then shifting cold stream to reduce shaded area in ECCs causes 11.2 % savings from base case. ExPAnD method used along with exergy diagram shows the potential for minimizing energy consumption by reducing irreversibility or exergy destruction. This methodology achieves by using several heuristics to reduce energy consumption and generate power as same as Aspelund et al., 2007; moreover, CCs is transformed to exergy diagram for exergy destruction. The results between base case and improved case (1C case) are shown in Table 5.1 where cooling water duty and exergy destruction decrease. Furthermore exergy efficiency is increased from 97.95 % to 98.4 % and shaft work savings is about 22.57 %.

The exergetic efficiency of compressor and expander are calculated by

$$\eta_{compressor} = \frac{Ex_{in}-Ex_{out}}{H_{in}-H_{out}} \tag{5.1}$$

$$\eta_{expander} = \frac{H_{in}-H_{out}}{Ex_{in}-Ex_{out}} \tag{5.2}$$

The results are shown in Table 5.2 which are the method 1 as improved case by shaft work targeting technique and method 2 as improved case by the ExPAnD method with novel exergy diagram. The improved case by method 2 provide the highest average exergetic efficiency of compressor so it means improvement by using ExPAnD method along with exergy diagram helps to improve the process more efficient and also reducing irreversibility in compressor.

**Table 5.1** The results between base case and improved case (1C case)

| | Base case | Improved case (1C) |
|---|---|---|
| **Cooling water duty (kW)** | 232,600 | 200,300 |
| **Required power (kW)** | 144,089.53 | 118,456.83 |
| **Generated power (kW)** | - | 6,895.24 |
| **Net process power (kW)** | 144,089.53 | 111,561.59 |
| **Exergy efficiency (%)** | 97.95 | 98.4 |
| **Exergy destruction (kW)** | 33,872.57 | 23,000 |

**Table 5.2** The exergetic efficiency of compressor and expander in each method

| No. | $\eta_{compressor}$ (Base case, %) | $\eta_{compressor}$ (Method 1, %) | $\eta_{compressor}$ (Method 2, %) | $\eta_{expander}$ (Method 2, %) |
|---|---|---|---|---|
| **1** | 75.14 | 75.83 | 76.04 | 73.32 |
| **2** | 73.32 | 73.59 | 73.93 | 67.81 |
| **3** | 71.34 | 70.72 | 59.2 | 80 |
| **4** | 73.02 | 73.02 | 73.86 | 68.18 |
| **5** | 69.27 | 68.94 | 71.37 | 60 |
| **6** | 61.5 | 65.42 | 64.9 | 95.15 |
| **7** | 65.38 | 64.12 | 65.34 | 60 |
| **8** | 45.81 | 58.39 | 58.12 | 31.43 |
| **9** | 52.43 | 51.23 | 71 | 53.99 |
| **10** | - | - | - | 88.55 |

For improvement by Mathematical Programming, a model based on the stage wise superstructure, as proposed by Yee and Grossmann (1990) is proposed. This model includes outlet temperature of compressor ($TH_{i,IN}$) as variable in order to reduce the temperature difference lead to reduce shaft work requirement, resulting in power consumption and energy consumption reduction. The use of Mathematical Programming provides the optimal solution. When the result from GAMS is validated by PROII, resulting in shaft work saving and cooling duty saving are about 30 % and 52 %. In case of HEN retrofit, the goal of retrofit case is to maximize the heat integration among process streams or reduce utilities usage by maximize the

NPV. The retrofitted HEN consists of 20 existing exchanger and 15 new exchangers added to the network. As a result of increased utilities usage, the usages of cold utilities and power consumption are decreased to 85 kW and 117,531 kW respectively. When the result from GAMS is validated by PROII, resulting in shaft work saving and cooling duty saving are about 10.62 % and 1.16 %.

### 5.2 Recommendation

For future work, the proposed methodology should be tested and applied for other subambient systems, for instance, Ethylene plant. It is recommended to estimate the capital expenditures (CAPEX) perform a detail of economic in order to fully evaluation and include a design of multistream exchanger.