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Cold Cracking Technology for Crude Oil Upgrading in Qaiyarah Heavy Oil Field; Technical and Economical Evaluation

Herish Bibani [a, *], Ayad A. Alhaleem [a], and Mohammad Sharifi [b]

a Petroleum Engineering Department, College of Engineering, University of Baghdad, Baghdad, Iraq
b Amirkabir University of Technology, Petroleum Engineering Department, Iran

Abstract

Heavy oil is classified as unconventional oil resource because of its difficulty to recover in its natural state, difficulties in transport and difficulties in marketing it. Upgrading solution to the heavy oil has positive impact technically and economically specially when it will be a competitive with conventional oils from the marketing prospective. Developing Qaiyarah heavy oil field was neglected in the last five decades, the main reason was due to the low quality of the crude oil resulted in the high viscosity and density of the crude oil in the field which was and still a major challenge putting them on the major stream line of production in Iraq. The low quality of the crude properties led to lower oil prices in the global markets as well as the high operation cost of production and transportation. The purpose of this paper is testing new technology applications on an Iraqi Heavy Oil Field and specifically (Qaiyarah Oil Field) by applying the cold cracking technique to upgrade Qaiyarah heavy oil properties through using series of electrical/ mechanical activities applied on the heavy crude that generates special kind of vibrations to re-structure the (H-C) bonds in the heavy oil to convert it to lighter crude with lower viscosity/ density which was the outcome of the distillation by reducing the unsaturated components and isolating the minerals and sulfur as sold components. The results were very optimistic, where the density has improved from 16 to 30.5 API degree, sulfur content has reduced from 6.4 to 1.507 weight percent and selling price per barrel would increase by 53% compare to 2.31% cost increment due to the upgrading operation. Therefore, applying the cold cracking technology is convenience for improving Qaiyarah oil properties as the main production stream line will be increased in Iraq.

Keywords: Cold cracking; Qaiyarah heavy oil field; heavy crude upgrading; synthetic oil; oil production cost.

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1- Introduction

It is crucial to study the heavy crude properties which is influenced by its heavy components [1]. Most of the major oil companies started looking for developing and resolving challenges of heavy oil fields in the world through studying subsurface, production operations and transportation to marketing, more specifically to develop the heavy oil industry globally, especially when considering that the unconventional crudes are making around 70% of the world hydrocarbon reserves [2]. As, the production from of high quality (light) crude oil is approaching its peak, more attention is has shifted in the petroleum industry is directed toward the development of a large quantity of heavy oil and bitumen to ensure sustainable supply to the growing demand for energy. These low quality hydrocarbons (heavy oil and bitumen) are usually known by high viscosity, low API gravity and high density [3].

There are great unconventional oil beds in Canada, Venezuela and Middle East that reach a total amount around 5 to 7 trillion barrels, with recovery potential in the order of 800 billion barrels, which could assist, satisfactorily, the future derivate needs for world consumption. However, the Athabasca oils (Canada) and the Bosman oils (Venezuela) contain a high sulfur content 4.27 and 5.27% in mass [4].

By increasing the cost of producing the heavy crudes compare with the conventional oil, developing and getting the conventional crudes started to reduce due to the extra production for compensating the global markets, especially when oil prices reached more than $100 per barrel. At that time the oil companies started to focus on heavy oil production again in a try to satisfy the demand markets for crude oil [5].

This action, put the initiation steps to be one of the major sources of blending crudes in the early future. Additives like naphtha is reducing the high viscosity while is blended with heavy oil [6], but usually there will be some sort of instability after the mixing process resulted in different kinds of undesired residuals. The viscosity of heavy oil is diminishing with increasing solvent concentration [7]. Heavy and extra heavy crude production and treatment issues started to be one of the most cortical matter in the oil industry of Iraq, since this type of crudes have a noticeable portion of Iraq oil reserves and the expectations that the conventional crude production will eventually drop and at that time to maintain the production plateau needs to develop the heavy crude fields which have a major challenge that is

*Corresponding Author: Name: Herish Bibani, Email: hairash.nadhum1308d@coeng.uobaghdad.edu.iq

the transportation to the export points since heavy oil transportation has become a complex and highly technical operation especially when it contains Sulphur [8].

Qaiyarah oil field have been discovered by the German in 1918 by the appearance of the seepages at the surface, where the major portion of the field is located to the west of tigress river about 65 Km southern of the City of Mosul, Fig. 1 [9]. The field dimension is about 15 Km length and 3.5 Km width. Qaiyarah field is an anticline trap forming part of a bigger structure composed of 4 anticlines: Qaiyarah, Najmah, Jawan, and Qasab. The three first structures are successive individual, culminations on a single fold axis, which trends approximately northwest from the western bank of the Tigris at Qaiyarah. Qasab is a parallel anticline, with two domes, which is offset to the northeast, and separated from Jawan by a broad, shallow synclinal saddle, Fig. 2 [9].

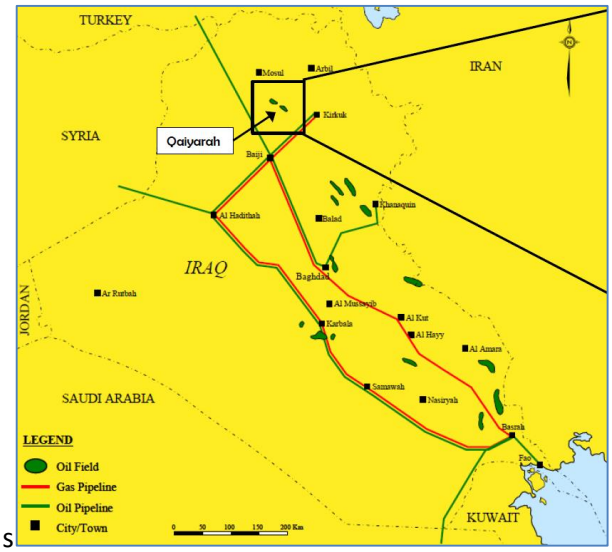

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Fig. 1. Qaiyarah Field Location [9]

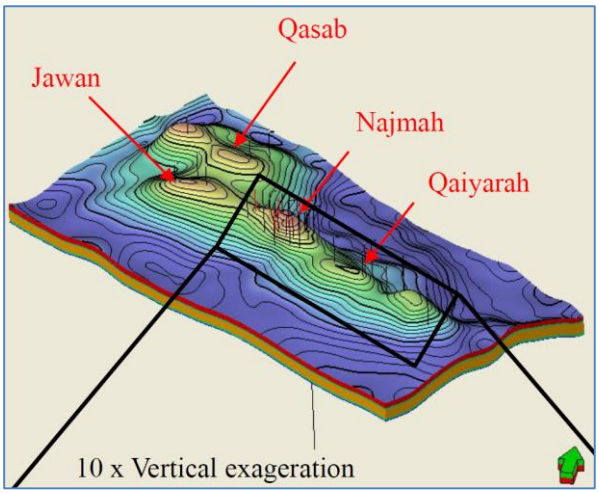

Fig. 2. Qaiyarah Field Reservoir Structure [9]

Because of the low quality properties of Qaiyarah crude oil, the production was limited only to a local refinery since 1970s.

The main aim of this paper is having technical and economical evaluation of this field using the latest techniques for heavy crude upgrading in a tray to upgrade the heavy crude of Qaiyarah oil field. Result of this study can be considered as an initiation step to continue developing other four fields in the region which have almost the same crude oil properties as shown in Table 1 mentioning the volume of available crude in the region in order to produce a synthetic crude that can compete the conventional crudes in north of Iraq. Fig. 3 shows a group of fields on the same trend line having the same properties.

Table 1. Available Crude in Qaiyarah and other Field in the Same Region [9]

Field	Qaiyarah	Najmah	Qasab	Jawan
STIIOP (MMSTB)	6,856	5,718	2,318	6,716
Reserve (MMSTB)	813	858	347	1007
API	16	17	17	17
Sulfur Content (Wt.%)	7.3	7.6	6.7	6

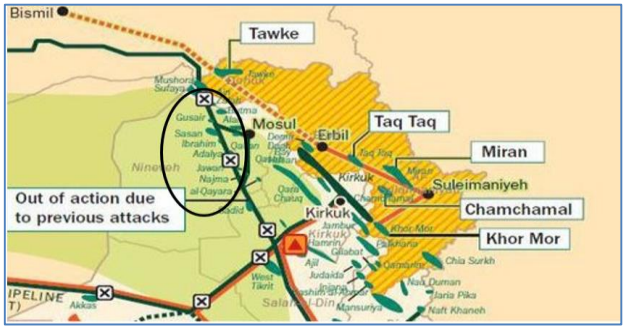

Fig. 3. Group of Heavy Oil Fields in North of Iraq [10]

2- Methodology

There is an important point related to producing unconventional crudes indicating besides the cost of production, there will be another issue of transportation cost, this is all because of its high viscosity/density so, its prices will be much lower than the conventional crudes.

By applying new technology of upgrading the properties of Qaiyarah heavy oil through applications of cold cracking technology to upgrade the crude properties to be a competitive for the conventional crudes and making a technical comparison analysis of the crude properties as well as economical evaluation of the crude prices before and after the upgrading that is going to be an encouragement push to develop many other fields in the region.

This paper will evaluate results of crude analysis taken from Qaiyarah oil field in north of Iraq before upgrading and after applying the upgrading to enhance the crude properties specifically density, viscosity and sulfur content which are considered as a major property that are effecting on the quality of crudes and eventually its prices.

After completing the production operations, the major challenge facing Qaiyarah crude is the transportation to the refineries or the export points and since there is no independent flow lines to transport the heavy crude

separately, the only options was available is to mix the heavy crude with conventional crudes of the northern fields in north of Iraq which have average API of 32, but this was causing a depositions in the flow lines leading to block the flow in the pipe lines and on the other hand reducing the quality of the selling crudes and this was unfeasible and not acceptable by Iraqi oil ministry.

There is a possibility to take advantage from previous experiences of heavy crude upgrading that are used in Canada and Venezuela since there are consider top pioneer countries in producing and upgrading heavy and extra heavy crudes. A feasibility study has been done showing a comparative of operating expenditure (OPEX) and barrel price before and after the upgrading using Eqs. 1 and 2 [3].

$$\text{Price of Qaiyarah heavy crude without upgrading} = \text{Brent Mixture} - \$32 \quad (1)$$

$$\text{Synthetic Crude with upgrading} = \text{Brent Mixture} + \$5 \quad (2)$$

2.1. Possibility of Upgrading Qaiyarah Heavy Crude

Qaiyarah field STIIOP is around 6.856 MMM STB and the reserve is estimated to be 813 MMSTB by primary production mechanism. Due to the high sulfur content and hydrogen sulfide reduced the options of selecting an optimum technique to upgrade the heavy crude properties without considering the huge volumes of produce sulfur. Table 2 and Table 3 represents Qaiyarah heavy crude oil composition and properties for the treated and untreated oil, respectively.

Table 2. Qaiyara Crude /Reservoir Fluid Analysis (Treated)[1] [9]

Composition	Weight percentage (Wt.%)
C1	0.22
C2	0.70
CO2	0.07
H2S[2]	0.91
C3	0.89
iC4	0.24
nC4	0.92
iC5	0.78
nC5	0.63
C6+	94.64
Sp.gr. for C6+ measured at 60/60 °F	0.9830
Sp. gr. Of the reservoir fluid measured at 60/60 °F	0.9444
Measured GOR (SCF/STB)	104

[1] Average analysis from two key wells.
[2] This value is relatively low, could be due to observing the hydrogen sulfide by the minerals of the container.

Table 3. Qaiyara Crude /Reservoir Fluid Analysis (Untreated)[1] [9]

Property	Measured value
API gravity	15.6
Kinematic Viscosity at 80°F (C St)	489
H2S (ppm)	1200
Sulfur (Wt %)	7.6
Asphaltine (Wt %)	12.2
Wax (Wt %)	2.0

[1] Average analysis from two key wells.

Based on the field development plan, there will a possibility to increase the production plateau to reach 130,000 bbl/day and this is considering a huge step in developing the field and based on that, upgrading the crude oil properties to be comparative to the conventional Iraqi crudes using latest upgrading processes to make Qaiyarah synthetic crude.

The next section will be the use of new technology in upgrading, which is improving Qaiyarah crude properties and make an optimum technical/ feasible evaluation.

2.2. Cold Cracking Technology

Cracking disrupts hydrocarbons into simpler molecules for upgrading the heavy crude oil quality [11]. Fig. 4 is showing a schematic diagram of the upgrading of heavy oil through the bond breakage in the asphaltene [12, 13].

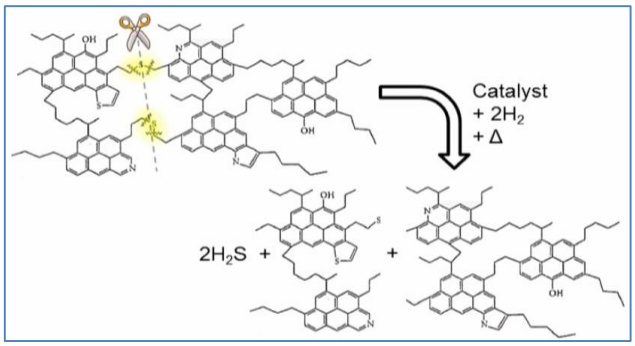

Fig. 4. Schematic Diagram of Upgrading of Heavy Oil through Bond Breakage [12]

Heavy crude oil eventually will be used to meet the growing demand for fuels since most if not all of the world's refineries are not suitable for processing these types crude, so upgrading processes are required to make synthetic crude oils from those resources compatible with the equipment installed [16]. The cold cracking technique consider a huge jump in the upgrading process by avoiding using chemical or thermal materials, also proving synthetic crudes with very high quality properties compare to the other traditional methods as shown in Fig. 5.

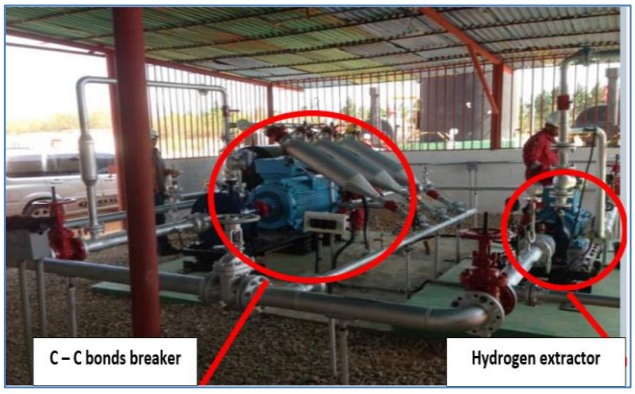

Fig. 5. Cold Cracking Unit and Hydrogen Extractor Unit [12]

In general, the conversion process is proposed to reduce the production of heavier components [13]. The idea behind this technique is a series of Electrical/mechanical activities applied on the heavy crude that generates special type of vibrations to re-structure the (H-C) bonds in the heavy oil to convert it to lighter crude with lower viscosity and density [12,15].

This technique will apply a vibration electron that cause rearrange the electrons of hydrogen – carbon and cause changing the physical and chemical properties for the atoms and this could be summarized below:

- Unstable the hydrogen electrons.
- Break down the (C - C) single and double bonds at the same time the (H – C) bonds to convert the heavy component to medium distillation products.
- Reconstruct the treated (H – C) bonds which was the outcome of the distillation by reducing the unsaturated components.
- Isolate the minerals and sulfur as sold components.

This technique worked efficiently on Qaiyarah crude by separating the hydrogen sulfide which is one of the major challenges in producing the heavy oil in the area, and took the hydrogen atoms to separate the sulfur as solid material. Fig. 6 is representing mechanism how the system can be working in Qaiyarah, since there is a refinery next to the field.

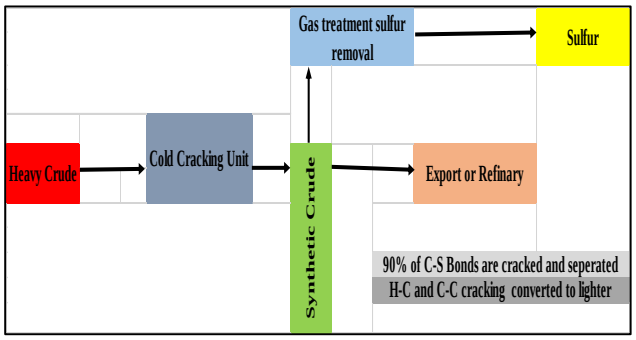

Fig. 6. Flow Chart Showing How the System Will Be Working in Qaiyarah

3- Results and Discussion

Sample of crude oil has been taken from Qaiyarah Field / South Degassing station to the central laboratories at North Oil Company in Kirkuk/Iraq for complete analysis and normal inspection data (NID). Similarly, another sample from same mentioned source was analyzed after apply the cold cracking technology on it. The results of crude oil analysis before and after the upgrading process is shown in Table 4.

It can be notice clearly that most the crude oil properties which is evolve to make the crude oil being heavy are upgraded positively and be competitive to the conventional crude oils. At the same time and as it can be seen from Fig. 7, the analysis results, there is a noticeable increment in the API of the synthetic crude with huge decreasing in the viscosity and the Sulphur content.

Table 5 shows the cost per barrel of Qaiyarah crude before and after applying any upgrading and price of selling crude as it was announced by Iraqi government through the Selling Oil Marketing Company (SOMO), Ministry of Oil (MoO/Iraq) on Jul./2022, where the selling price for Qaiyarah oil was 50.4 $/bbl of and average selling price for the conventional oil from other oil fields of Iraq was 92.6 $/bbl at the export point in Jihan Perl in Turkey, while Brent price was 118 $/bbl.

Table 4. Crude Oil Analysis Before and After the Treatment

Parameter	Crude analysis before treatment	Crude analysis after treatment
Source	Qaiyarah / north degassing station	Cold cracking unit outlet
Sampling date	Feb.-2019	Mar.-2019
SP.GR (60/60 F°)	0.959	0.876
API	15.9	30.5
Water content (%Vol.)	5.4	6
H2S (ppm)	659	110
BS & W% Vol. by centrifuge	6	6
Salt (ppm)	7.25	7.25
Acid number (mg KOH/g)	1.63	1.63
Organic chloride (ppm)	4.6	4.55
Sulphur ,%Wt	7.6	1.507
Kinematic viscosity at (80 F°) (Cst)	489	15.679

Table 5. Qaiyarah Crude Activity Cost/ bbl Before and After Upgrading

Activity/ bbl	Before upgrading	After upgrading
Production cost	7.2	7.2
Contractor cost	5	5
Crude transportation by trucks	1	
Operating cost using the upgrading units	-	3
Unit maintenance cost	-	0.31
Total	13.2	15.51

Analyzing the results of the treatment technically and comparing the prices over all showed encouraging results to go further with this technology through applying it on the heavy oil field in Iraq. After upgrading the crude to reach 31 in API gravity which is almost close to the selling mixture of North of Iraq crudes that was around 32 API gravity. By that, the profit percentage from single barrel will increase around 53% in a comparative of OPEX increment by almost 2.31 $/bbl.

The feasible study can be summarized through as a comparison between the synthetic crude which is upgraded and actual Qaiyarah heavy crude that was with API gravity ranging 16 – 20 taking into account the two equations that mentioned earlier as average of selling price of heavy crude and synthetic crude as it is also shown in Fig. 8. Although there are some uncertainties in oil price and other practical issues in cold cracking technology but looking at Fig. 8, it can be seen that using this technology can lead to huge economic benefit. More detailed feasibility analysis can be conducted to consider all practical issues and reduce the uncertainties.

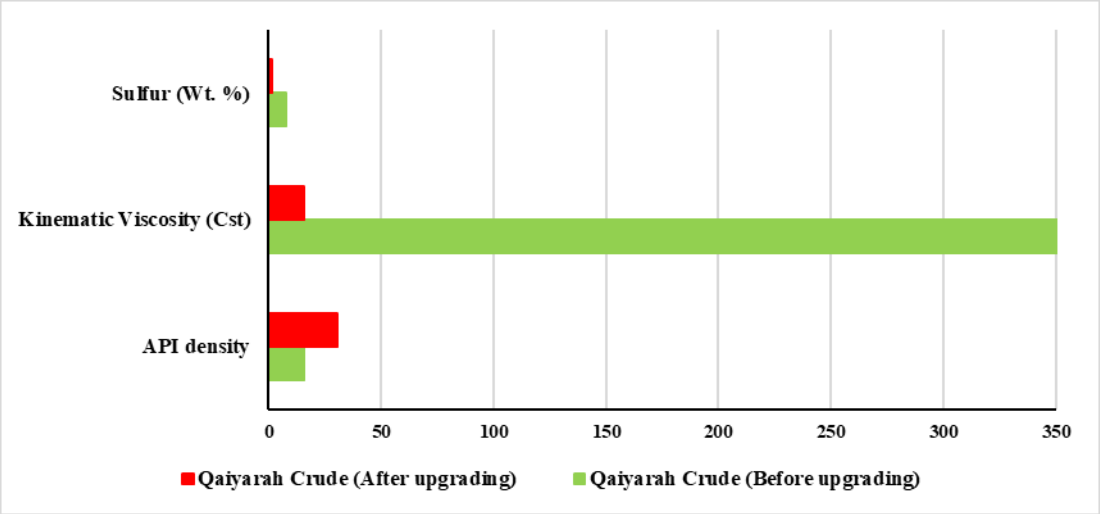

Fig. 7. Results Comparisons in Qaiyarah Properties Before and After Upgrading

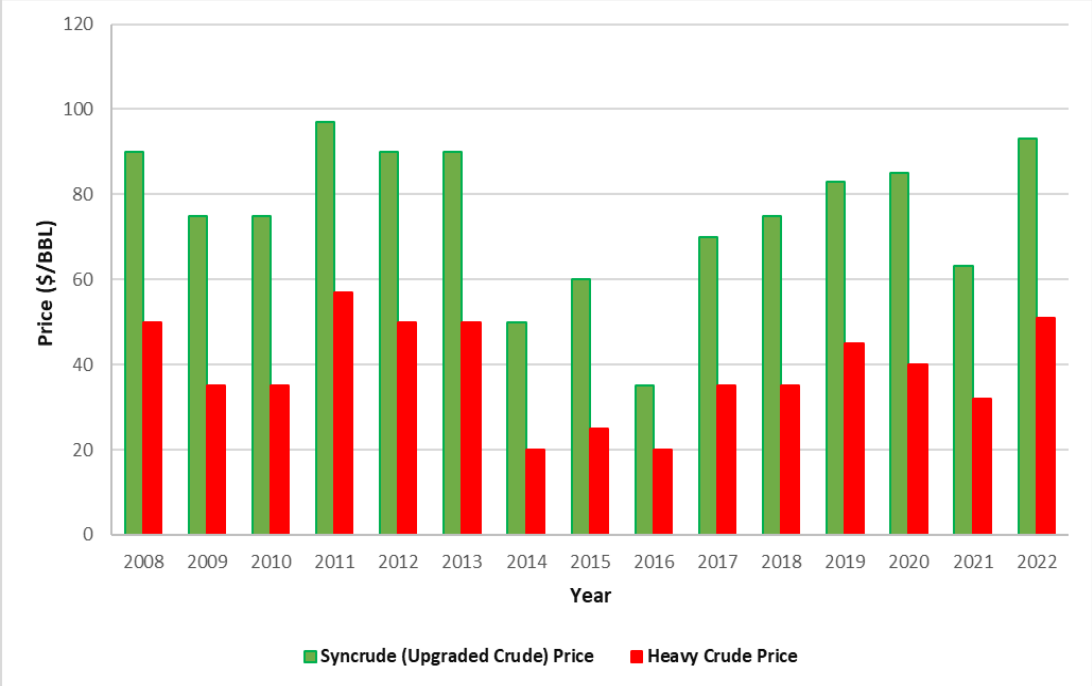

Fig. 8. Price Comparison Between Qaiyarah Heavy Crude and Synthetic (Upgraded) Crude, SOMO/ MoO/Iraq

4- Conclusions

Changing in physical and chemical composition of the heavy crude by applying cold cracking technology has a noticeable positive impact in making a synthetic crude and can be considered a competitor to the conventional crudes. Qaiyarah crude oil have been upgraded from 16 to 30.5 API degree by taking advantage of increasing the hydrogen bonds to upgrade the crude quality by reducing the density and viscosity as well as the sulfur content and this will upgrade the crude quality and eventually the crude price as well as reducing the transportation problems. Most important is, the possibility of mixing the synthetic crude with conventional crude from the other fields in the same region to be exported because of the convergence of the properties for the mixed crudes.

Based on that; it is highly recommended to go further with this technology's application in the Iraqi heavy oil field through installing a primary test unit for further future strategy to develop these fields and particularly Qaiyara field.

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تقنية التكسير البارد لتحسين مواصفات النفط الخام في حقل القيارة النفطي دراسة فنية وإقتصادية

هيرش ناظم حمه رش بيباني [١، *]، أياد عبد الحليم [١]، ومحمد شريفي [٢]

١ قسم هندسة النفط، كلية الهندسة، جامعة بغداد، بغداد، العراق
٢ جامعة اميركبير للتكنولوجيا، قسم هندسة النفط، ايران

الخلاصة

يصنف النفط الثقيل على انه مصدر نفطي غير تقليدي بسبب صعوبة استخراجه وانتاجه في حالاته الطبيعية وصعوبة نقله وتسويقه. ان حلول تحسين مواصفات النفوط الثقيلة لها تأثيرات إيجابية من الناحية الفنية والإقتصادية وبالأخص عند وصولها الى مستوى تنافسي للنفوط التقليدية وبالأخص من الناحية التسويقية. اهمل تطوير حقل القيارة النفطي في العقود الخمسة الماضية ويعود السبب الرئيسي في ذلك الى رداءة مواصفات هذا النفط من ناحية الكثافة واللزوجة العاليتين والتي كانت ولازالت تمثل تحدياً كبيراً في وضع انتاج الحقل ضمن المنظومة الإنتاجية في العراق حيث ان أسعار النفط الثقيل تعتبر منخفضة جدا في الأسواق العالمية إضافة الى الكلف التشغيلية العالية من ناحية الإنتاج والنقل.

إن الهدف من هذه الدراسة هو اختبار تقنية جديدة على الحقول العراقية ذات النفوط الثقيلة وبالتحديد حقل القيارة النفطي من خلال تطبيق تقنية التكسير البارد لتحسين مواصفات النفط الثقيل من خلال استخدام سلسلة من الفعاليات كهربائية/ ميكانيكية تسلط على النفط الثقيل بتوليد نوع خاص من الإهتزازات لإعادة هيكلية أواصر الـ (كاربون–هيدروجين) في النفوط الثقيلة لتحويلها الى نفوط خفيفة او متوسطة ذات كثافة ولزوجة اقل، حيث أظهرت نتائج جيدة من خلال تحسين قيم الكثافة من ١٦ الى ٣٠,٥ درجة بمقياس معهد البترول الأمريكي الـ (API) وانخفاض انتاج الكبريت من ٦,٤ الى ١,٥٠٧ وزناً وزيادة في سعر البيع للبرميل الواحد بنسبة ٤٠% مقارنة بـ ٢,٣١% زيادة في كلفة انتاج البرميل الواحد من جراء فعاليات تحسين المواصفات.

الكلمات الدالة: التكسير البارد، حقل القيارة النفطي الثقيل، تحسين الخام الثقيل، نفط صناعي، كلفة إنتاج النفط.