CHAPTER 1
INTRODUCTION

1.1 Background of Study

Oil refineries resemble mini-economies in that they have to achieve effective use of resources, minimize energy consumption and reduce emission in order to stay competitive in the current marketplace. Refineries are also major parts of a national economy: in the UK alone, there are nine major refineries, processing over 1.8 million barrels of crude oil per day [1].In refinery, the operation is involve of heating large quantities of crude oil and distillation unit has been identified as the main energy consumer, because the crude oil feed must be heated and partly vapourised as it passes from ambient temperature to around 380 °C. A large fraction of the heat required for distillation (*c*. 60–70%) is recovered from the product and pump-around streams of the distillation unit, using heat exchangers (HEXs). These HEXs are usually connected together in a network called the crude preheat train (CPT).

Many crudes give rise to fouling which reduces the thermal efficiency, increase capital expenditure for over-designed units, increase cleaning and maintenance cost and in the worst case is plant shutdown. Fouling also change the surface roughness and the cross sectional areas available for flow which causing problems in pumping a given flow rate through the heat exchanger in crude preheat train (CPT). The annual loss attributable to heat exchanger fouling in US and UK to the order of USD 16.5 billion [2,3]. Hence, heat exchanger performance is very important for the overall refinery economics.

The fouling mitigation techniques are therefore becoming more importance as the techniques use to overcome this problems such as improve the crude compatibility, use of anti-foulant chemicals and tube inserts, use more efficiency equipment which increase capital cost, manipulating of operating parameters, and regular cleaning of fouled during the operation cycle. Cleaning of fouled heat exchanger is still considered to be a desirable responsive action. Casado[4] proposed a model based on the cost cleaning in the fouled exchanger. He selected asymptotic model for counter-flow exchanger and implemented thermal analysis of the hot and cold streams. In Ref. [5], the simulation of heat exchanger was performed using energy balance equations and relationships between the heat transfer coefficients of the hot and cold streams and fouling factors.

1.2 Problem statement

Fouling is a serious operating problem in oil refinery crude preheat train (CPT).Result of fouling include reduce the thermal efficiency, loss of production rates, additional cleaning and maintenance and in the worst case is plant shutdown. Fouling changes the outlet temperature of the hot and cold stream, heat transfer and heat transfer coefficient of crude preheat train

In order to maintain the thermal efficiency of crude preheat train (CPT) at acceptable level, the heat exchanger are cleaned periodically. Cleaning the heat exchanger based on predetermined schedule will reduce the economic loss of the plant. The heat exchanger scheduling problem requires three elements:

- A reliable model to stimulate the network performance in CPT
- Appropriate models for predicting the fouling behavior
- An optimization techniques for an optimum cleaning schedule

A temperature deviation can be predicted if a reliable model to simulate the network performance is developed. If the temperature deviations from the design value exceed a specified limit, it may turn the plant to shut down. Then, the simulation of crude preheat train will predict the outlet temperature and the cleaning schedule can be plan based on the simulation output. Hence, simulation of crude preheat train will have a significant effect on production analysis.

1.3 Objectives

The objectives of this research are:

1. To determine the heat loss and economic loss in crude preheat train.
2. To develop a programming for simulating the heat exchangers performances in crude preheat train.

1.4 Scope of Study

The scope of study will evolve around the programming on MATLAB and Excel to determine the heat loss and economic loss in crude preheat train and find variations in outlet temperature of hot and cold streams by given a fixed configuration, process parameters and constraints set. Learning on the method is also needed as the calculation process is required to be implemented on the coding.

Overall, the project scope has been divided into two stages whereby the first stage is the study of the theories behind the simulation of heat exchanger networks as well as the method used in estimating the output temperature of cold and hot streams. Meanwhile, the second stage is to simulate the calculation of HEN to predict the output temperature using MATLAB. The simulation used to calculate the output temperature of cold and hot streams by certain value of input.

CHAPTER 2
LITERATURE REVIEW

2.1 Fouling behavior of a refinery heat exchanger

2.1.1 Equipments studied

Preheat train are complex which fouling are often non-linear in temperature and velocity dependency, so it is possible to derive analytical solution describing network performance. Based on V.R Radhakrishnan et al. (2007) [8] case studied in the crude preheat train, there are 11 heat exchangers with a total rating of 66.5 MW. The unit chosen for this study is one of the principal heat exchangers for the recovery of heat. Table 1 shows the importance characteristic of the heat exchanger.

Characteristics of the heat exchanger studied

Parameter	Value
Heat duty	2650 kW
Heat transfer area	186 m^2
Overall heat transfer coefficient – Design clean value	293 $W/m^2 K$
Overall heat transfer coefficient – Design fouled value	217 $W/m^2 K$
Number of shell passes	1
Number of tube passes	6, Counterflow
Number of tubes	548
Tube OD	19.05 mm
Tube pitch	25.4 mm square pitch
Shell side fluid	Crude oil
Tube side fluid	Low sulfur waxy residue (LSWR)
Shell-side design ΔT	9.2 °C
Tube-side design ΔT	42 °C

Table 1: Characteristics of the heat exchanger studied

2.1.2 Heat exchanger historical performance

Majority of heat exchangers used in crude preheat train are shell and tube devices. Lumped parameter models were used to evaluate the performance of individual heat exchangers as assuming uniform thermal properties, known values of heat transfer coefficients and the existence of single phase flow. The NTU-effectiveness (ε) method is used to calculate the duty and outlet temperature for each HEX using standard equation. This method lends itself to simulating the thermal performance of PHT network, as the inlet and outlet temperature from each HEX appear in simultaneous linear equations which can be written in matrix form and solve rapidly.

In V.R Radhakrishnan et al. (2007) [8] case studied, the heat exchanger underwent mechanical cleaning during a turnaround in May 2002. Fig 1 shows the performance of the chosen heat exchanger for a period of 3 years starting from the turnaround.

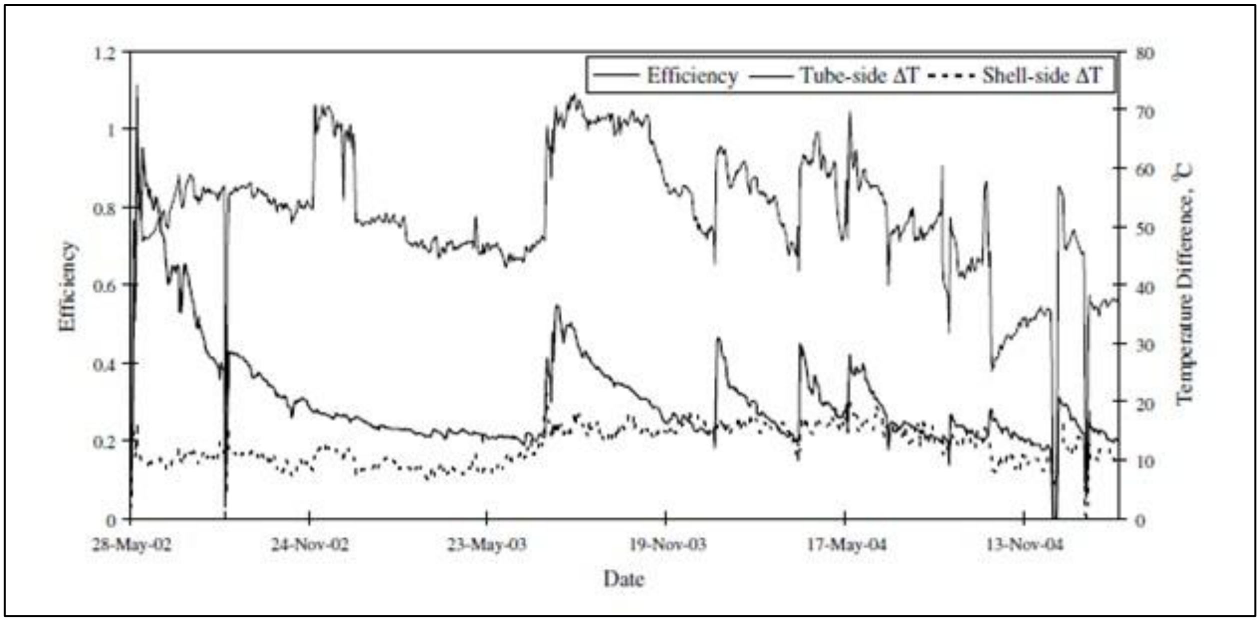


Figure 1: Heat exchanger performance

As seen in Fig 1, the efficiency dropped to almost 20% by June 2003.The heat transfer efficiency was calculated by U_{dirty}/U_{clean} .The heat transfer coefficient under fouled condition U_{dirty}, was calculated using the actual log mean temperature difference (LMTD).The heat exchanger was then cleaned by a process called as ‘hot melting’ which diesel and other cleaning chemical are circulated over the heat transfer surface for several hours till he deposits were dissolved and removed. It is observed that the peak efficiency was not complete restored to its value after the turnaround but only value of around 60%. Peak efficiency is the maximum efficiency restored after the hot melting or turnaround. There are two reasons it cannot achieved 100% to its value. The first reason was because the cleaning was done only the shell-side by hot melting and fouling on tube-side was not removed. The second reason was the deposits on the shell-side were not removed completely by hot-diesel solvent. The increase rate of the fouling and decreased restored peak efficiencies after hot-melting continued until February 2005 and the heat exchanger was taken out for another turnaround.

2.1.3 Fouling mitigation techniques

The formation of fouling in heat exchangers networks in a plant is the only factor that changes the outlet temperatures of cold and hot streams. Formation of deposits in heat exchanger decrease the heat transfer coefficient and heat transfer rate. So, the heat exchanger needs more heat to preheat the crude oil by increase the temperature which will increase the operating cost. If the temperature deviation from the design values exceeds the limits, the plant is needed to be shutdown. There are some techniques that be used in order to reduce the fouling rate which is mitigation techniques [9]:

- Reducing the rate fouling by adding antifoulant chemical which adds directly to the operating cost
- Using more efficient heat transfer equipment with a grater size and efficiency, usually increase the capital cost
- Regular cleaning of fouled units during the operating cycle

Basically, cleaning is the effective technique and fast method to remove fouling. Cleaning is affect both of the operating and capital cost as there will be penalties incurred while unit is being cleaned. The network must be configured so that the units can be taken off-line for cleaning. By suggest a proper cleaning schedule the operating cost and capital cost will be reduced.

2.2 Heat Exchanger Simulation

The heat exchanger network simulation consists of constructing a set of nonlinear equations describing the performance of each exchanger and a set of linear equation describing the links of the unit and the splitting and mixing of the streams [4].The simulation of heat exchanger can be perform by using energy balance equation and relationship between the heat transfer coefficient of the hot and cold streams and fouling factors.

The heat transfer rate in heat exchanger is explained as

$$Q = UAF\Delta T_{lm} \qquad (1)$$

Where

Q = heat transfer rate kW

U = overall heat transfer coefficient kW/m^2 K

A = surface area m^2

ΔT_{lm} = logarithmic mean temperature difference (LMTD)

Assume no energy loss, an energy balance of cold and hot streams of an exchangers gives

$$Q_{cold} = \dot{m}_c c_{p,c}(T_{cold,out} - T_{cold,in}) \qquad (2)$$

$$Q_{hot} = \dot{m}_h c_{p,h}(T_{hot,in} - T_{hot,out}) \qquad (3)$$

where

$\dot{m}$ = mass flow rate, kg/hr

c_p = specific heat kJ/kg K

The overall heat transfer coefficient for a fouling heat exchanger, U_f can be calculated by relate to the fouling resistance

$$\frac{1}{U_f(t)} = \frac{1}{U_c} + R_f(t) \tag{4}$$

$U_f(t)$ = overall heat transfer coefficient for fouling heat exchanger at time t, kW/m^2 K

U_c = overall heat transfer coefficient for clean heat exchanger, kW/m^2 K

$R_f(t)$ = fouling resistance, m^2 K/kW

Based on Based on Smaïli et al. (2001) [7], two most common forms of fouling used are

I. Linear fouling

$$R_f = c \tag{5}$$

Where c is constant for a particular heat exchanger

II. Asymptotic fouling

$$R_f(t) = R_f^{\infty}\left(1 - exp(-t^{'}/\tau)\right) \tag{6}$$

Where R_f^{∞} is the asymptotic fouling resistance, $t^{'}$ is the time elapsed since the last cleaning action and τ is a fouling time constant

Using all the above equation, the temperature outlet for cold and hot streams can be computed from

$$T_{c,out} = \left[\frac{k_1(\exp(-\mathrm{k}_2\mathrm{F}(\mathrm{k}_1-1))-1)}{exp(-k_2F(k_1-1))-k_1}\right] T_{h,in} + \left[\frac{(1-k_1)exp(-k_2F(k_1-1))}{exp(-k_2F(k_1-1))-k_1}\right] T_{c,in} \quad (7)$$

$$T_{h,out} = T_{h,in} - \frac{1}{k_1}\left(T_{cold,out} - T_{cold,in}\right) \quad (8)$$

where k_1 and k_2

$$k_1 = \frac{\dot{m}_h c_{p,h}}{\dot{m}_c c_{p,c}} \quad (9)$$

$$k_2 = \frac{UA}{\dot{m}_h c_{p,h}} \quad (10)$$

By defining M_h and M_c

$$M_h = \frac{k_1(\exp(-\mathrm{k}_2(\mathrm{k}_1-1))-1)}{exp(-k_2(k_1-1))-k_1} \quad (11)$$

$$M_c = \frac{(1-k_1)exp(-k_2(k_1-1))}{exp(-k_2(k_1-1))-k_1} \quad (12)$$

The outlet temperature of a cold stream from an exchanger can be written in the form of:

$$T_{c,out} = M_h T_{h,in} + M_c T_{c,in} \quad (13)$$

Using equation (2), (3), and (9), the outlet temperature for hot stream is expressed as

$$T_{h,out} = T_{h,in} - \frac{1}{k_1}(T_{c,out} - T_{c,in}) \quad (14)$$

Using the above equations and considering the arrangement of networks, the simulation of the heat exchanger network was implemented.

2.3 Constraints in temperature value

The outlet temperatures of the exchanger are limited as below:

$$T_{n,p} \gg X^L \; or \quad X^U \gg T_{n,p}$$

Where X^L and X^U is lower and upper limits of the heat exchanger outlet temperature. Seasonal variations in operating strategies could be incorporated by specifying upper and lower limit.

2.4 Heat exchanger in series (dependent exchangers)

The following types of heat exchanger arrangements must be considered in the software program.

- If the heat exchangers are in parallels, a change in the cleaning schedule of each exchanger will not affect cleaning of the others. Thus the exchangers are called 'independent' in this case and optimizing the cleaning schedule for each exchanger could be performed independently. This will reduces the computational run time enormously
- If the heat exchanger units a in a series, a change in the cleaning schedule will affects the cleaning schedule of the unit.

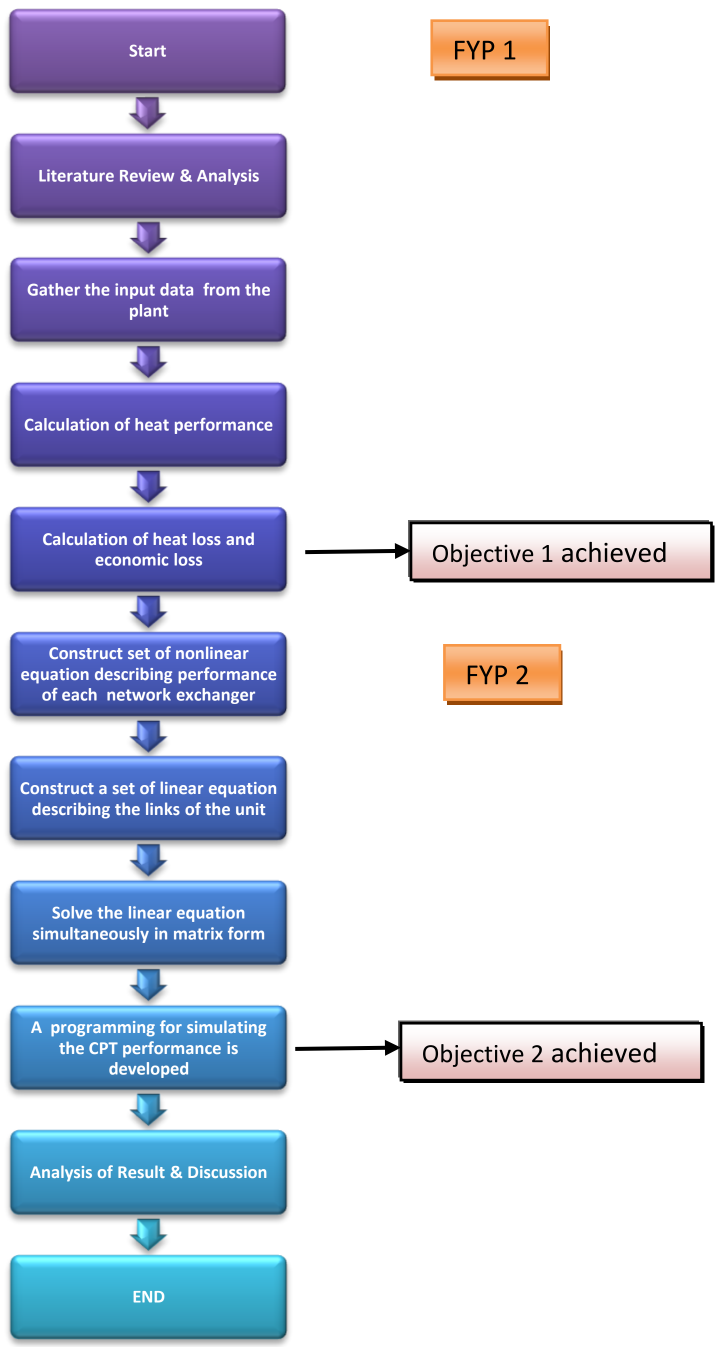
2.5 Matlab

MATLAB is a program for computation and visualization. It is widely used and is available on all kinds of computers, ranging from personal computers to supercomputers. MATLAB is controlled by commands and it is programmable. There are hundreds of predefined commands and functions and these functions can be further enlarged by user-defined functions [6].

Furthermore, MATLAB has a really powerful command. For instance, it can solve linear systems with one single command, and perform a lot of advanced matrix manipulations. It also has powerful tools for graphics in two and three dimensions. The MATLAB can be used together with other programs. The graphic capabilities of MATLAB can, for instance, be used to visualize computations performed in a FORTRAN program [6].

MATLAB also can be used to calculate the curve fitting and interpolation. It provides interpolation functions for both two and three dimensions. MATLAB can return the values of a set of points to its intermediate points by interpolating the data. This can be done in a different ways. Thus, MATLAB is the suitable software to be used in this project.

CHAPTER 3
METHODOLOGY



3.1 Project Activities

In order to achieve the aim of the project, some research has been done on several resources from books, technical papers and internet. For the first step, the gathering information needs to be done on the fouling mitigation, cleaning schedule problem, and simulation method. After all the studies have been done and the parameters have been identified, the author started constructs a calculation using Microsoft Excel and obtain the outlet temperature as the output.

The next stage is the simulation stage whereby the calculation will be simulated in order to make it easier to achieve the outlet temperature as the output. During this stage, knowledge of MATLAB software is a requirement.

3.2 Tools

For the accomplishment of the project, there are needs for a certain software application especially for Modelling and Simulation process for our design. For this project, the author use Microsoft Excel to construct the calculation and do modelling and simulation using MATLAB software.

3.3 Construct Calculation Using Matrix Equation

In this project, a matrix equation is used in order to solve the linear equation simultaneously to predict future output of outlet temperature. The matrix equation can be form as:

$$(A)(X) = (B)$$

where

A = n x n matrix coefficients

X = column vector of unknowns

B =column vector of constants

The linear equation become easier to solve and the unknowns can be obtained faster by solve simultaneously in matrix equation. In order to get the output of unknowns, the matrix can be solving by using Inverse matrix. After rearrange the equation, the unknowns can be define as form,

$$(X) = (A^{-1}) * (B)$$

In this project, the unknowns can be defining as temperature outlet of hot and cold streams. So, the matrix equation have been constructed and can be write as,

$$\begin{pmatrix} T_{c1,out} \\ T_{c2,out} \\ T_{c3,out} \\ T_{c4,out} \\ T_{c5,out} \\ T_{c6,out} \\ T_{c7,out} \\ T_{c7,out} \\ T_{c8,out} \\ T_{c9,out} \\ T_{c10,out} \\ T_{c11,out} \\ T_{h1,out} \\ T_{h2,out} \\ T_{h3,out} \\ T_{h4,out} \\ T_{h5,out} \\ T_{h6,out} \\ T_{h7,out} \\ T_{h8,out} \\ T_{h9,out} \\ T_{h10,out} \\ T_{h11,out} \end{pmatrix} = inv \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -B2 & -1 & 0 & 0 & A2 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & B3 & -1 & 0 & 0 & A3 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & B4 & -1 & 0 & 0 & 0 & A4 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -B5 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -B6 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -B7 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & B8 & -1 & 0 & 0 & A8 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -B9 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -B10 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -B11 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{1}{k1} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ \frac{-1}{k2} & \frac{1}{k2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -\frac{1}{k3} & \frac{1}{k3} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -\frac{1}{k4} & \frac{1}{k4} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{-1}{k5} & \frac{1}{k5} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \frac{-1}{k6} & \frac{1}{k6} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & -\frac{1}{k7} & \frac{1}{k7} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{k8} & \frac{1}{k8} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{k9} & \frac{1}{k9} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{k10} & \frac{1}{k10} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & -\frac{1}{k11} & \frac{1}{k11} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \times \begin{pmatrix} (B1 * Tcin1) + (A1 * Thin1) \\ 0 \\ 0 \\ 0 \\ (A5 * Thin5) \\ (A6 * Thin6) \\ (A7 * Thin7) \\ 0 \\ (A9 * Thin9) \\ (A10 * Thin10) \\ (A11 * Thin11) \\ (Thin1 + (Tcin1/1.10721)) \\ 0 \\ 0 \\ 0 \\ T_{h5,in} \\ T_{h6,in} \\ T_{h7,in} \\ 0 \\ T_{h9in} \\ T_{h10,in} \\ T_{h11,in} \end{pmatrix}$$

CHAPTER 4

RESULT and DISCUSSION

The author had taken the input data from TAPIS in 8 March 2007 for the heat exchanger E1 until E11. The heat exchangers networks of this unit consist of eleven exchangers are shown in Figure 3. The data given are inlet temperature of cold and hot streams when operation starts, flow rate of cold and hot stream, overall heat transfer coefficient in clean condition, specific heat coefficient of cold and hot streams, area of heat exchanger and fouling resistance of heat exchanger are listed in Table 3. Based from data in Table 3, the calculation was constructed using Microsoft Excel and MATLAB.

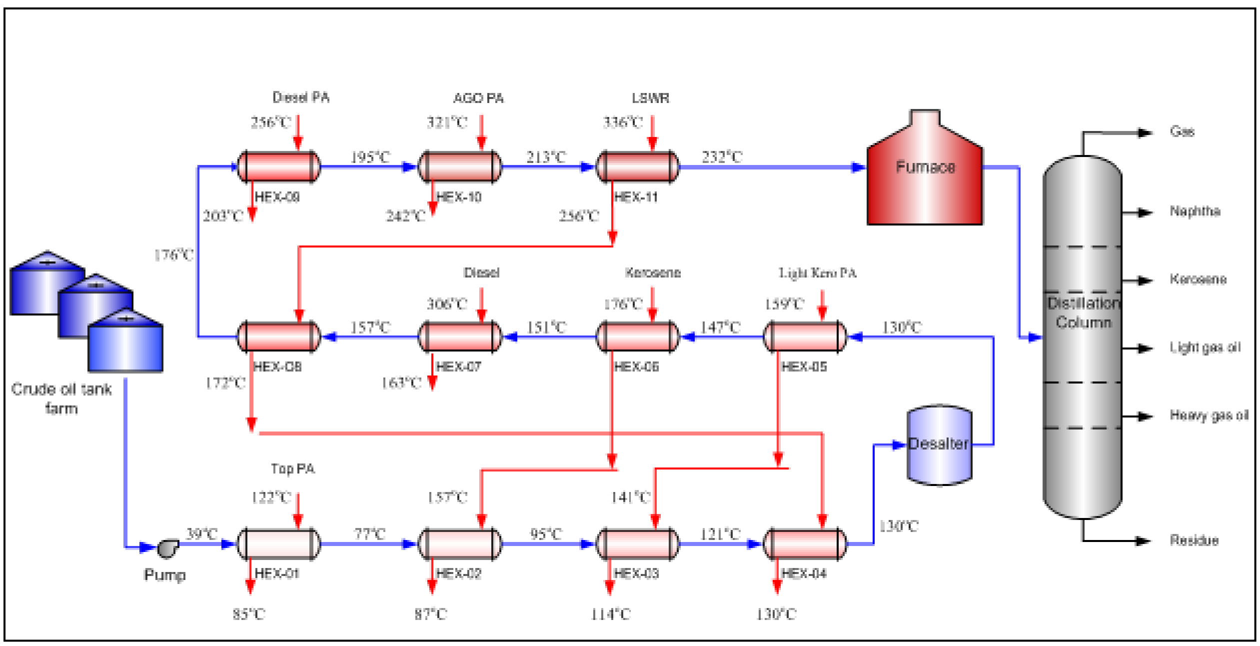


Figure 2: Schematic Diagram of Crude Preheat Train

Table 3: Specification of heat exchanger of E1 until E11

Exchanger name	$T_{h,in}$ °C	$T_{c,in}$ °C	$\dot{m}_c$ kg/s	$\dot{m}_h$ kg/s	$c_{p,c}$ J/kg °C	$c_{p,h}$ J/kg °C	F	U_{clean} W/m^{2}K	A m^2	dRf/dt m^2 K/kW
E1	129.91	37.83	109.44	108.69	2210.10	2463.92	0.832	466	650	9.00E-7
E2	146.54	84.60	109.44	32.35	2338.71	2432.08	0.953	402	576	7.00E-05
E3	138.92	99.66	109.44	114.91	2401.40	2552.04	0.977	520	1144	4.00E-05
E4	166.54	117.18	109.44	30.28	2455.11	2429.85	0.959	188	744	2.00E-04
E5	154.40	127.01	107.80	114.94	2501.47	2615.77	0.939	360	1624	6.00E-05
E6	163.76	142.62	107.80	12.69	2533.04	2559.77	0.983	331	238	4.00E-05
E7	263.85	144.68	107.80	4.25	2547.94	2728.27	0.974	145	296	2.00E-05
E8	269.86	149.55	107.80	29.12	2606.99	2719.31	0.927	331	581	2.00E-05
E9	276.74	178.80	107.80	34.70	2696.97	2741.53	0.973	306	495	2.00E-05
E10	323.78	201.18	107.80	27.17	2788.14	2854.37	0.979	445	243	4.00E-06
E11	324.89	223.31	107.80	30.36	2855.73	3008.39	0.991	438	327	2.00E-04

Assume the data collect from the plant is a linear fouling. The fouling rate for 120 days are computed by integrated R_f every day with $R_{f0} = 0$.The values of k_1, k_2 , M_h, M_c, the outlet temperature of cold and hot stream, and heat transfer for hot and cold stream were computed in Excel using equation (9),(10), (11), (12), (13) and (14). The calculation is done in cleaning condition and fouling condition. The result from the calculation was showed in Appendix A.

From the results of the simulation, the input data of the simulation is to enter the day. The user will ask to enter the day for the outlet temperature.

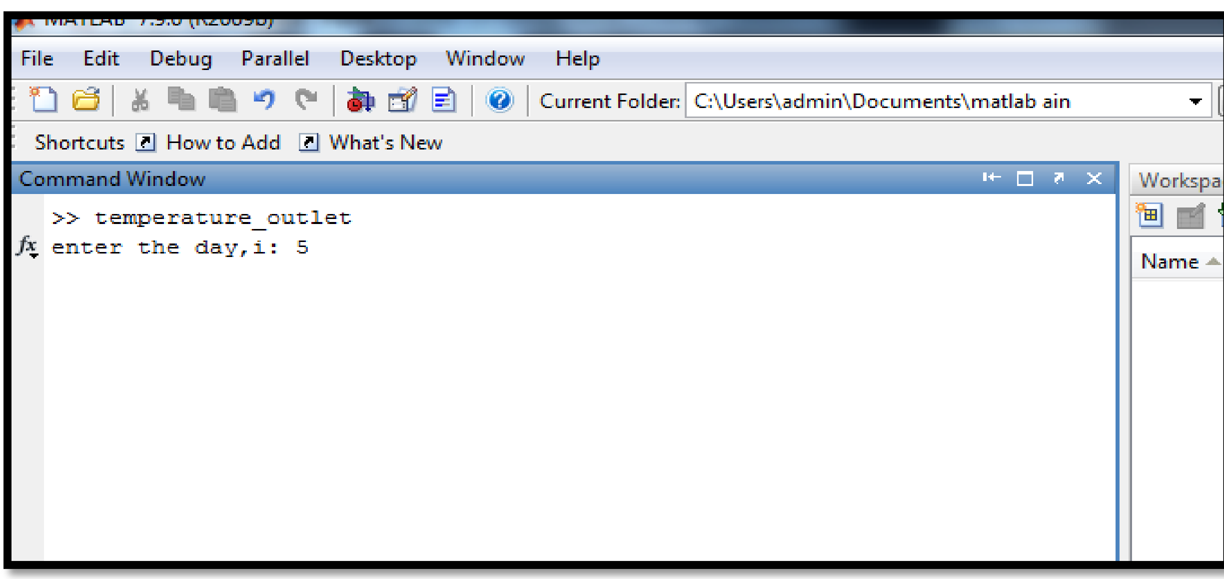


Figure 3: Input data for simulation crude preheat train in Matlab

The output temperature of the simulation will obtained as,

HE		Days	
	1	2	3
Tcout1	85.98	85.9641	85.9540
Tcout2	102.55	102.4286	102.3102
Tcout3	128.31	128.1083	127.9045
Tcout4	138.56	138.2918	138.0104
Tcout5	149.47	149.3053	149.1359
Tcout6	150.98	150.8260	150.6690
Tcout7	165.70	165.1948	165.1844
Tcout8	182.87	182.7077	182.5368
Tcout9	205.29	205.1065	204.9172
Tcout10	226.76	226.5855	226.4125
Tcout11	247.46	246.5851	245.7481
Thout1	86.43	86.4368	86.4460
Thout2	92.62	92.9754	93.3278
Thout3	115.83	115.9053	115.9819
Thout4	129.13	129.3480	129.6314
Thout5	132.69	132.8467	133.0013
Thout6	151.08	150.9767	150.8722
Thout7	183.43	183.0408	182.6973
Thout8	248.98	248.8852	248.7827
Thout9	208.23	208.2923	208.3481
Thout10	240.59	240.5293	240.4666
Thout11	255.10	257.4796	259.7177

Figure 4: Output data for simulation crude preheat train in Matlab

From the results of the simulation, the outlet temperature of hot and cold streams can be predicted by enter the day that the users want. In this programming, the amount of fouling, variations in overall heat transfer in fouled condition and variations in outlet temperature of hot and cold streams can be estimated.

From the results, the fouling resistance is increase from day 1 until day 120 for heat exchanger E1 until E11. In Appendix A it shows that the fouling reduces the heat transfer rate of heat exchanger and increase the outlet temperature of hot and cold stream in comparison with clean condition. The heat loss due to fouling is calculated and it increases as the fouling increased. The heat losses for heat exchanger E1 until E11 versus day are showed in Figure 5, Figure 6 and Figure 7.

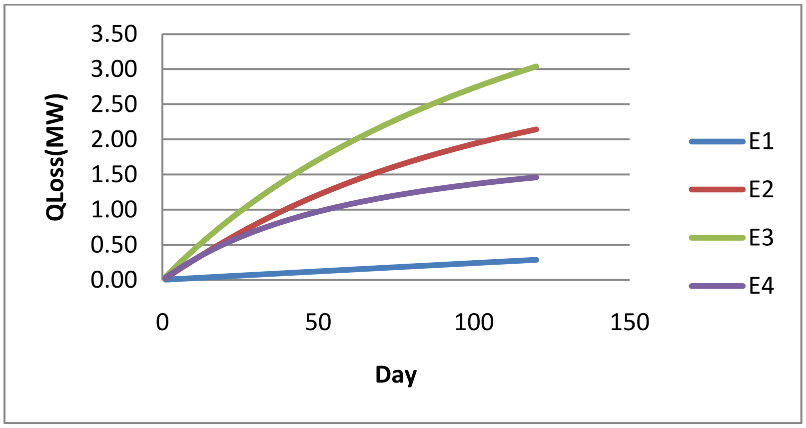


Figure 5: Heat transfer loss versus day for E1-E4

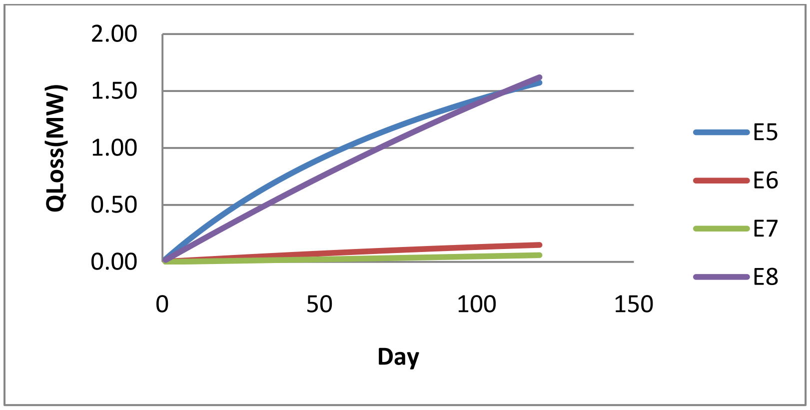


Figure 6: Heat transfer loss versus day for E5-E8

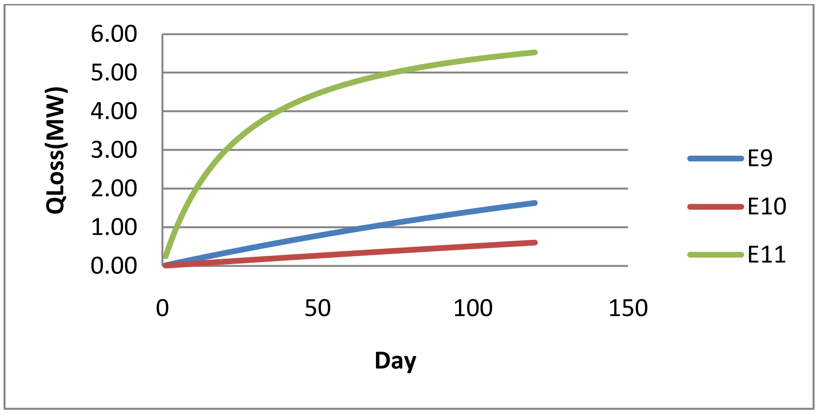


Figure 7: Heat transfer loss versus day for E9-E11

From the graph in Figure 5, Figure 6 and Figure 7, E11 has the highest heat transfer loss which is about 5.52 MW and E7 has the lowest heat transfer loss which is 0.06 MW. Increasing the day to operate the heat exchanger, the heat transfer loss will increase as the fouling resistance increase which lead to more fouling formation. In results, the overall heat transfer coefficient and heat transfer rate is decrease and the maintenance cost to clean the heat exchanger will increase.

The heat transfer loss will affect the economic loss. Figure 8 shows the total economic loss for heat exchanger E1 until E11 as the E11 get the highest total economic loss. Since, E11 get the highest heat transfer loss, so it will has the highest economic loss. Thus, the heat transfer loss will affect the economic loss of heat exchanger. From the calculation heat transfer loss and economic loss in Excel, the data for economic value and maintenance cost are obtained for each heat exchanger.

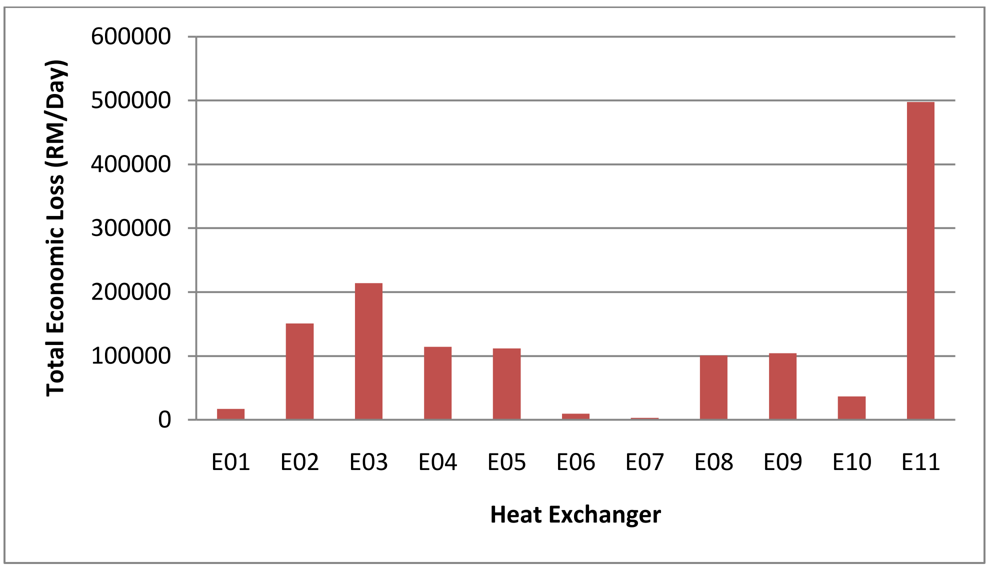


Figure 8: Total Economic Loss (RM/Day) for E1-E11

CHAPTER 5
CONCLUSION AND RECOMMENDATION

As for the conclusion, a method for simulating heat exchanger networks and finding the amount of fouling and predicting the change in outlet temperature of hot and cold streams is presented. The variables that affecting the performance of HEN has been identified and the full calculation were already constructed in order to find the value for the output temperature of cold and hot streams. The heat transfer loss versus day and total economic loss versus day for eleven heat exchangers were predicted based on the HEN simulation in Excel. The maintenance cost and the economic value also has been obtained from the calculation in Excel. By construct the matrix equation, the linear equation is solved simultaneously as the output temperature of hot and cold streams is obtained by using MATLAB simulation. The simulation of crude preheat train can be used in planning the optimal cleaning schedule and the objective function can be computed in order to minimize the cost.

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