CHAPTER VI

SCOPE, CASE STUDY, AND PROCEDURE

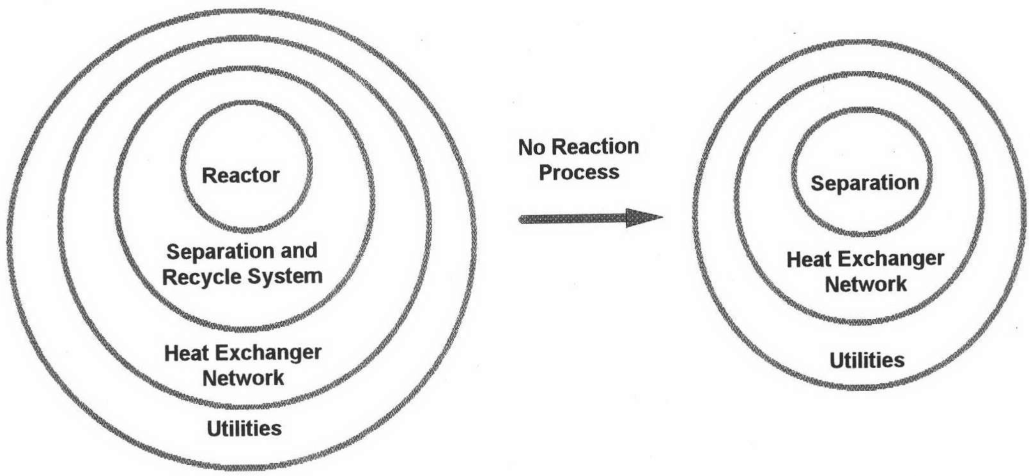
Scope and Case Study

Scope of this work is the debottlenecking of the topping unit of plant No.2 (40 KBD) in Bangchak Petroleum Company (BCP) to handle the higher capacity (50, 60 KBD) by using a simulator -- PRO/II. At each capacity, crude feed varies from light crude to heavy crude to handle refining of any crude feed. Three crude feeds (or cases) include

1. Case A: a heavy crude--Arabian light 100%vol-- has the maximum heavy products of the three cases.
2. Case B: a light mixing crude--Tapis and Qatar (30:70 %vol)-- has the maximum light products of the three cases.
3. Case C: a middle mixing crude--Tapis and Oman (62:38 %vol)-- has the maximum middle products of the three cases.

The Hierarchy of Chemical Process Design

The debottlenecking hierarchy is similar to the process design hierarchy. First, the process design starts at the reactor where raw materials are converted into products and byproducts. Unreacted feed materials are usually recycled, while products and byproducts must be separated. Thus design of the separation and recycle system follows reactor design. The reactor and separation and recycle system designs together define the process heating and cooling duties. Thus heat exchanger network design comes third. These heating and cooling duties which can not be satisfied by heat recovery dictate the need for external utilities (steam, cooling water, etc.). Thus utility selection and design come fourth. This hierarchy can be represented symbolically by the “onion diagram” shown in Figure 6.1a [19]. The diagram emphasizes the sequential, or hierarchical, nature of process design. Some refinery processes (e.g. topping unit) do not have a reactor; thus, the design starts with the separation system and moves outward to the heat exchanger network and utilities (shown in Figure 6.1b).



(a) For general process design

(b) For no reaction process
(e.g., the topping unit in refinery process)

Figure 6.1 The "onion model" of the process design [19]

Simulation Procedure

In a chemical process, the transformation of raw materials into desired products usually consists of many unit operations; for example, reaction, separation, mixing, cooling and heating. These units are combined into a complete process. To model a complete (or a part of) process, a simulator is used to generate the model or flowsheet, which is a diagrammatic representation of its unit interconnections [19], called the modeling. The model will predict the products corresponding to the actual operating data for the same feeds and operating conditions, shown in Figure 6.2a. Once the model or base model has been defined, it can be used to evaluate its performances [19,30]. For instance, it predicts how a process would behave if feed flowrate is varied to higher than the existing design, shown in Figure 6.2b. This is the process simulation (detail in chapter 2).

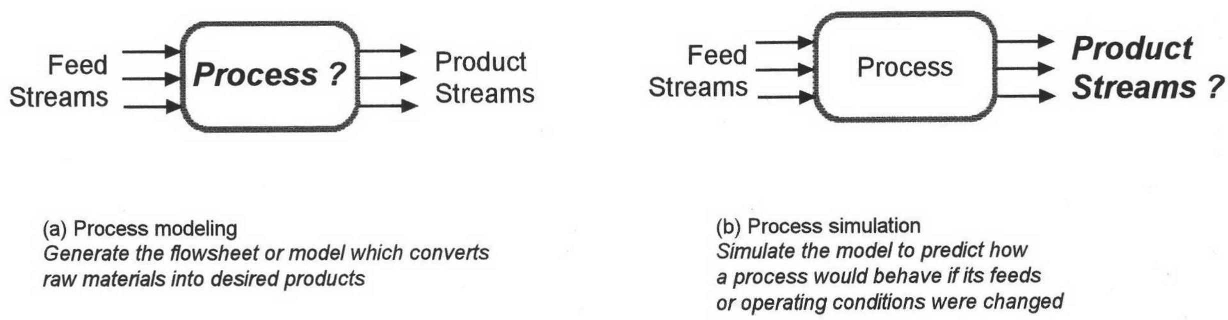


Figure 6.2 Modeling and Simulation[19]

For this work, the existing topping unit is first modeled as the base model, and then this model is used to debottleneck for a higher capacity. Debottlenecking procedure consists of five steps as follows:

1. Find the base model of the topping unit.
2. Verify the base model by actual operating data.
3. Identify the bottlenecks at higher capacities (50 and 60 KBD)
4. Debottleneck by modifications of the existing unit.
5. Evaluate these debottlenecking in economic terms.

Find the Base Model of the Topping Unit

Use the simulator to find the base model of the topping unit which based on the design-case data. Two design cases of this unit include

1. Case A: Arabian light crude (100%vol.) at 40 KBD
2. Case B: Qatar and Tapis mixing crude (70:30%vol.) at 40 KBD

Because topping unit consists of many units, the process design hierarchy must be applied to start modeling at the separation system and move outward to the heat exchanger network and utilities (as shown in Figure 6.1b).

The separation of topping unit consists of three distillation columns: (1) HP fractionator, (2) ATM fractionator, and (3) Debutanizer. To model these distillation columns, theoretical trays -- which can match predicted results with design data -- must be identified first. Tray efficiencies usually range 50 to 60 percentage [31]. In Table 6.1, the typical overall tray efficiency is shown in each section of a distillation column.

Table 6.1 Typical overall tray efficiencies of refinery columns[3].

Crude Units	
• Stripping section	30
• Flash zone to gas oil	30 - 40
• Gas oil draw to diesel draw	40 - 50
• Diesel draw to kerosene draw	55 - 55
• Top section of column	55 - 65
Main Fractionators	
• Quench zone	20
• Middle of column	30 - 45
• Top section of column	45 - 55

With this factor, the model can predict the products (flowrate and their properties--ASTM, flash point, etc.) after feeds are supplied. In modeling, the product specifications are termed the problem equations which have the process variables such as temperature, pressure, duty and flowrate of feed, product, sidedraw and pumparound [3,19]. Therefore, the number of equations must equal the number of variables to yield a unique solution [3]. If the modeling results--product specification and operating condition--correspond with the design-case data(%difference ranges ± 5%)[10], this model is the base model of the column distillation. HP fractionator must be modeled first because its products are the feeds of Debutanizer and ATM fractionator. And then, Debutanizer or ATM fractionator are modeled. Three models combine for the complete separation of the topping unit. After the separation model has been defined, all hot and cold streams are known. They are used to model the HEN and utilities (furnace and cooler). Combine the column models with the HEN and utility model to the complete base model of topping unit. Next step, this model will be verified with the actual operating data.

Verify the Base Model by Actual Operating Data

Verification of the base model has two steps. First, the actual operating data must be tested for its validity. Simple testing method is the error of material balance between feeds and products which ranges ± 1 wt%error, shown in Equation 6.1 [30].

$$\text{Material balance error} = \frac{(\text{weight of feed - weight of products}) \times 100}{\text{weight of feed}} \qquad (6.1)$$

Actual collected data are usually higher than ± 1wt%error. However, it can be slightly adjusted to valid this criteria. Second, some parameters must be adjusted to correspond the predicted data of the base model with the actual data. These parameters include tray efficiency, duty, and flowrate of pumparound and product [31]. After the base case model can match the predicted data with the actual data, it can be used to identify bottlenecks at higher capacity.

Identify the Bottlenecks at Higher Capacities

When the feed rate increases to 50 and 60 KBD, bottlenecks or limits of the topping unit occur. To identify bottlenecks, sequence of simulation is the same as the hierarchy of modeling: (1)distillation column ((1.1) HP fractionator and (1.2) Debutanizer and ATM fractionator), (2) HEN, and (3) furnace and cooler. Their bottlenecks are listed as follows:

1. Distillation column bottlenecks are divided into two types [10]:
    - Efficiency bottleneck means the product purity being less than the specification.
    - Hydraulic (or capacity) bottleneck means the tray flooding higher than design limit (more than 85%flooding).

2. Bottlenecks of HEN, furnace, and cooler are divided in two types:
    - Heat transfer area is inadequate to transfer heat targets.
    - Hydraulic bottleneck means higher pressure drop than design limits (e.g. pressure drop in tube of heat exchanger is more than 1 bar)

In simulation, the bottlenecks are found by rating the existing unit with the simulator, and are solved by modification at their points--called debottlenecking.

Debottleneck by Modification the Existing Unit

The column debottlenecking (detail in chapter 3) is the first task, and has two alternatives

1. Modify the bottlenecking tray
    - Reduce downcomer area to increase bubble area leading to increase tray efficiency
    - Increase the tray spacing to avoid the flooding
    - Use the downcomer area to handle higher capacity

2. Replace the bottlenecking tray with the packing (random or structured packing), leading to increase both efficiency and capacity.

The first method is cheaper and easier to modify than the second, but results in less expanding capacity than the second.

The HEN debottlenecking is the second task, and must use the pinch analysis (detail in chapter 4) to debottleneck with two constraints:

1. Avoid splitting a stream to more than two spitted streams for easy flow controlling.

2. Reuse all the existing heat-exchanger in the new HEN to save capital cost.

The utility debottlenecking is the final task. For the heater, the duty is the limit which can be solved by adding new units (80%eff.) in parallel connection. For the cooler, debottlenecking has two methods:

1. If area is not enough but pressure drop is low, solve by adding the exchanger in series connecting.

2. If area is not enough and pressure drop is very high, solve by splitting a stream to branch streams and adding new heat-exchanger in new branch streams. The stream splitting reduces the flowrate per stream, leading to reduce a pressure drop.

Moreover, pumps must be considered. If they can not drive desired heads, new pumps must be added (usually in parallel connection). When the topping unit has been debottlenecked, it will be evaluated in economic terms. Its basis and method have been described in chapter 5.