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CONVERSION OF TSIMORORO HEAVY OIL INTO LIQUID FUELS

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Abstract

Madagascar, the world's fourth largest island, is rich in biodiversity and mineral resources. There are huge deposits of hydrocarbons underground. Madagascar, for example, has a mining area called 3104 from Tsimiroro in the Morondava Basin, with an estimated 1.7 billion barrels of heavy oil reserves. Petroleum is both an energy source and a raw material. Therefore, the purpose of this study is to convert this heavy oil into different cuts. To this end, the methodology consisted of construction of a cracking plant, subsequent distillation of catalytic cracking products, and physicochemical analysis of heavy oil, cracking products and distillates. The results showed that the crude oil contained 46.58% aromatics with a viscosity and density of 2847.76 cSt and 0.98 respectively. Catalytic cracking produced 3.0% coke and 6.8% non-condensable gases, but the yield of combustible cracked oil reached 90%. The distillation of the cracked liquid produced light, medium and heavy fractions with a yield of respectively 14%, 78 % and 8 %. These results have shown the effectiveness of the process adopted, nevertheless, some improvements are being considered to optimize the quality of the fuel obtained. Of course, the use of eco-friendly alternatives is required to protect the environment, but for Madagascar, the development of this black resource, combined with measures to reduce environmental impact, is an important part of today's society, energy and It will be a way to overcome economic problems.

Key words : Heavy oil, Catalytic cracking, Distillation, Light fraction

Résumé

Madagascar, la quatrième plus grande île au monde, est une terre riche aussi bien par sa biodiversité que par ses ressources minières. Elle est dotée d’un sous- sol avec un énorme gisement d’hydrocarbure. Ainsi, Madagascar possède un bloc nommé 3104 de Tsimiroro, dans le bassin de Morondava avec une estimation de 1,7 milliards de barils d’huile lourde. Le pétrole est à la fois source d’énergie et matière première. L’objectif visé dans cette étude est donc la conversion de cette huile lourde en différentes coupes : légères, moyennes, lourdes de grande valeur. A cet effet, la méthodologie a consisté en la conception d’un appareil de craquage, puis en la distillation du produit de craquage catalytique, et en l’analyse physicochimique de l’huile lourde, des produits de craquage, ainsi que des distillats. Les résultats ont montré que l’huile brute contient 46,58% d’aromatique avec une viscosité et densité respectivement de 2847,76 cSt et 0,98. Le craquage catalytique génère 3,0% de coke et 6,8% de gaz non condensable, cependant un rendement de 90% d’huile de craquage a été obtenu. La distillation du liquide craqué a permis d’obtenir des fractions légères, moyennes et lourdes avec un rendement respectivement de 14 % ,78 % et 8%. Ces résultats ont montré l’efficacité du procédé adopté, néanmoins, quelques améliorations seront envisagées pour optimiser la qualité des combustibles obtenus. Pour Madagascar, l’exploitation de cette ressource noire accompagnée par des mesures d’atténuation des impacts environnementaux serait l’une des voies pour pallier les problèmes sociaux- énergétiques et économiques actuels.

Mots clés : Huile lourde, Craquage catalytique, Distillation, Coupe légère.

1- Introduction

Recognized for its exceptional biodiversity whether marine or terrestrial, Madagascar is indeed one of the richest spaces in the world biologically, it is home to 2% of the world's biodiversity and an exceptional amount of unique animal and plant species, 80 to 90% of which are endemic (J-S Ratsisompatrarivo et al, 2016) . Due to its geographical position, the subsoil of the large island is also full of precious stones and considerable oil deposits, an island with high potential treasures (V.Varian et al, 2012) (Soci, 1924) .

Huge hydrocarbon potential is distributed along the west coast of Madagascar. Tsimiroro is one of the earliest and most advanced projects, as this part of the country is a large sedimentary basin. The latter is an important oilfield belonging to the Morondava 'onshore' basin, located in the Menabe region, 300 km west of the capital. Known as Block 3104, its area is 6,670 km2 and 1.1 billion barrels out of an estimated 1.7 billion barrels are recoverable (V.Varian et al, 2012) .

The petroleum sector occupies a very important and prominent position in the global economy and is a preeminent strategic resource. Therefore, this project was carried out to investigate whether it is possible to extract crude oil or liquid fuel from Tsimiroro heavy oil. In fact, the main objective of this study is to extract crude oil and oil trimmings from heavy fuel oil with maximum efficiency. Therefore, the recovery consists of two steps. One is a thermal or catalytic cracking step, in which the largest molecules are converted to lower molecular weight molecules, yielding distillable products. The second step is the distillation of the cracking oil.

The specific objectives are to design a cracking apparatus, to distillate the cracking liquids from the experiments and to analyze the physicochemical properties of the heavy oil and its derivatives.

2- Methods

The methodology consisted of four stages: first the design of a cracking apparatus, then the experiment of cracking heavy oil followed by distillation and finally the physico-chemical analyses of heavy oil, cracking oil and distillates

2-1 Raw material and catalyst

- The raw material used is Tsimiroro heavy oil produced by the company MADAGASCAR OIL SA with no prior treatment.

- Catalytic cracking catalysts are of natural clay origin. Clay, as a rock, is made up of a mixture of silicates consisting of various substances in the form of particles where the diameter is less than 2µm, such as: carbonates, silica, alumina, sulphides, iron oxide and hydroxide. They are generally composed of oxides such as SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, CO_2 and H_2O with compositions that vary according to the place of origin (A.K.Coker, 2021) .

Three types of catalyst C1, C2, C3 based on natural clay were tested during this study.

2-2 Device design and experiments

The cracking apparatus includes:

- A fixed bed reactor of cylindrical volume approximately 0.006 m^3, 180 mm diameter and 2 mm thick, with a total height of 270 mm.
- A heating system since the reactor was heated to its walls in 2 zones: the lower part of the reactor and its contour. It consists of a burner, a fuel and an electric pump with a temperature control valve for pumping the fuel. Kerosene with a calorific value of 43,000 kJ/kg was used as fuel
- A cooling system equipped with a condensation column (tubular) and a vapor pipeline (pipe). The condensable hot permanent gases coming out of the reactor are driven into the

condensation zone. Steam and gases enter the column head and are immediately cooled by heat exchange between the water circuit and the hot steam.

- ➢ A safety system for the tightness of the equipment was provided by bolted flanges at the reactor and simple joints at the connection points. Its main purpose is to reliably contain liquids and protect the environment from contamination from leaking liquids.

The metallurgical assembly was designed using a stainless steel. The general principle of assembly is shown in Figure 1.

2-3 Catalytic and thermal cracking

Thermal cracking consisted of heating a mass of heavy oil at high temperature, at about 500°C, while the catalytic cracking was a heating of a heavy oil mass in the presence of a mass catalyst m. The goal is not only to reduce energy consumption, but also to produce more with a better quality product thanks to the selectivity of the catalyst.(J. G. Speight, 2013)

Kerosene was the fuel used in this study. Four experiments were conducted, one of which included two tests:

- ✓ Experiment 1 : Thermal Cracking
- ✓ Experiment 2 : Catalytic cracking C1
- ✓ Experiment 3 : Catalytic cracking C2
- ✓ Experiment 4: Catalytic cracking C3**bles**

Table 1 represents the different parameters of the experiments such as temperature, pressure, fuel volume and mass of heavy oil and catalyst.

2-4 Distillation of cracking liquids

Petroleum hydrocarbons contain extremely complex mixtures. The resulting cracking liquid underwent atmospheric distillation and vacuum distillation. Atmospheric distillation consisted in heating the cracking liquid in a distillation column, and thanks to the difference in boiling temperature of the components in presence and with vaporization, the volatile, light, intermediate products were collected. The heavy residue of the atmospheric distillation was then distilled under vacuum, ie at reduced pressure to collect medium and heavy fractions such as diesel (M. A. Fahim, 2010) .

The necessary equipment for distillation are: tank as reactor, tank heater, thermometer, condenser, vacuum pump. Thus, the cracked oils obtained were distilled to obtain petroleum cuts, according to ASTM D 2892[8], represented in the Table 2

2-5 Physicochemical characterization of heavy oil, cracking oil and distillates

2-5-1 The parameters to be analyzed

The kinematic viscosity, density, water and sediment content, SARA content, flash point and flammability point of the crude oil were determined. For cracking oil, these same parameters were analyzed except for the water and sediment content. The density and Reid vapour pressure of distillate products and by-products were also measured. For the quality control of the products obtained, chromatography on thin layer of crude oil, cracking oil, distillates with kerosene, diesel and petrol of petrol station was also carried out.

2-5-2 Methods of analysis

- ✓ The kinematic viscosity V in centistoke is the flow resistance of a liquid subjected to gravity. It was determined according to ASTM D 445

$$\mathbf{V = C \times t}$$

C: coefficient varying according to tube series and temperature. For 100 to 40°C series:C is equal to 0.01566
t: flow time determined using stopwatch

- ✓ The density

The density of liquids is the ratio of the density of the sample to the density of distilled water at the test temperature. Measurements were made with a 25 mL glass capillary cap pycnometer and manipulations were performed according to the ISO 3838- 2004 protocol. Being a petroleum product, the density of the heavy oil is expressed in « API degree” according to the ISO 3838 - 2004 formula.

$$\boxed{\mathbf{API} = \frac{\mathbf{141,5}}{\mathbf{Specific\ gravity\ at\ 15°C}} - \mathbf{131,5}}$$

✓ Flash point:

This is the minimum temperature at which the test portion must be taken so that vapors emitted spontaneously ignite in the presence of a flame under normal temperature and pressure conditions. The point of ignition of a liquid is the temperature at which it ignites in the presence of a spark. They were determined with the use of a Pensky-Martens closed-loop flash point device. The protocol was governed by ISO 2719-2016.

✓ Basic Sediment and Water

This method allowed the determination of the amount of water and sediment by centrifugation of the sample. The centrifugation was done for 30 minutes at 3,000 revolutions per minute in an ORTO ALRESA centrifuge. The standard of handling followed was ISO 3734- 1997. The volume was by visual reading and then expressed according to the formula

$$\boxed{\mathbf{BSW} = \frac{S}{V} * 100}$$

With S : volume of water and sediment after centrifugation ;
V : volume of sample.

✓ The quantity of asphaltenes

It was obtained by precipitating them by petroleum ether. Saturated, aromatic and resins (SAR) were recovered by preparative chromatography on layer, n-hexane was the migration solvent and revelation with the UV lamp at 256nm gave a brown reflection for resins, purplish for the aromatic and yellow for the resins

The percentage of asphaltene is given by:

$$\boxed{\%\ \text{asphaltene} = \left(\frac{mass\ (\ asphalten, filter) - mass\ (empty\ filter)}{plug\ mass}\right) * 100}$$

SAR percentages are given by:

$$\boxed{\%\ \text{compound} = \left(\frac{(\ sample\ set\ mass - asphalten\ mass) * mass\ of\ compound}{\sum\ \ mass\ (S,A,R) * sample\ set\ mass}\right) * 100}$$

✓ Reid vapour pressure :

REID vapour pressure measurements are used in the petroleum industry to measure the volatility of gasoline and other volatile petroleum products with a 15°C density between 0.710 and 0.785. The device used in the analysis meets ASTMD 5191, IP 409 (37.8°C), IP 481 and EN 13016-1 standards. The unit is kPa. The higher the value is, the more volatile the product.

- ✓ Quality control of products obtained by CCM

Thin-film chromatography was performed to compare the quality of distillates and cracking oils obtained in relation to the petroleum products of the service stations, as well as in relation to the original crude oil: A small drop of gasoline from theSP95 Service, PL Kerosene, P1, P2 and P3 products from the distillation of cracked oil, GO Gas Oil, HF Filtered Cracked Oil, HC Cracked Oil, HL Crude Heavy Oil were deposited on the CCM plate. The migration solvent was 100% heptane and revelation was achieved with UV at 265nm.

3- Results

3-1 The products of cracking

3-1-1 Returns

The main product of cracking was cracking oil (CL or cracked liquid), however this process also generated coke (solid residue) and non-recovered gases (NCG or non-condensed gas). Yield is the ratio of final mass/volume to initial mass/volume

- The cracking oil yield is:

$$\boxed{r_{hc} = \frac{V_f}{V_i} \times 100}$$

Vf: volume or final mass of cracked oil obtained
Vi : Volume or initial mass of heavy oil.

- The coke yield is:

$$\boxed{r_{coke} = \frac{M_f}{m_i} \times 100}$$

M_f: final mass of cracked oil obtained
M_i: the initial mass of heavy oil.

The non-condensable gas yield is:

$$\boxed{r_{GNC} = 100 - (r_{hc} + r_{coke})}$$

During thermal and catalytic cracking, the yield of the cracking liquid varies from 81.67% to 90.17%, that of coke from 3.02% to 15.21%. The gas loss varies from 3.12% to 6.80%. The Table 3 represents the details of this percentage.

3-1-2 Energy consumed during cracking

The amount of energy consumed is given by the relation

$$\boxed{Q = m\, C_p\, \Delta T + Pth}$$

With $Pth = S \times (T - t_a) \times K / 860$

The power is: $P = Q/t$, P: Power, Q/t: Energy provided by time

The specific heat of heavy oil is: **Cp = 4,476 to 5,002 J/kg**.°(H. Zare et al., 2023).

Take Cp = 5000 J/kg.°C

K = 0.55 kcal/h.m2°C for an indoor tank, thickness = 100 mm, S = 0.1780 m^2

Applying this formula, we have:

- ✓ For thermal cracking of heavy oil of mass 0.570 kg, for 9h 56 min or 35400 s at 515°C, the amount of fuel (Kerosene) consumed is 0.456 L. This is the amount of energy consumed **Qth = 7.732 kW/kg** of heavy oil.
- ✓ For catalytic cracking C1, the amount of fuel required to heat 0.568 kg of heavy oil to 400°C for 07h 36 min or 27 360 s is 0.284 L. Thus, the amount of energy consumed is **Q1 = 4.830 kW/kg** of heavy oil
- ✓ Catalytic cracking C2 consumed 0.150 L of kerosene to heat 0.503 kg of heavy oil for 04h 42 min or 16 920 s at 400°C, or 0.26 L of fuel / kg of heavy oil. Approximately **Q2 = 2.884 kW/kg** heavy oil.
- ✓ The amount of kerosene consumed for 400°C to heat 0.550 kg of heavy oil for 03h 26 min or 12 360 s is 0.110 L or 0.20 L of fuel / kg of heavy oil. Approximately **Q3 = 1.925 kW/kg** heavy oil.

3-2 Distillation products and by-products

During distillation, four products were obtained, one named P1 from atmospheric distillation and three named P2, P3 and P4 from vacuum distillation. Product P1 is a clear and transparent liquid, highly volatile and highly flammable by flame contact. Its boiling temperature ranges from 21°C to 155°C. It is classified as a light cut. The 3 products P2, P3, P4 from vacuum distillation are non-volatile and do not ignite at room temperature. They are classified as average. Product P3 is an oily and slightly viscous liquid, yellow in color and P4 is a slightly yellow colored liquid

When filtering the cracking oil, a product called P5 was obtained. It is orange brown in color and slightly viscous and oily. The purpose of the filtration is to know not only whether the black color of the cracking oil is eliminated or not but also to know the possibility of direct use of this filtered oil in thermal power plants**.**

Finally a heavy fraction named P6 was obtained at the end of the distillation of cracking oil

3- 3 Physico-chemical properties of crude oil, cracked oil and distillates

- ✓ Crude oil

The density of crude heavy oil is 0.9756 or 12.81 API., it is too heavy to distill compared to ordinary oil. Its kinematic viscosity at 50°C is 2847.7641 cst, it is a very viscous liquid. The flash point and ignition point of the heavy oil were 132°C and 135°C, respectively. Its water and sediment content was less than 0.05%. After calculating the percentages, the heavy oil consists of 13.79% asphaltenes, 15.88% saturated, 23.47% resins, and 46.85% aromatic

- ✓ Cracking oils

The 20°C density value of thermal and catalytic cracking oils ranges from 0.860 to 0.89. The lowest kinematic viscosity was 4.95 for catalytic cracking C3 and 11.14 for catalytic cracking C2. All cracking liquids ignite at room temperature. Compared to crude oil, a significant variation was observed regarding the percentage of SARA. The Table 4 represents the details of this result.

- ✓ Distillates

The density measurements of products P1, P2, P3, P4, P5 were performed by pycnometer at a temperature of 20°C. The density of liquid petroleum products is generally determined at 15°C, using an areometer (NF T 60-101 method). The ASTM D1250-80 tables allowed the conversion of the density from 20°C to 15°C. Distillate density values were synthesized in *the* Table 5. Thus, according to the density values, the distillates obtained can be grouped into three fractions: a light cut of the order

of 13.950%, a medium cut and a heavy cut respectively around 77.847% and 8.195%

- ✓ Quality control of products obtained by Thin Layer Chromatography

The purpose of this step was to compare the quality and composition of distillates, cracking oils with the petroleum products of the service stations, as well as with the crude oil of origin. The chromatographic profile shown on the Figure 2 showed that traces of blue hues are heavy components. They are present in crude heavy oil, C3 cracking oil as well as filtered oil. P1 and P2, respectively, are similar to gasoline and kerosene. They are light fractions. The product P3 is devoid of heavy fractions, its profile shows that it belongs to the gas oil family

4- Discussion

4-1 Cracking yields and energy consumption

The thermal cracking of the heavy oil yielded a liquid product rate of 84.69% and a fairly high coke rate of 11.26%. Compared to catalytic cracking C2 and catalytic cracking C3, the yield increased to 90%, with a coke production of up to 3,02%. For catalytic cracking C1, an increase in coke, a decrease in gaseous products and a decrease in cracking liquid were noted. Thus, the low temperature (400°C) increases the residence time and causes the formation of coke because of the difficulties of desorption of the surface of the catalyst. The natural catalyst C1 therefore has no specific activity compared to thermal cracking (500°C)

For catalytic cracking C3, the decrease in coke yield and the increase in gas yield are due to the increase in catalytic activity. However, among the four crackers tested, it is the catalyst C3 that generated less residues and losses, with a higher cracking liquid yield, it is also the least energy-consuming process. Thus, the results obtained with catalytic cracking C3 evoke the efficiency of catalytic cracking on both product yield and fuel consumption. From the economic and energy point of view, for thermal cracking, a quantity of 7.732 kW of energy was consumed for one kg of heavy oil, by contrast this value is 1.925 kW/kg of heavy oil using the catalyst C3, which is 4 times more economical.

4-2 Distillation des huiles de craquage

The purpose of distillation is to separate the oil cuts present in the cracking oil. Its efficiency depends on the performance of the device, the height of the column, and especially the temperature used. Atmospheric distillation of catalytic cracking liquid C3 allowed recovery of products with a boiling temperature below 200°C because the maximum temperature of distillation of petroleum in the laboratory was limited to 200°C. Subsequent distillation was provided by the use of a vacuum pump. The results obtained showed that on average 13.950% are light slices, approximately 77.847% and 8.195% are medium and heavy slices respectively. The catalytic cracking process followed by distillation is very beneficial compared to the previous study carried out in 2008 which was a direct distillation of heavy oil without pretreatment (A. J. Sylviano, 2008).

Compared to the world production of petroleum products whose demand for light products is between 10 and 30%, about 40% of the average cut and up to 20% of heavy products, the catalytic cracking liquid C3 that generated more average cut is therefore well comparable with the various crude oils such as Brent, Saharan crude and Saudi Arabia according to the Figure 3 (J. Eyssautier, et al. 2012) .

4-3 Physico-chemical characteristics of crude oil and products obtained

4-3-1 For crude oil and cracked oils

The viscosity of the crude heavy oil is 2847,76 cst, it is twice the value found in the previous study that was conducted in 2008. The viscosity of the cracking oil obtained with catalytic cracking C3, is 4.95 cst, this result testifies that the heavy products are well cracked in lighter and medium hydrocarbons, and it never returns to its initial state. The viscosity of heavy oil decreases with the increase in temperature and the use of catalyst C3. Catalytic cracking product C1 was also found to be even more viscous than high temperature (515°C) thermal cracking. As a result, the increase in viscosity in catalytic cracker C1 may be due to sediments from the natural catalyst C1 at low temperatures (400°C) (J. Ancheyta, 2011) .

The density of the heavy oil at 20°C is **0.975**. Liquids produced by thermal and catalytic cracking have a much lower density than the original heavy oil; from **0.886 to 0.86**, this could be due to an increase in aromatics or light cuts in the cracking oil (A. K. Coker, 2018) .

The flash point and ignition point of the crude heavy oil was 132°C and 135°C. Thus, at room temperature, the heavy oil is safe, it does not form an explosive vapor mixture only from 132°C and flammable from 135°C. While for cracking oils, they have already begun to ignite, at room temperature, so light products are well present in the mixture (M. A. Fahim et al., 2010) .

The asphaltene content of crude oil is 13.79%. Asphaltenes are solid, black brown, hard and brittle bodies, they also characterize the heavy and polar fraction content of the crude, they are responsible for the color of the product. Asphaltenes represent not only the less valued fraction of oil, but also they are the causes of various problems such as their flocculation forming deposits that obstruct the production and transport piping, their tendency to form various types of entangled fractal aggregates. The viscosity of crude oil is related to the asphaltene content. It was found that the rate of asphaltenes decreased during cracking, however asphaltenes are not completely eliminated (S. Fakher et al., 2020)].

The SAR content indicates the distribution of the different chemical families present in crude oil. Saturated are composed of n-alkanes, iso-alkanes and cycloalkanes (or naphthenes). Aromatics are generally made up of benzene and its derivatives. In the resin family, we find very polar compounds including long chains of alkanes that can contain cycles, heterocycles and different atoms such as nitrogen, oxygen, sulfur and even heavy metals (Ni, V).

The increase in saturated content in catalytic cracking liquids C1 and C2 is normal because it had a bond break during cracking, but the decrease in this content for C3 cracking could be due to the strong chemical reaction and saturated molecules can be transformed into other lighter, smaller molecules (gases) that could not be recovered [J. G. Speight, 2013].

The aromatics content of the catalytic cracking liquids C2 and C3 practically did not vary from crude since the cracked amount was compensated by the decomposition of asphaltenes, because the asphaltene molecules contain several aromatic molecules.

4-3-2 For distillates

For product P1: the value of its density at 15°C is 0.75, the analysis of its flash point at 37.8°C gave a value of 14 kPa. P1 is therefore a very volatile substance because:

If PV (REID Vapour Pressure) < 5 Pa: substance is very low volatile

If 5 Pa <
PV < 1000 Pa (1kPa): substance is moderately volatile
If 1 kPa < PV < 5kPa: volatile substance
If PV > 5 kPa: substance is very volatile

The density of P2 at 15°C is 0.768. The 15°C density values for engine gasoline are between 0.740 and 0.780. Thus, P1 and P2 belong to the engine gasoline family but an improvement such as catalytic reforming to increase the octane number, and the addition of additives such as more volatile benzene reduces the flash point, makes the product even more volatile (A. K. Coker, 2021)](J. H. Gary, 2020) .

Product P4 can be classified as jet fuel, having a density of 0.802 between 0.780 and 0.810 at 15°C. Jet fuels are aviation fuels. For qualitative analysis, its use in aviation is mainly due to its high calorific value, there must be a very low freezing point. Its melting temperature should be -50°C and 5.25 to 10.5 mmHg at 20°C saturated vapour pressure at 20°C. But due to lack of technical means, this analysis could not be performed.

The density of product P3 at 15°C is 0.829, it is similar to diesel, as its density is between 0.810 and 0.860. Its flash point is 47°C, very close to the standard for diesel, which is 50°C. But this difference may be due to the presence of a quantity of light cut that is not well separated during vacuum distillation.

4-4 Coke recovery

Petroleum coke is the final by-product of the cracking process. It is not a dangerous product and should not be a source of concern, its valuation will be considered, so nothing is lost everything is transformed. Its recovery will be non-energy. It could be used in various fields such as cement, metallurgy, foundry. Petroleum coke is also used in many products, including tires, batteries and steel. Having a strong absorption and adsorption capacity, it can also be used as an activated charcoal (A. Safitri, et al., 2022)

5- Conclusion

To conclude, studies have shown that crude heavy oil has physicochemical properties that are not directly suitable for the refinery. Its density and viscosity are very high. The presence of high asphaltene content indicates the presence of very heavy and complex fractions. Thus, thermal methods, which are thermal cracking and catalytic cracking followed by distillation, have been chosen for its recovery

The first treatment, which is thermal cracking, carried out at high temperature (515°C) gave yields of 84% with a high proportion of coke, whereas for catalytic cracking treatments, These showed better yields and decreased coke yield. Under the best operating conditions, about 90% by weight of liquids could be obtained with only less than 3% by weight of coke. Coke formation is inevitable for all cracking reactions.

The treatment of heavy oil by catalytic cracking results in a highly improved liquid product. The distillation of catalytic cracking oil C3 resulted in a light product that was identified as gasoline based on physico-chemical analysisThe energy consumed during processing is four times more economical than thermal cracking. Other products such as gasoil, kerosene, were also obtained by vacuum distillation.

Cracked liquids retain some of the contaminants from the original crude oil, such as sulfur and asphaltenes. Thus, a pretreatment that consists of removing the sulphur content and then the elimination of asphaltenes will be considered.

In terms of socio-environmental impacts, the realization of such a project requires special studies. Although it has economic benefits for the country, but it also has a reverse side which is environmental

pollution. Then related mitigation measures should be established such as upgrading the treatment unit, recycling the waste, and then reforestation to increase carbon dioxide sequestration.

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8-Tables

Table 1 : The different parameters of cracking experiments

Types of cracking	Mass of heavy oil in g	Mass of catalyst in g	Temperature in °C	Pressure in a bar	Initial fuel volume in l
Thermal cracking	Essai1 : m1 =577,74	0	515	1	1
	Essai2 : m2= 563,73	0			
Catalytic cracking C1	Essai1 : m1 =586,56	350	400	1	1
	Essai2 : m2= 550,43	551			
Catalytic cracking C2	Essai1 : m1= 479,28	290	400	1	1
	Essai2 : m2= 527,63	530			
Catalytic cracking C3	Essai1 : m1= 556,06	280	400	1	1
	Essai2 : m2= 544,40	545			

Table 1 shows the weights of the heavy oil and catalyst, temperature, pressure and initial fuel volume used in the experiments. An experiment consists of two tests

Boiling temperatures	**Pressure**
Initial point – 200°C	Atmospheric
200°C – 300°C	100 mmHg
300°C – 370°C	10 mmHg
370°C – 400°C	< 10 mmHg

Table 2 : Petroleum distillation (ASTM D2892)

	Thermal cracking	Catalytic cracking C1	Catalytic cracking C2	Catalytic cracking C3
Volume obtained in mL	495,5	**476**	**463**	**506**
% cracking liquid	84,696	**81,670**	**89,675**	**90,170**
Coke mass (g)	63,4702	**85,363**	**24,990**	**16,6512**
% Coke	11,1245	**15,210**	**4,981**	**3,025**
% Loss (gas)	4,179	**3,122**	**5,343**	**6,805**

Table 2 shows the temperature and pressure values used in atmospheric and vacuum distillation of cracking oils

Table 3 : Yields of cracking products

Table 3 represents the average of the products obtained with the two tests carried out for each type of cracking, it also synthesizes the percentage of coke and gas which are considered as residue and loss respectively

Analyses	Huile brute	Craquage thermique	Catalytic cracking C1	Catalytic cracking C2	Catalytic cracking C3
Density at 20°C	0.975	0,889	0,886	0,885	0,860
Kinematic viscosity cSt	2847.76	10,24	11,14	10,78	4,95
BSW	< 0.05%	-	-	-	-
Flash point	132°C	Ignites at room temperature			
Ignition point	135°C				
% Asphaltènes	13.79%	9,80	11,14	9,99	8,19
% Résins	23.46%	39,19	34,42	28,91	34,42
% Aromatics	46.85%	34,93	23,61	30,66	45,43
% Saturated	15.88%	16,06	30,81	30,42	11,95

Table 4 : Physico-chemical properties of crude oils

Table 4 summarises the physico-chemical characteristics of crude oil, cracking oils from thermal cracking and catalytic cracking.

Table 5 : Densities of the products obtained

Table 5 summarises the density values of the products P1to P5 obtained during the distillation of the cracking liquid C3.

9- Figures

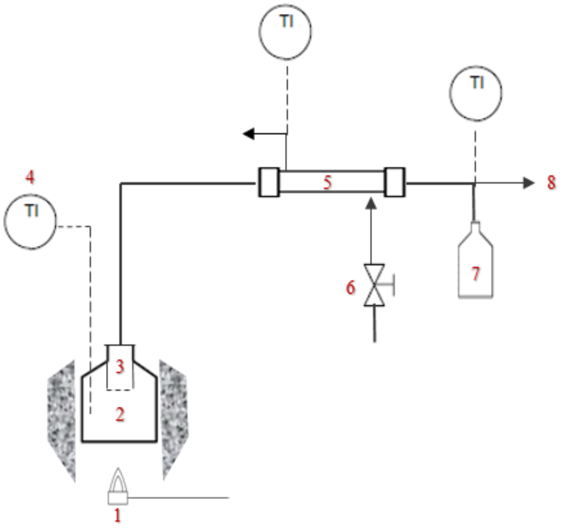


Figure 1 Diagram of the assembly of a cracking device

Legend :

1.Burner 2. Reactor 3. Catalytic bed

4. IT: Temperature Sensor

5. Condenser

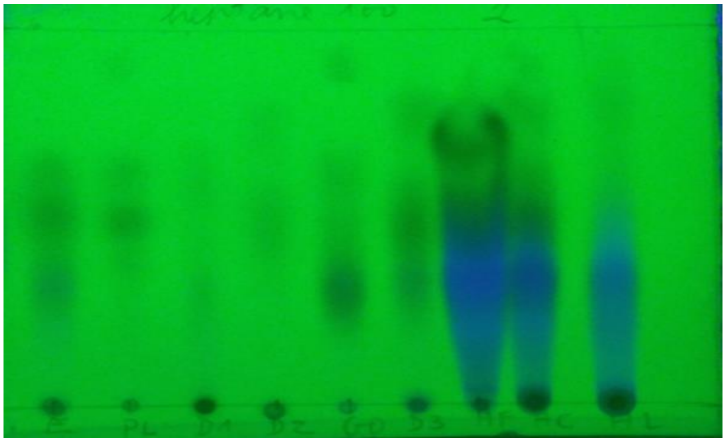
6. Manual valve

7.Product recovery tank

8. Out of non-condensable gases

PRODUITS	**DENSITE (20°C)**	**DENSITE (15°C)**
Produit P1	0,749	**0,754**
Produit P2	0,763	**0,768**
Produit P3	0,824	**0,829**
Produit P4	0,792	**0,802**
Produit P5	0,880	**0,883**

Figure 1 shows the principle of assembly when designing the cracking apparatus



Legend: From left to right:

- SP95 Gasoline Service Station
- Kerosene PL
- P1 deposit of distillate sample
- P2 deposit of distillate sample
- GO Gas Station Diesel
- P3 deposit of distillate sample
- HF filtered cracking oil deposit
- HC cracking oil deposit
- HL heavy crude oil deposition

Figure 2 : Chromatographic profile of crude oil and its derivatives

Migration solvent: heptane 100%, Revelation UV 365nm

Figure 2 shows the profile of the products P1, P2, P3 from the distillation of the cracking liquid C3 with the petroleum products of the service station. This was done for the control of the products obtained.

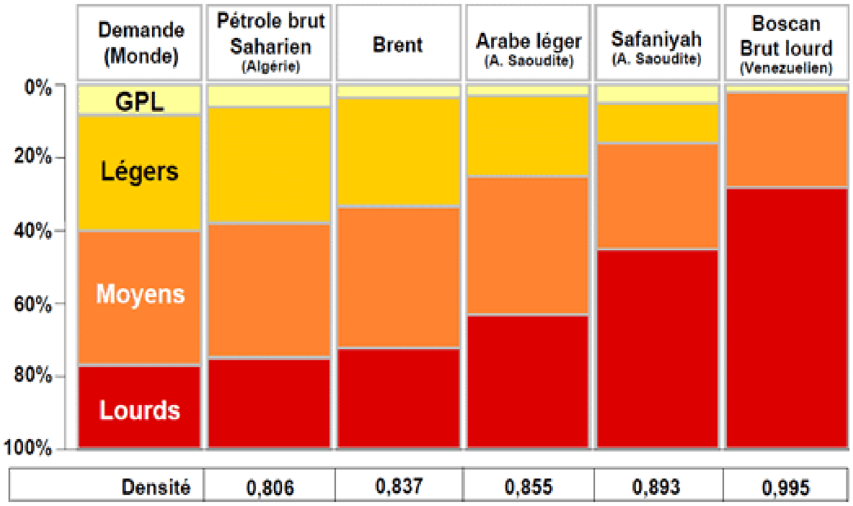


Figure 3 : Comparison of yields of different crude oils [11]

Figure 3 shows the refining yields of the various crude oils, this graph allowed to compare the crude oil obtained during the cracking of tsimiroro heavy oil with Brent and other crude oils of the international market.