بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

Sudan University of Science & Technology

College of Petroleum Engineering

Department of Transportation and Refining

Simulation of Delayed Coking Unit in KRC

محاكاة وحدة التفحيم المؤخر في مصفاة الخرطوم

Submitted in partial fulfillment of the requirement for the Bachelor of Engineering (Honor) Degree in Transportation and Refining Engineering

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October 2016

الإستهلال

قال تعالى :

{وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ} [التوبة:١٠٥]

صدق الله العظيم

“Have not I commanded thee? Be strong and of good courage; be not afraid, neither be thou dismayed: for the LORD thy God is with thee whithersoever thou goest”

Joshua 1:9

Dedication

We would be honor to dedicate this project to our parents, the two persons that gave the tools and values necessary to be where we are standing today.

To all brothers, sisters, friends, teachers, colleagues, relatives, and anyone who assisted, advised, and supported us and our project.

Acknowledgement

The completion of this project may could not have been possible without the participation and assistance of so many people whose names may not all be mentioned, their contribution are sincerely appreciated and gratefully acknowledged.

The group would like to express appreciation and indebtedness to our supervisor miss. Isra for her guidance, leadership, endless support, kind, understanding, and for giving us help as much as she can.

Thanks to the Dean of the faculty and to Eng. Mohamed Othman for his help and support, also thanks is to the collage of Petroleum Engineering and Technology, especially all members of transportation and refining engineering department and special thanks for Khartoum Refining Company.

To all relatives, friends, and others who in one way or another shared their support, thank you.

Above all, to the great Almighty, the author of knowledge and wisdomwe thank you.

Abstract:

Crude oils around the world tends to be more dense in recent years and needs to be treated in a suitable way, one way is the use of thermal cracking processes. One of these processes is the delay cocking which is a unit to recover light products from heavy crudes besides producing petroleum coke. Fula crude is heavy crude which enter the delay coking unit in Khartoum refinery after mixing it with Petrodar crude that comes from Southern Sudan. In this thesis, simulation of the real process in Khartoum refinery has been done using Aspen HYSYS simulator, and the effect of varying the mixing ratio on the unit yield was tested.

It was found that different mixing ratios have approximate results and were very close to the data of Khartoum refinery where the Fula crude is the sole feed.

Correlation calculation was conducted, the results were compared with simulation results and the original process data and it was found that the results were also close in some products yields but are varying in others such as diesel and HCGO. In this thesis also some aspect of coking drum design and calculation were conducted.

Key words: simulation, delayed coking unit, coke drums design, aspen HYSYS.

التجريد

طرق التكسير الحراري للخامات النفطية أصبحت واسعة الاستخدام على مستوى العالم بسبب ميل الخامات في الآونة الأخيرة لأن تصبح أكثر كثافة. و من هذه الطرق طريقة التفحيم المؤخر في وحدة التفحيم و التي تقوم باستخلاص المنتجات الخفيفة من الخامات الثقيلة بالاضافة لانتاج الفحم.
خام الفولة و هو خام ثقيل تتم معالجته في وحدة التفحيم المؤجل في مصفاة الخرطوم حيث يتم مزجه مع خام بترو دار القادم من جنوب السودان.
في هذا البحث تم عمل محاكاة لما يحدث في المصفاة باستخدام برنامج المحاكاة Aspen HYSYS حيث تم تجربة مزج الخامين بعدة نسب ووجد أن نتائج تغير النسب متقاربة جداًو قريبة من البيانات المتحصل عليها من المصفاة عندما يكون خام الفولة هو الخام الوحيد الداخل إلى الوحدة.
تم عمل حسابات باستخدام المعادلات و قورنت بنتائج المحاكاة و ببيانات العملية الحقيقية الحادثة في المصفاة و وجد أن النتائج أيضاً قريبة في بعض المنتجات و مختلفة الى حد ما في البعض الآخر مثل الديزل و زيت التفحم الثقيل و تم عمل تصميم لحاوية الفحم الخاصة بالوحدة.

Some Abbreviations:

DCU: Delayed Coking Unit

HCGO: Heavy Coker Gas Oil

KRC: Khartoum Refining Company

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chapter 1 Introduction

1.1 Introduction

In the recent days the crude oil around the world are going in the direction of being heavier than the past, as a result refineries should be ready to deal with such crudes. Most of the processes used in global refineries going to suffer from this problem.

One of the most efficient and important processes which is used to deal with this problem is delayed coking.

In today's competitive refining environment, delayed coking still remains the industry's leading economic choice in heavy oil upgrading technology. At most delayed coking sites, it is more profitable to limit coke generation due to its relatively low market value in comparison with the Coker's other products. The top coking facilities are continually optimizing operations to increase flexibility for processing a variety of feed-stocks, while maximizing higher-valued liquid and gas products. Equally critical in daily operations is the emphasis on maintaining a safe and reliable processing unit.

The ‘‘bottom of the barrel’’ has become more of a problem for refiners because heavier crudes are being processed and the market for heavy residual fuel oils has been decreasing. Historically, the heavy residual fuel oils have been burned to produce electric power and to supply the energy needs of heavy industry, but more severe environmental restrictions have caused many of these users to switch to natural gas. Thus when heavier residuals is in the crude there is more difficulty in disposing them economically.

There are many ways of treatment of heavy crude in refining industry one of the most important ways to treat heavy crudes is delayed coking unit (DCU), it's a process which treats the heavy hydrocarbon that's can't be fractionated at normal distillation column to light keys. It is an important residue conversion process or so-called "bottom-of the- barrel" process where residues from heavy, high-sulfur crudes are converted to transportation fuels, by the delayed coking unit DCU.

1.2 Problem statement:

Khartoum refinery is conducting trial operations using Fula and Petrodar crudes due to the availability of Petrodar crude.We are interested in studying the effect of these trial operations on the products yields and further conduct experiment usingsimulation to see the effect of changing the mixing ratio between the two crudes.

1.3 Project objectives:

- Simulation of the delayed coking unit to see the effect of mixing Fula and Petrodar crude oils.
- Predict products yields using correlations and compare the results with the simulation results.
- Study and conduct coking drum design procedure.

chapter 2 Literature Review

2.1 Thermal Cracking and Coking:

(M. A. Fahim, T. A. Al-sahhaf & A. S. Elkilani 2010) Thermal cracking is the cracking of heavy residues under severe thermal conditions. The liquid products of this process are highly olefinic, aromatic and have high sulphur content. They require hydrogen treatment to improve their properties. Coking is the process of carbon rejection from the heavy residues producing lighter components lower in sulphur, since most of the sulphur is retained in the coke.

2.1.1 Visbreaking:

(G, H. Gary & G. E. Handwerk 2001) Vis-breaking is a relatively mild thermal cracking operation mainly used to reduce the viscosities and pour points of vacuum tower bottoms to meet fuel oil specifications or to reduce the amount of cutting stock required to dilute the residual to meet these specifications. Refinery production of heavy fuel oils can be reduced from 20–35% and cutter stock requirements from 20–30% by vis-breaking. The gas oil fraction produced by visbreaking is also used to increase cat cracker feed stocks and increase gasoline yields.

Long paraffinic side chains attached to aromatic rings are the primary cause of high pour points and viscosities for paraffinic base residua. Vis-breaking is carried out at conditions to optimize the breaking off of these long side chains and their subsequent cracking to shorter molecules with lower viscosities and pour points. The amount of cracking is limited, however, because if the operation is too severe, the resulting product becomes unstable and forms polymerization products during storage which cause filter plugging and sludge formation. The objective is to reduce the viscosity as much as possible without significantly affecting the fuel stability. For most feed-stocks, this reduces the severity to the production of less than 10% gasoline and lighter materials.

The severity of the vis-breaking operation can be expressed in several ways: the yield of material boiling below 330F (166C), the reduction in product viscosity, and the amount of standard cutter stock needed to blend the vis-breaker tar to No. 6 fuel oil specifications as compared with the amount needed for the feedstock.

There are two types of vis-breaker operations, coil and furnace cracking and soaker cracking.

2.1.2 Flexicoking:

(G, H. Gary & G. E. Handwerk 2001) Flexi-coking is a process in which the Feed can be any heavy oil such as vacuum residual, coal tar, shale oil, or tar sand bitumen. Flexi-coking: is A thermal cracking process which converts heavy hydrocarbons feeds into light hydrocarbons. Feed stocks can be any pumpable hydrocarbons including those containing high concentrations of sulfur and metals.

2.1.3 Fluid Coking:

(G, H. Gary & G. E. Handwerk 2001) Fluid coking is a thermal cracking process consisting of a fluidized bed reactor and a fluidized bed burner

2.1.3.1 Process description—Fluid coking:

(G, H. Gary & G. E. Handwerk 2001) Fluid coking is a simplified version of flexi-coking. In the fluid coking process only enough of the coke is burned to satisfy the heat requirements of the reactor and the feed preheat. Typically, this is about 20 to 25% of the coke produced in the reactor. The balance of the coke is withdrawn from the burner vessel and is not gasified as it is in flexi-coking.

The primary advantage of Flexi-coking over the more simple fluid coking is that most of the heating value of the coke product is made available as low sulfur gas which can be burned without an SO2 removal system on the resulting stack gas, whereas such a system would be necessary if coke which contains 3 to 8 wt% sulfur is burned directly in a boiler.

2.1.3.2 Yields from flexicoking and fluidcoking:

(G, H. Gary & G. E. Handwerk 2001) Products from Flexi-coking and fluid coking are the same as those from delayed coking except for the amount of reactor coke product which is burned or gasified. Thus the coke yield from a fluid coking unit would be about 75 to 80% of the coke yield from a delayed coking, and the yield of coke from Flexi-coking would be in the range of 2 to 40 wt% of the delayed coking yield.

2.2 Delayed coking:

(G, H. Gary & G. E. Handwerk 2001) Delayed coking is a type of thermal cracking in which the heat required to complete the coking reactions is supplied by a furnace, while coking itself takes place in drums.

The feed to Coker is usually vacuum residue but it can also accept fluid catalytic cracking slurry and vis-breaking tar (residues).

2.2.1 Role of Delayed Coker

The products from the Coker are unsaturated gases (C1–C4), olefins (C¼2_ C¼4) and i-C4. The cocker is the only unit in the refinery which produces coke.

The role of the delayed Coker is to handle very heavy undesirable streams and to produce desirable refinery products.

Process Descriptiоn

The process includes a furnace, two coke drums, fractionator and stripping section.

A control valve system directs the feed to enter one of the drums, where the reactions take place and coke is deposited on the drum walls, and the products flow back to the distillation column. In this case, the drum is in the ‘‘filling’’ mode. At the same time, the other drum is cut off from the rest of the system while the coke is being removed. The drum in this case is in the ‘‘cutting’’ mode.

Vacuum residue enters the bottom of the flash zone in the distillation column or just below the gas oil tray. Fractions lighter than heavy gas oil are flashed off and the remaining oil is fed to the coking furnace.

2.2.2 Delayed coking chemistry:

(M. A. Fahim, T. A. Al-sahhaf & A. S. Elkilani 2010) Coke can be formed from the condensation of poly-nuclear aromatics. Coke formation can occur through the condensation of olefins and butadiene with aromatics to yield low hydrogen content coke. Thermal cracking of C_6 hydrocarbons may yield certain amount of coke (CH0.8) as shown in Table. These reactions also yield unsaturated hydrocarbons which might react with aromatics to yield coke precursors.

Table 2.1 Delayed coking reactions.

Reaction No.	Reaction	Coke yield mass fraction	Type of light-end product
1	$C_6H_{14} \rightleftarrows 1.15\ C_5H_{12} + 0.34\ CH_{0.8}$	0.05	Alkane
2	$C_6H_{14} \rightleftarrows 1.33\ C_4H_{10} + 0.68\ CH_{0.8} + 0.8\ H_2$	0.10	Alkane
3	$C_6H_{14} \rightleftarrows 1.32\ C_2H_4 + 3.36\ CH_{0.8} + 3.01\ H_2$	0.50	Alkene
4	$C_6H_{14} \rightleftarrows 0.66\ C_4H_6 + 3.36\ CH_{0.8} + 3.68\ H_2$	0.50	Diene
5	$C_6H_{12} \rightleftarrows 1.36\ C_2H_4 + 3.28\ CH_{0.8} + 2.97\ H_2$	0.50	Alkene
6	$C_6H_6 \rightleftarrows 1.48\ C_2H_4 + 3.04\ CH_{0.8} + 2.82\ H_2$	0.50	Alkene

2.2.2.2 Delayed Coking Variables:

(G, H. Gary & G. E. Handwerk 2001) There are three classes of variables affecting coking. They are related to process operating variables, feedstock characterization and engineering variables

In delayed coking, the temperature controls the quality of the coke produced. High temperature will remove more volatile materials. Coke yield decreases as temperature increases. Short cycle time will increase capacity but will give lower amounts of liquid products and will shorten drum lifetime. Increasing pressure will increase coke formation and slightly increase gas yield. Feedstock variables are the characterization factor and the Conradson carbon which affect yield production. Sulphur and metal content are usually retained in the coke produced. Engineering variables also affect the process performance. These include mode of operation, capacity, coke removal and handling equipment.

2.2.2.3 DCU Operation:

(G, H. Gary & G. E. Handwerk 2001) The fractionation facilities are operated continuously. Usually just two coke drums are provided.

Fill drum with coke 24 Switch and steam out 3 Cool 3 Drain 2 Unhead and decoke 5 Head up and test 2 Heat up 7 Spare time 2 Total 48

Coker operators typically will increase capacity by operating with shorter cycle times. Usual design factors will allow a 20% increase in capacity by shortening coking cycles from 24 to 20 hours, and moderate debottlenecking projects will allow coking cycles as low as 9 to 12 hours. Shorter cycle times usually mean a lower yield of liquid products because of higher drum and fractionating tower pressures which may be needed to prevent too high vapor velocities and fractionator and compressor overloading. Shorter cycle times can result in a shorter drum life because of additional

drum stresses due to more rapid temperature cycles. In one case shortening the coking cycle from 21 hours to 18 hours reduced the remaining drum life by about 25%.

2.2.3 Types, properties, and uses of petroleum coke:

(G, H. Gary & G. E. Handwerk 2001) There are several types of petroleum coke produced depending upon the process used, operating conditions and feedstock properties. All cokes, as produced from the Coker, are called ‘‘Green’’ cokes and contain some high-molecular-weight Hydrocarbons (have some hydrogen in the molecules) left from incomplete carbonization reactions. These incompletely carbonized molecules are referred to as volatile materials in the coke (expressed on a moisture-free basis). Fuel grade cokes are sold as green coke, but coke used to make anodes for aluminum production or electrodes for steel production must be calcined at temperatures from:1800 to 2400°F (980 to 1315°C) to complete the carbonization reactions andreduce the volatiles to a very low level.

Much of delayed coking coke is produced as hard, porous, irregular-shapedlumps ranging in size from 20 inches (50 cm) down to fine dust. This type ofcoke is called sponge coke because it looks like a black sponge.

A second form of petroleum coke being produced in increasing quantitiesis needle coke. Needle coke derives its name from its microscopic elongatedcrystalline structure. Needle coke is produced from highly aromatic feed-stocks

(FCC cycle oils, etc.) When a coking unit is operated at high pressures [100 psig(690 k Pa)] and high recycles ratios (1: 1). Needle coke is preferred over spongecoke for use in electrode manufacture because of its lower electrical resistivityand lower coefficient of thermal expansion.

Occasionally a third type of coke is produced unintentionally. This cokeis called shot coke because of the clusters of shot-sized pellets which characterizeit. Its production usually occurs during operational upsets or when processingvery heavy residuals such as those from some Canadian, Californian, and Venezuelancrudes. These shot clusters can grow large enough to plug the coke drumoutlet (_12 in. or 30 cm). It is also produced from some high sulfur residuals

Shot coke is undesirable because it does not have the high surface area ofsponge coke or the useful properties, characteristic of needle coke, for electrodemanufacture.

The main uses of petroleum coke are as follows:

1. Fuel.

2. Manufacture of anodes for electrolytic cell reduction of alumina.

3. Direct use as chemical carbon source for manufacture of elementalphosphorus, calcium carbide, and silicon carbide.

4. Manufacture of electrodes for use in electric furnace production ofelemental phosphorus, titanium dioxide, calcium carbide, and siliconcarbide.

5. Manufacture of graphite.

It is important to note that petroleum coke does not have sufficient strengthto be used in blast furnaces for the production of pig iron nor is it generallyacceptable for use as foundry coke. Coal-derived coke is used for these purposes.

The sulfur content of petroleum coke varies with the sulfur content of theCoker feedstock. It is usually in the range of 0.3 to 1.5 wt%. It can sometimes,however, be as high as 8%. The sulfur content is not significantly reduced bycalcining.

2.2.4 Process description - Delayed coking:

(G, H. Gary & G. E. Handwerk 2001) For the coking to take place before subsequent processing, hence the term ‘‘delayedcoking.’’

Typically furnace outlet temperatures range from 900–930°F (482–500°C).

The higher the outlet temperature, the greater the tendency to produce shot cokeand the shorter the time before the furnace tubes has to be decoked. Usuallyfurnace tubes have to be decoked every three to five months.

Hot fresh liquid feed is charged to the fractionator two to four trays abovethe bottom vapor zone. This accomplishes the following:

1. The hot vapors from the coke drum are quenched by the cooler feedliquid thus preventing any significant amount of coke formation in the fractionator and simultaneously condensing a portion of the heavy endswhich are recycled.

2. Any remaining material lighter than the desired coke drum feed isstripped (vaporized) from the fresh liquid feed.

3. The fresh feed liquid is further preheated making the process moreenergy efficient.

Vapors from the top of the coke drum return to the base of thefractionator.

These vapors consist of steam and the products of the thermal cracking reaction:gas, naphtha, and gas oils. The vapors flow up through the quench trays previouslydescribed. Above the fresh feed entry in the fractionator there are usuallytwo or three additional trays below the gas oil draw off tray. These trays

arerefluxed with partially cooled gas oil in order to provide fine trim control of thegas oil end point and to minimize entrainment of any fresh feed liquid or recycleliquid into the gas oil product.

The gas oil side draw is a conventional configuration employing a six- toeight-tray stripper with steam introduced under the bottom tray for vaporizationof light ends to control the initial boiling point (IBP) of the gas oil.

Steam and vaporized light ends are returned from the top of the gas oilstripper to the fractionator one or two trays above the draw tray. A pump-aroundreflux system is provided at the draw tray to recover heat at a high temperaturelevel and minimize the low-temperature-level heat removed by the overhead condenser.

This low-temperature-level heat cannot normally be recovered by heatexchange and is rejected to the atmosphere through a water cooling tower oraerial coolers.

Eight to ten trays are generally used between the gas-oil draw and the naphthadraw or column top. If a naphtha side draw is employed, additional trays arerequired above the naphtha draw tray.

2.2.5 History of delayed coking:

The year in which delayed coking was first developed is given in historical listings of petroleum advances as 1928. As it is known that in early refineries severe thermal cracking of residue would result in the deposit of unwanted coke in the heaters, by evaluation of the art of heater design, methods were found by which it was possible to raise rapidly the temperature of the residue above the coking point without depositing the coke in the heater itself. Provision of an insulated surge drum downstream of the heater so that the coking took place after the heater, but before subsequent processing, resulted in the name “Delayed coking.”

The next step was to add a second coke drum, which doubled the run length and led to the development of the art of switching coke drums while still maintaining operation. In the early 1930s the drums were limited in size to 10 ft in diameter.7 Coke drums as large as30 ft in diameter have recently been installed

2.2.6 Capital cost and utilities for flexicoking and fluidcoking:

(G, H. Gary & G. E. Handwerk 2001) As a rough approximation it can be assumed that the investment for a fluid coking unit is about the same as that for a delayed coking unit for a given feedstock and that a Flexi-Coker costs about 30% more.The utility requirements for Fluid Coking are significantly higher than those for

delayed coking primarily because of the energy required to circulate the solids between fluid beds. The air blower in a Flexi-Coker requires more power than that for a Fluid Coker. The process Licensor should be consulted to determine reasonably accurate utility requirements.

2.3 Some of the previous studies on delayed coking unit:

2.3.1 Delayed Coking: Industrial and LaboratoryAspects:

(Reinoso et el, 1997) Processes occurring in a delayed coker are complicated and attempts have been made, at the laboratory level, to simulate industrial delayed coking. Although the latter studies are useful, it is impossible to scale-down to the laboratory level. Industrial delayed coking is a turbulent process and such movements cannot be simulated easily in the laboratory. Of industrial importance are the multiphase systems, i.e. volumes of unreacted isotropic pitch residue, transported through the bulk, fluid anisotropic mesophase, so creating ordering into acicular structures in the vicinity of the multiphase systems. Four petroleum residues were analysed chemically. Pyrolyses were carried out under pressures of up to 1.0 MPa. Complete mass balances were obtained and the semicokes examined by optical microscopy. Feedstocks for delayed cokers can be blends of petroleum residues, some of which can produce considerable amounts of volatile materials. Volatile evolution, at the optimum operating condition of the delayed coker, can bring about improvements in resultant coke quality. In industrial delayed coking it is important not only to consider the chemistry of the feedstocks, but attention must also be given to the physico-chemical aspects of coker operation.

2.3.2 Intelligent switching expert system for delayed coking unit based on iterative learning strategy:

(Yu et el 2011) Delayed coking is the most effective process to decarbonize and demetallize heavy petroleum residues.

However, it relies much on the field engineers' experiences and expertise in practice for operating the controllers effectively and compatibly in delayed coking. This study establishes a knowledge database of intelligent switching expert system by analyzing the on-site data and operator's experiences. A feed-forward control strategy based on iterative learning is introduced to erase disturbances arising from switching operation. The intelligent switching expert system (ISES) proposed here is guaranteed

to be converged by introducing a convergence factor. The effectiveness and maneuverability of the ISES are proved by the simulation results on Shadow Plant Simulation Platform.

2.3.3 Thermal coupling between crude distillation and delayed coking units:

(Plesu et el 2003) The paper presents an industrial case study. Crude distillation unit (CDU) and delayed coking unit (DCU) are important plants in oil refineries, presenting huge energy consumption, especially due to high flowrates of process material streams. Any acceptable solution for energy saving is important in this context. The idea of thermal coupling between these two plants is good as they have potential to exchange energy, but the problem is to choose the most appropriate way to do it. The objective of this work is to present the possibility to exchange energy between the two plants, continuing a previous work [Energy saving by integration of CDU-delayed coke plants, third Conference, Process Integration, Modelling and Optimisation for Energy Saving and Pollution Reduction, where a part of the solution was already presented. The difficulty to find a solution arisen from the fact that DCU is working semicontinuous.

More insights in the process allowed finding new possibilities, more attractive for rational use of energy, with better applicability. A feasibility study will be performed to give also economic sound of all the implications for the modifications proposed.

2.3.4 Advanced Control of the Delayed Coking Unit in Khartoum Refinery:

(Hamed, Gasmelseed & Elamin, 2014) A cascade control strategy was developed to control the pressure of the coking drum using the flow of the heater fuel as manipulated variable. The block diagrams of the systems were constructed and the process transfer functions were identified using MATLAB Black Box model. Then the overall transfer functions, the open and closed-loops, and the characteristic equations were determined, and the control systems were tuned to obtain the adjustable parameters using Routh-Hurwitz, Direct Substitution, Root locus, Nyquist, and Bode methods. The adjustable parameters were appropriately inserted into the characteristic equation for the offset investigation, stability analysis and response

simulation. It is found that using of PID controller for the Primary loop provides the highest gain than P and PI controllers and also it eliminates the Offset.

chapter 3 Methodology

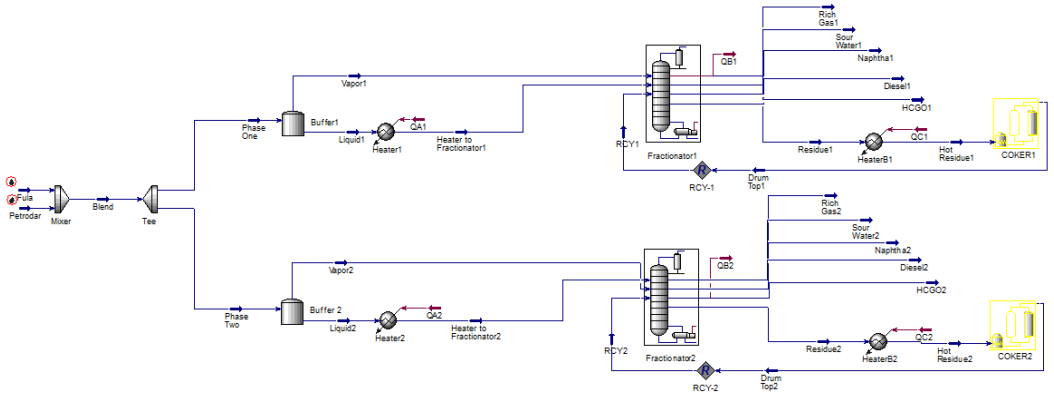
In this chapter we will focus on the procedure in which the simulation process will take place and also we will get into the detail design procedure for the drums.

project work:

- Selection of the case study and data
- Simulation procedure
- Material balance
- Coke drum design

3.1 Selection of the case study and data:

Our case study is the delayed coking unit of Khartoum refinery which consists of two sets. Phase I and Phase II the capacity of each is 1 Mt/year; the total capacity of DCU is 2 Mt/year.



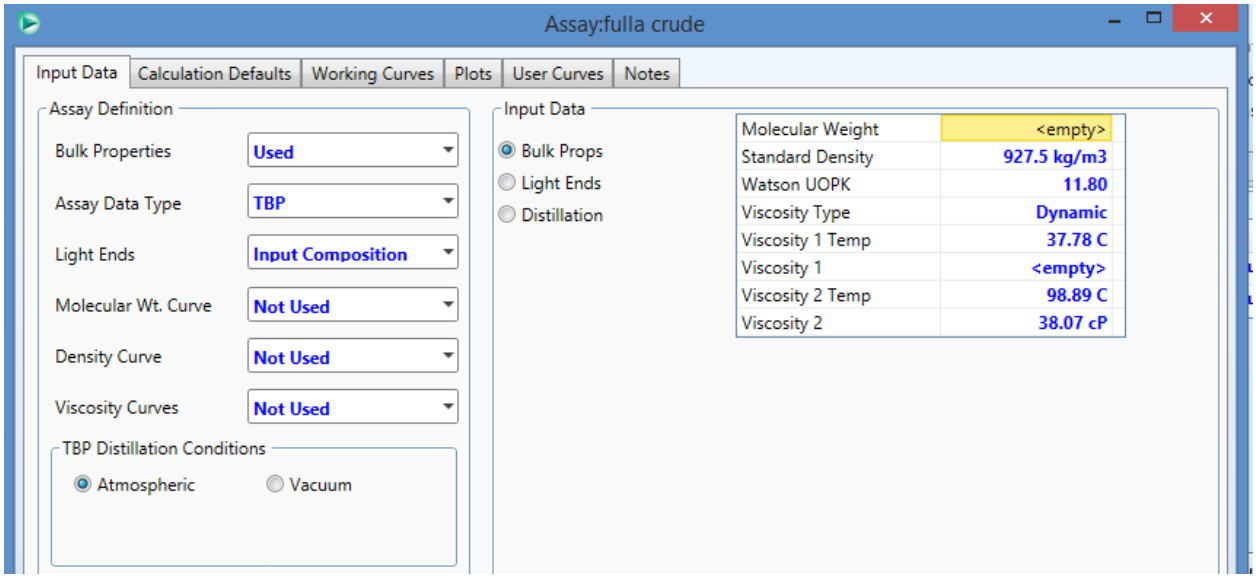
3.2 Simulation procedure:

3.2.1 Simulation software:

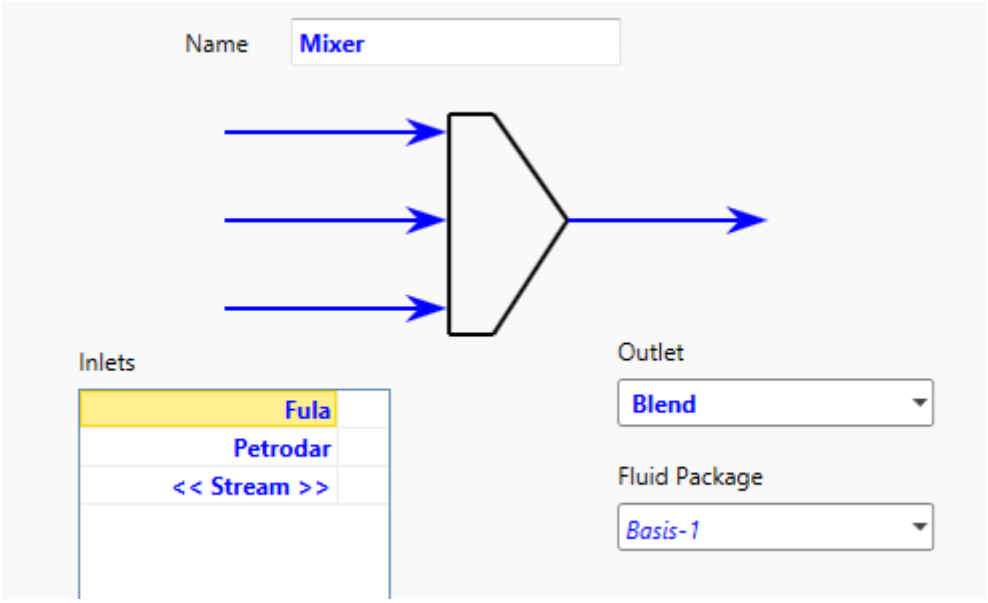
In this project we are using aspen Hysys v8.8 which is one of best simulation software in the field of downstream processing.

3.2.2 Simulation steps:

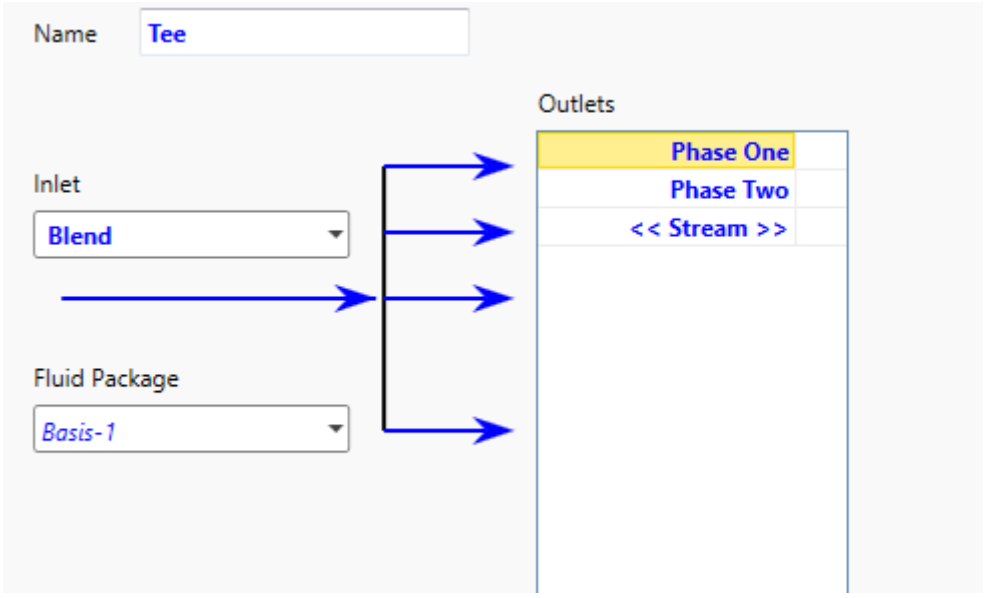
Petroleum assay instillation



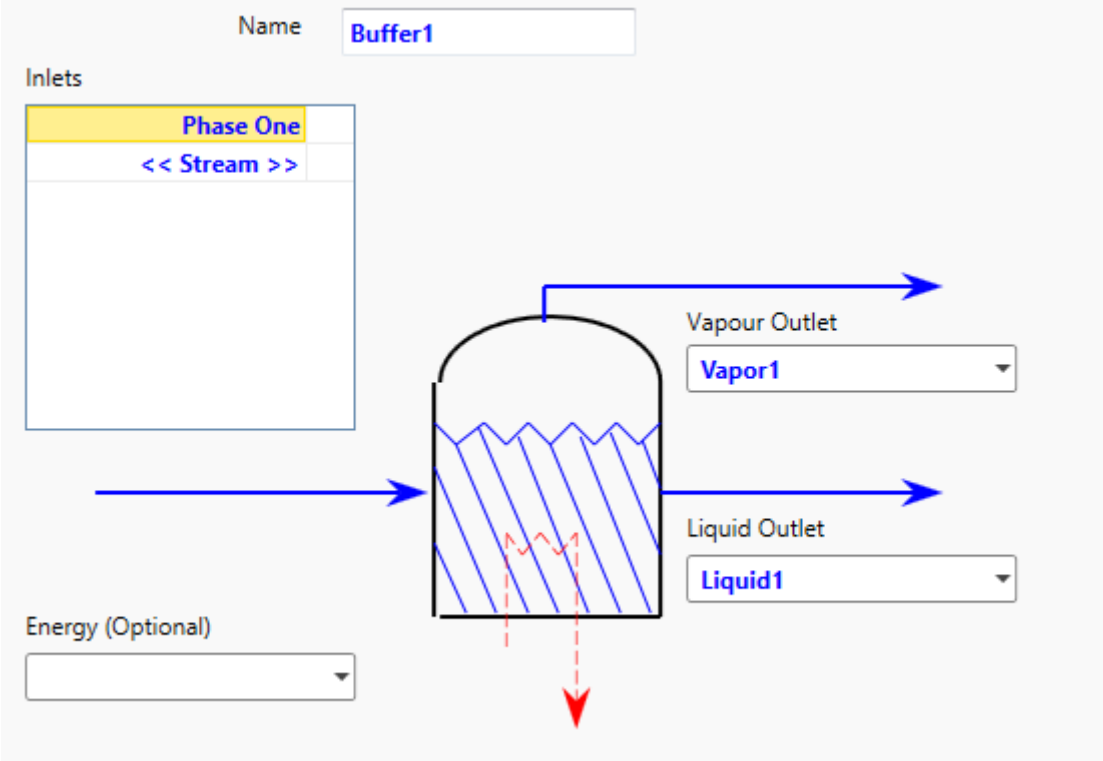
Mixing of Fula and Petrrodar crudes:



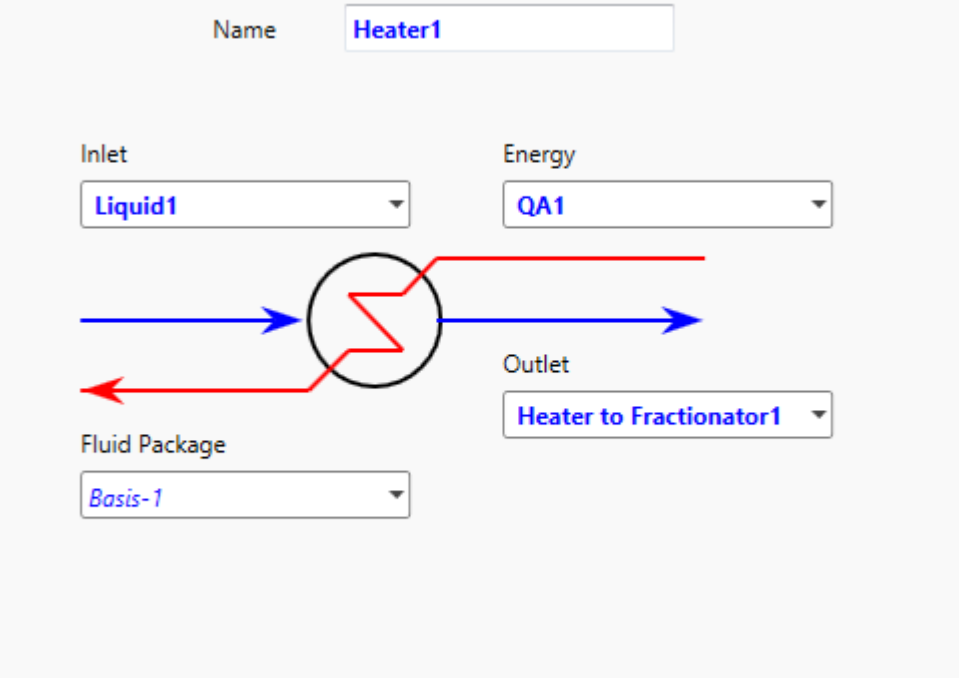
Divide the feed into phase one and two:



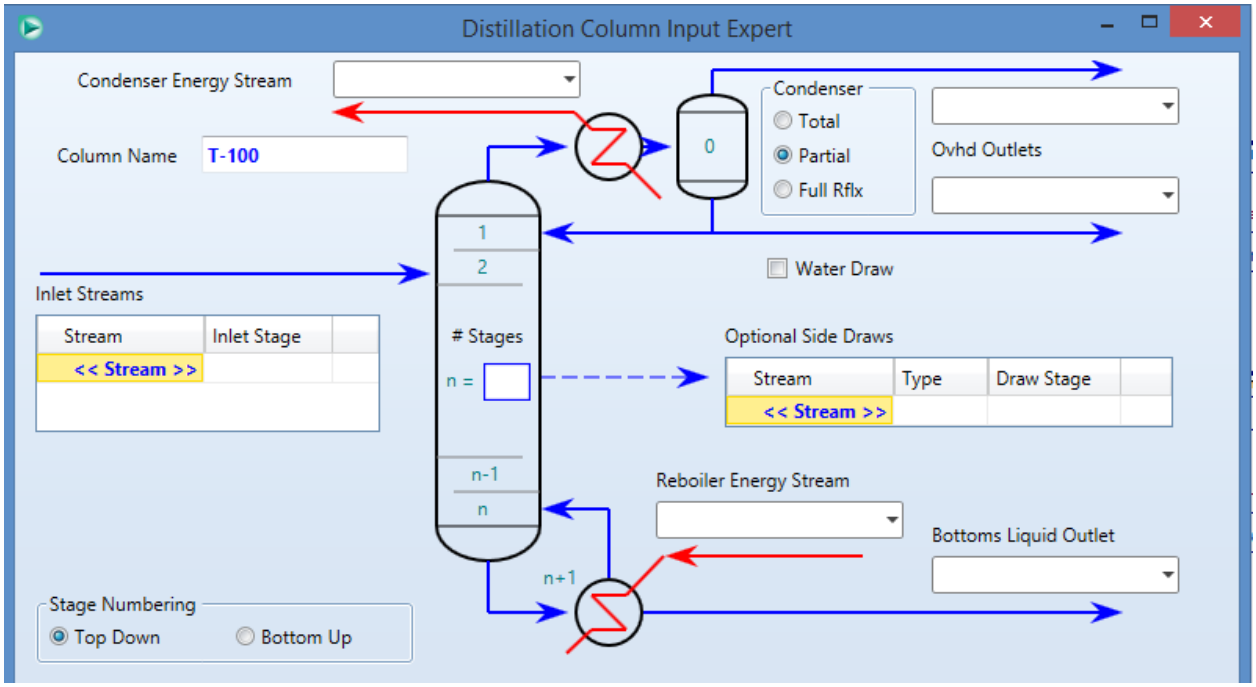
Starting phase one simulation by a buffer tank:



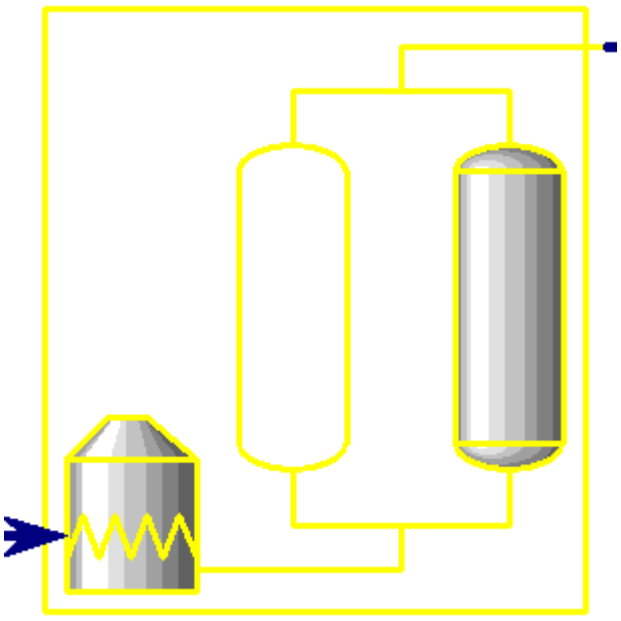
Now we preheat the feed:



The feed now is ready for distillation column:



Finally we calibrate the Coker and run the simulation then record the results:



3.3 Material balance:

An overallmaterial balance will be calculated for the whole process using the simulation software. And a correlation method will be used to predict the products yields manually.

3.3.1 Material balance by Prediction:

Estimation of product yields can be carried out using correlations based on the weight percent of Conradson carbon residue (wt% CCR) in the vacuum residue

$$\text{Gas}(C_4^-)\text{wt\%} = 7.8 + 0.144 \times (\text{wt\% CCR})$$
$$\text{Naphtha wt\%} = 11.29 + 0.343 \times (\text{wt\% CCR})$$
$$\text{Coke wt\%} = 1.6 \times (\text{wt\% CCR})$$
$$\text{Gas oil wt\%} = 100 - \text{Gas wt\%} - \text{Naphtha wt\%} - \text{Coke wt\%}$$

Diesel wt% = 64.5% * Gas oil wt

HCGO wt% = 35.5% * Gas oil wt

3.4 Drum Design:

According to ASME BPVC section VIII division 1, the design of coke drums can be conducted by these stipulations:

3.4.1 Minimum Thickness*:*

Theminimum thickness permitted for shells and heads, afterforming and regardless of product form and material, shallbe 1⁄16 in. (1.5 mm) exclusive of any corrosion allowance.

3.4.2 Design temperature

Maximum design temperature:

It must be not less than the mean temperature of the metal used expected at operation conditions.

Minimum design temperature:

It must be the lowest expected temperature in service and considerations must include any source of cooling in the process.

Design pressure

For each element it must be for the most severe pressure condition

3.4.3 Loadings

In designing a vessel loadings are including : design pressure , weight of the vessel , weight of attached equipment, attachment of internals and vessel supports , cyclic and dynamic reactions , temperature gradient and abnormal pressure, snow, wind etc.

3.4.4 Maximum allowable stress:

The maximum allowable tensile stresses of different materials are given in special tables, and the maximum longitudinal stress must be smaller than the values of (maximum allowable tensile stress B where its value can be determined from the applicable material chart. The value of Bshall be determined as follows:

Step 1 using the selected values of *t* and *R*, calculate the value of factor *A* using the following formula:

$$A = \frac{0.125}{(R_o / t)}$$

Step 2 using the value of A calculated in Step 1, enter the applicable material chart below.

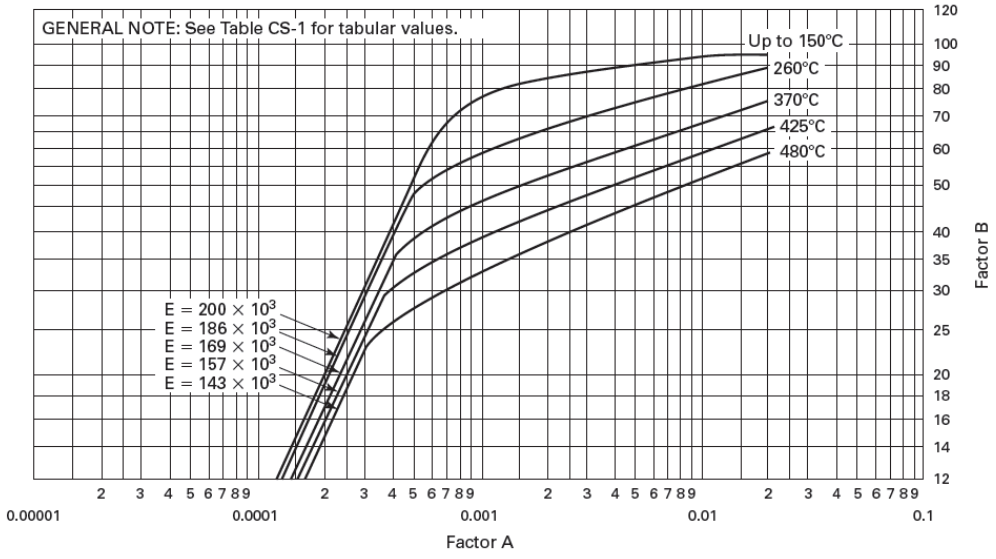


Figure 3.1 B factor calculation.

Move vertically to an intersection with the material/temperature line.

Step 3 from the intersection obtained in Step 2, move horizontally to the right and read the value of factor *B.*

This is the maximum allowable compressive stress for the values of t and R used in Step 1.

Step 4for values of A falling to the left of the applicable material /temperature line, the value of B shall be calculated using the following formula:

$$B = \frac{AE}{2}$$

3.4.5 Castings

Quality factors

For static castings quality factor shall not to exceed 80% and for nonferrous and ductile cast iron materials, quality factor not to exceed 90% but for carbon, low alloy steels, higher quality factors can be applied.

Defects

It should be a basis for the rejection of the casting and it can be repaired by welding, to exceed 90% to 100% quality factor, repaired castings must be stress relived.

Identification and marking

Each casting with quality factor greater than 80% must be marked with name, trade mark, quality factor and material designation. Etc.

3.4.6 Thickness:

The thickness of the coke drum can be calculated using the following formulas:

- Circumferential Stress:

$$t = \frac{PR}{SE - 0.6P} \quad \text{or} \quad P = \frac{SEt}{R + 0.6t}$$

- Longitudinal Stress:

$$t = \frac{PR}{2SE + 0.4P} \quad \text{or} \quad P = \frac{2SEt}{R - 0.4t}$$

Where:

t = minimum required thickness.

E = joint efficiency.

P = internal design pressure.

R = inside radius of the shell course under consideration,

S = B = maximum allowable stress value.

chapter 4 Calculation and Results

4.1 Simulation results:

The **Tables 4.1** to **4.4** shows the results For mixing ratios of 70/30, 50/50, 25/75, 0/100% for Fula and Petrodar respectively.

Table 4.1 Mixing ratio 70% Fula and 30% Petrodar:

Name		Yield	Flow Rate
		m%	kg/h
Input	Fula	70	175000
	petrodar	30	75000
	Subtotal	100	250000
	Rich Gas	8.686	21714
	Naphtha	15.441	38602
	Sour Water	0.184	461
Output	Diesel	43.392	108479
	Coke	12.8	32000
	HCGO	18.924	47310
	Loss	0.573	1434
	Subtotal	100	250000

Table 4.2 Mixing ratio 50% Fula and 50% Petrodar:

Name		Yield	Flow Rate
		m%	kg/hr
Input	Fula	50	125000
	Petrodar	50	125000
	Subtotal	100	250000
	Rich Gas	8.688	21719
	Naphtha	15.43	38596
	Sour Water	0.184	461
Output	Diesel	43.4	108495
	Coke	12.8	32000
	HCGO	18.919	47297

	Loss	0.572	1332
	Subtotal	100	250000

Table 4.3 Mixing ratio 25% Fula and 75% Petrodar:

Name		Yield	Flow Rate
		m%	kg/hr
Input	Fula	25	62500
	Petrodar	75	187500
	Subtotal	100	250000
Output	Rich Gas	8.686	21716
	Naphtha	15.44	38601
	Sour Water	0.185	462
	Diesel	43.4	108497
	Coke	12.8	32000
	HCGO	18.918	47295
	Loss	0.571	1427.5
	Subtotal	100	250000

Table 4.4 Mixing ratio 0% Fula and 100% Petrodar:

Name		Yield	Flow Rate
		m%	kg/hr
Input	Fula	0	0
	Petrodar	100	250000
	Subtotal	100	250000
Output	Rich Gas	8.69	21725
	Naphtha	15.44	38591
	Sour Water	0.093	233
	Diesel	43.4	108500
	Coke	12.8	32000

	HCGO	18.92	47299
	Loss	0.657	1642.5
	Subtotal	100	250000

4.2 Delayed Coker Yield Prediction:

4.2.1 Using correlation

Gas wt% = 7.8 + 0.144 * (wt% CCR)

Gas wt% = 7.8 + 0.144 * 4.4

=8.4336 %

So mass flow of the gas = 250000 * 0.084336 = 21084 kg/h

Naphtha wt% = 11.29 + 0.343 * (wt% CCR)

Naphtha wt% = 11.29 + 0.343 * 4.4 = 12.8 %

So mass flow of the naphtha = 0.128 * 250000 = 32000 kg/h

Coke wt% = 1.6 * (wt%CCR)

Coke wt% = 1.6 * 4.4 = 7.04%

So mass flow of the coke = 0.0704 * 250000 = 17600 kg/h

Total gas oil = 100 - Gas wt% - Naphtha wt% - coke wt%

Total gas oil= 100 - 7.04 - 12.8 - 8.43 = 71.73 %

Total gas oil = 0.7173 * 250000 = 179325 kg/h

HCGO wt% = 0.355 * total gas oil

= 0.355 * 179325 =63660 kg/h

Diesel % = 0.645 * 179325 = 115664 kg/h

4.3 Results comparison and discussion:

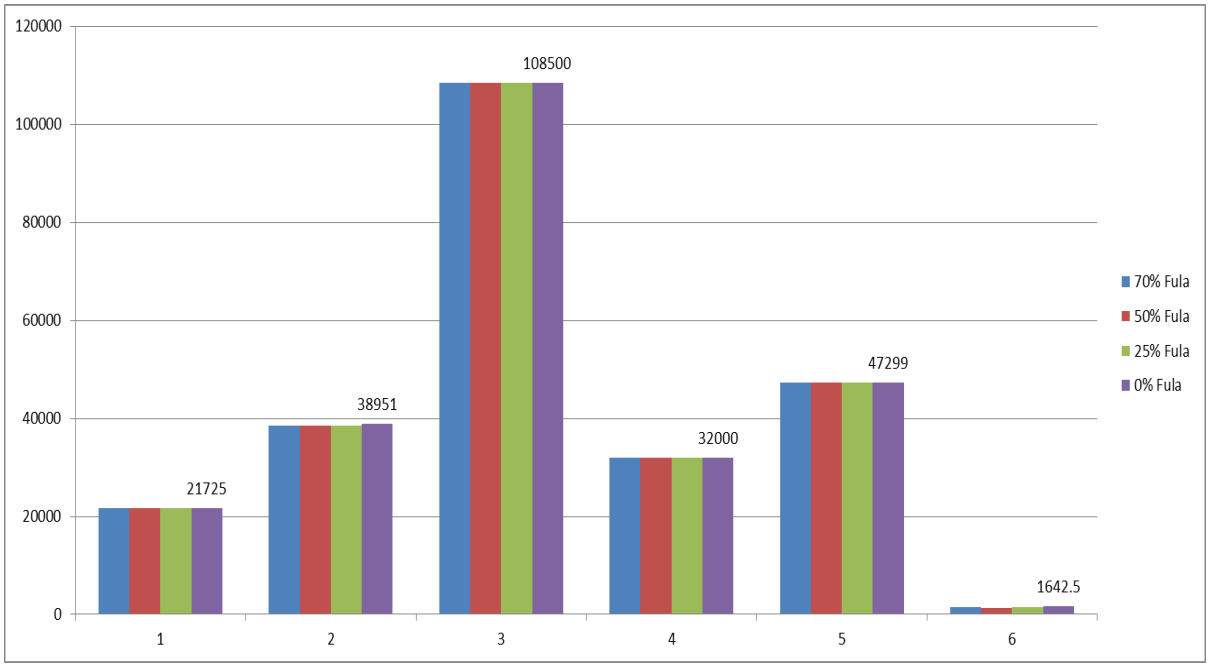


Figure 4.1 Comparison between mixing ratios.

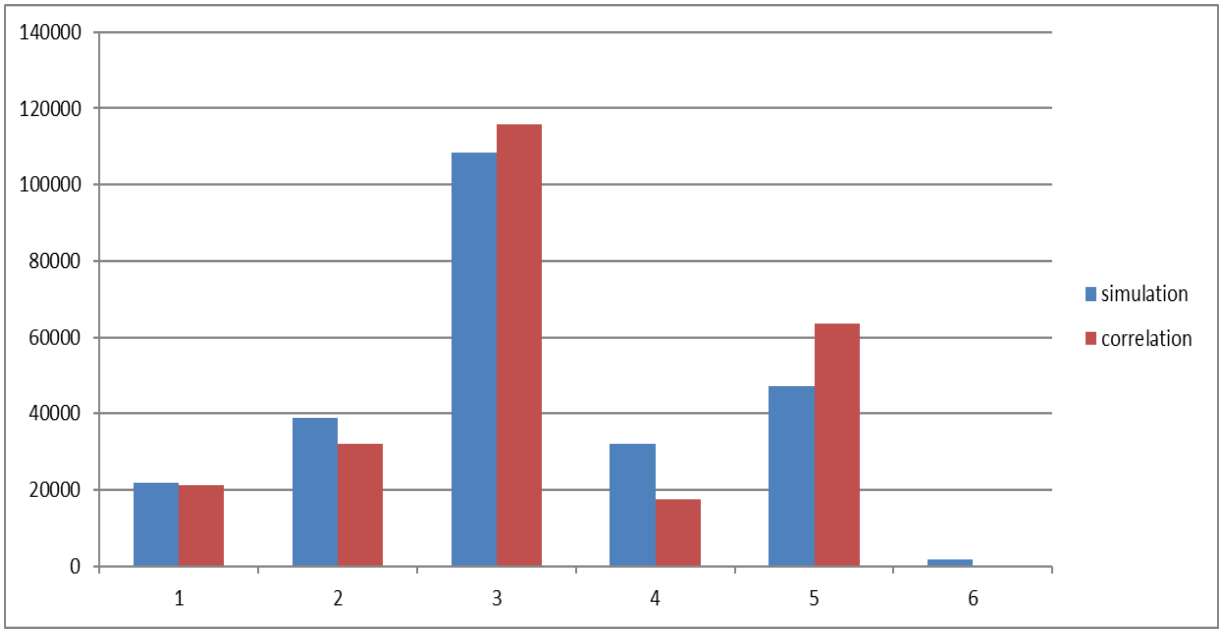


Figure 4.2 Comparison between simulation and correlation.

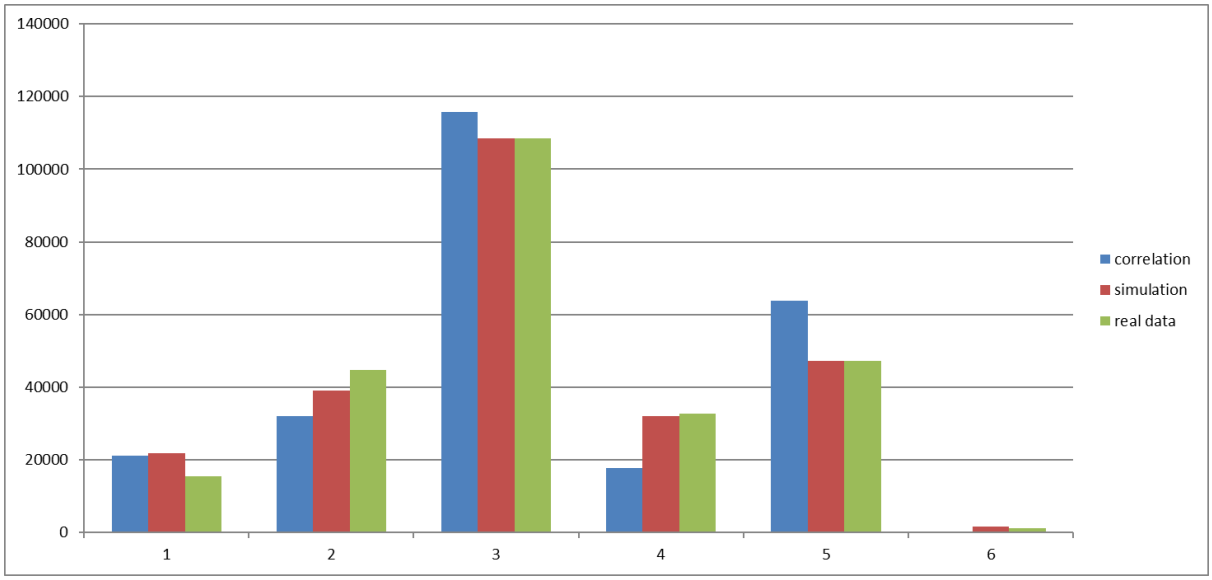


Figure 4.3 Comparison between correlation simulation and real data.

The numbers from 1 to 6 represent the products rich gas, naphtha, diesel, coke, HCGO, and loss respectively.

4.3.2 Findings:

From figures 4.1 to 4.3 we observe the following:

1. When changing the mixing ratios no significant change has been observed and that is due to the similarities between Fula and Petrodar crude.
2. When using correlation there is variation in some product yield in comparison with the simulation results.
3. The results from the simulation are very close to those from the real operation data.

4.4 Drum design calculations:

4.4.1 Maximum allowable stress

$$A = \frac{0.125}{\frac{R_0}{t}}$$

Where:

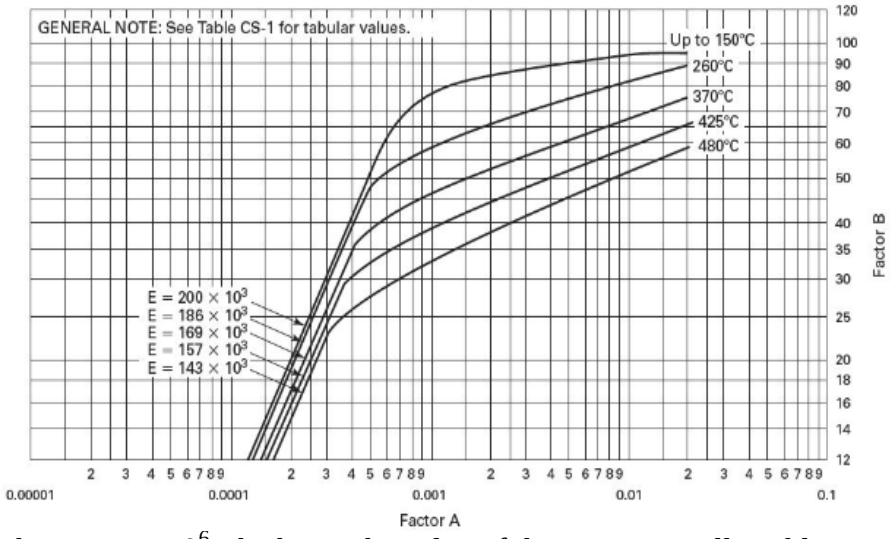
E = modulus of elasticity of material at design temperature
Ro= outside radius of drums
t = the minimum required thickness

We assume a thickness value of 56.5 mm to start the calculations. So A value will be

$$A = \frac{0.125}{\frac{4.2565}{0.0565}}$$

$A = 0.0015$

Using the following chart to determine B value



We found that B = $45*10^6$ which it is the value of the maximum allowable stress S

4.4.2 Minimum thickness

(1) Circumferential Stress:

$$t = \frac{PR}{SE + 0.6P}$$

Where:

E =joint efficiency
P = internal design pressure
R = inside radius of the shell course
S =maximum allowable stress value
t = minimum required thickness of shell

$$t = \frac{170 * 10^3 * 4.2}{45 * 10^6 * 0.6 + 0.6 * 170 * 10^3}$$

t =0.0158 m

(2) Longitudinal Stress:

$$t = \frac{PR}{SE - 0.6P}$$

Where:

E =joint efficiencyP = internal design pressure R = inside radius of the shell course S =maximum allowable stress valuet = minimum required thickness of shell

$$t = \frac{170 * 10^3 * 4.2}{45 * 10^6 * 0.6 - 0.6 * 170 * 10^3}$$

t =0.0159 m

We choose 0.0159 as the greater thickness of them to be the minimum thickness of drums.

4.4.3 Drum Design results:

design pressure	**170 kpa**
Design temperature	**480 ^{o}C**
Maximum allowable stress	**45 Mpa/m^2**
Thickness	**0.0159 m**

chapter 5 Conclusion and Recommendations

5.1 Conclusion:

In this project we have studied the effect of mixing Fula and Petrodar crudes and we've found no significant changes in products yields when doing so. We've also studied a correlation by (M. A. Fahim, T. A. Al-sahhaf & A. S. Elkilani 2010) to predict products yields and we've found some variation in products yields in comparison with the real operation data and simulation results. Finally we've studied aspects of drum design procedure and conducted some calculation.

5.2 Recommendations:

For further study of delayed coking unit specially the one operating at Khartoum refinery it might be efficient to operate the unit with Petrodar crude only and keep Fula crude underground as a reserve, another alternative is to construct a new unit operating with Petrodar crude instead of mixing it with Fula crude in one unit to double the yields of product, also changing process path by making crude or crudes mixture enter the unit's drums before entering the fractionator to minimize the corrosion effects of these type of crude on the fractionator and that's a field of further study.

5.3 List of References:

M. A. Fahim, T. A. Al-sahhaf & A. S. Elkilani, 2010, *fundamentals of petroleum refining.* Department of Chemical Engineering Kuwait University. Kuwait

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Xiaodong Yu,Yujie Wei, Dexian Huang, Yongheng Jiang, Bo Liu, Yihui Jin, 2011, *Intelligent switching expert system for delayed coking unit based on iterative learning strategy*. Beijing, Elsevier Ltd.

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