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Improving Oil Recovery By Steam cycle Injection

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Abstract Optimize the production rate dealing with a treatment of heavy oil crude in X field located in Dallas, Texas, is a perfect nominee to this thermal recovery according to its high density and high viscosity Since Cyclic Steam injection (C.S.I) is one of the most proper and significant thermal recovery process. The prosperity of this technique is defined by a number of drive mechanisms like; viscosity reduction which is the most important one and the main goal of utilizing C.S.I. A single well (vertical) is fixed to act as an injector and producer at the same time, and by a collection of three phases; injection, soak and production, a cycle of C.S.I is formed and this cycle is frequently done on the single well to improve the rate of production. we conducted a study of steam using CMG software to hold calculations required to compute the recovery main objective of this topic study is the expense of the recovery by injection steam, Optimize (CSI) parameters for a CMG model, with a brief study of the sensitivity of the cycle parameters during cyclic steam stimulation process (i.e. steam injection rate with temperature, injection period, soak period, steam quality, etc...) with respect to the software limitations. The optimum values obtained from simulation result are implemented to reach the maximum possible recovery for the well under study.
Keywords: Production; CSI, CMG, Oil recovery.

تحسين انتاجية النفط بالحقن الدوري بالبخار

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الملخص تحسين معدل الإنتاج الذي يتعامل مع معالجة النفط الخام الثقيل في الحقل X الموجود في دالاس، تكساس، هو نموذج مثالي لهذا الاسترداد الحراري وفقًا لكثافته العالية ولزوجته العالية نظراً لأن الحقن بالبخار الدوري (CSI) هو أحد أنسب وأهم عملية الاسترداد الحراري. الالية المستخدمة في هذه الطريقة تعتمد على عدد من قوى الدفع مثل العمل على تقليل لزوجة الخام والتي تعتبر اهم عامل وهي الهدف الرئيسي من عملية الحقن .C.S.I ' يتم تثبيت بئر واحد (رأسي) ليعمل كحاقن ومنتج في نفس الوقت، ومن خلال مجموعة من ثلاث مراحل؛ الحقن، النقع والإنتاج، يتم تشكيل دورة C.S.I ويتم إجراء هذه الدورة بشكل متكرر على البئر الفردي لتحسين معدل الإنتاج. أجرينا دراسة باستخدام سوفت وير CMG لإجراء العمليات الحسابية المطلوبة لحساب الهدف الرئيسي للاسترداد في دراسة الموضوع، وهو حساب الاسترداد عن طريق الحقن بالبخار، ومعاملات التحسين (CSI) لنموذجCMG ، مع دراسة موجزة للتأثير معاملات الدورة أثناء عملية التحفيز الدوري للبخار (معدل حقن البخار ودرجة الحرارة، وفترة الحقن، وفترة النقع، وجودة البخار، إلخ ...) فيما يتعلق بقيود البرامج. يتم تنفيذ القيم المثلى التي تم الحصول عليها من نتيجة المحاكاة للوصول إلى أقصى قدر ممكن من الاسترداد للبئر الذي تمت دراسته.

الكلمات المفتاحية: الإنتاج، الحقن الدوري بالبخار (CSI) ، سوفت وير CMG، استرداد النفط.

Introduction

Enhanced oil recovery (EOR) refers to any reservoir process used to change the existing rock/oil/brine interactions (fluid/fluid interaction; fluid/rock interaction) in the reservoir in order to increase the oil recovery, and this interaction might reduce the interfacial tension, oil swelling, reduce oil viscosity; also wettability modification. (EOR) is last stage of the oil production, The following flow sheet shows the types of various EOR methods that are currently employed in the oil industry [1] see Fig. 1.

EOR has a lot of methods and every method has its own considerations to use it. Carbon dioxide flooding is commonly used to recover oil from reservoirs in which the initial pressure has been depleted through primary production and possibly water flooding [2]. also another method is the foam, Once the foam is formed, it is intended to propagate throughout the formation as an in-depth mobility control to improve sweep efficiency through the CO_2 flood [3],although Thermal recovery processes are globally the most advanced EOR processes, [4].

One of those methods is the Thermal methods. Thermal methods are common in technologies used for the production of heavy and ultra-viscous oils [5] , [6] , [7].

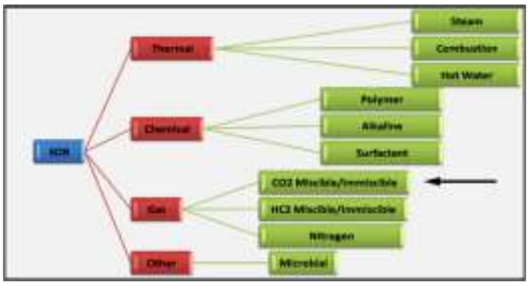

Fig 1: Flow Sheet for EOR Methods[1].

Thermal methods are based on supplying heat to the reservoir. In this way, the improvement in oil recovery is mainly due to the reduction of the oil viscosity and, consequently. the heating of the reservoir induces the expansion of solid and fluid phases, steam distillation and visbreaking [6], [8],[9].
The main processes that use thermal methods for heavy oil recovery are Steam methods, like Cyclic Steam Stimulation (CSS), Steam Flooding (SF) and Steam Assisted Gravity Drainage (SAGD), In-situ combustion (ISC) and Hot water flood.

Cyclic steam injection is also termed huff and puff; this operation involves only one well that functions either as injection and production well. In this process steam is injected into the reservoir for several days or weeks to heat up the oil. Then, steam injection is stopped and the well is shut in to allow the reservoir soak for several days. In the reservoir, the steam condenses, and a zone of hot water and less viscous oil forms. Later on, the well is brought into production and the hot water and thinned oil flow out. This cyclic process of steam injection, soaking, and production can be repeated until oil recovery stops [10].

Methodology

The procedures will be as following:

1 Represented Data:

The model has being built by using CMG simulator based on the data collected from the X field Reservoir Oil Pressure, Oil Density, etc. and some experimental report's data such as relative permeability, bubble point pressure and saturations.

I. Reservoir simulation data:

Mode Description prepared a 3 dimensional single well CSI field units 13X1X4 radial grid as showing Fig 2 and Table 1

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Fig (2) 3 dimensional single well CSI

II.Flow bath behaviour :

Water- oil relative permeability and Liquid –gas relative permeability data provided From report based on the experimental data, where the initial oil saturation was 0.6 and initial water saturation was 0.4. see Table 2 and Table 3.

Table 1. Reservoir Data for the Model.

Grid Dimension	13X1X4
Water Density (Stock Tank)	62.4 lb/cu ft
Oil Density (Stock Tank)	18.53
Gas Density (Stock Tank)	68.64 lb/MCF
Water Compressibility	3.3×10^{-6} psi^{-1}
Rock Compressibility	5.0×10^{-6} psi^{-1}
Water Formation Volume Factor	1.00000
Water Viscosity	1.121cp
Reservoir Temperature	77 ^0F
Separator Conditions (Flash Temperature and Pressure)	60 ^0F 14.7 psi
Reservoir Oil Pressure	1700psi
Initial Water Saturation	0.4
Initial Oil Saturation	0.6
Relative Permeability	(See Table 2)
Wellbore Radius	0.25 ft

Table 2. water- oil Relative Permeability Data.

Sw%	K_{rw} md	K_{row} md
0.45	0.0	0.4
0.47	0.000056	0.361
0.50	0.000552	0.30625
0.55	0.00312	0.225
0.60	0.00861	0.15625
0.65	0.01768	0.1
0.70	0.03088	0.05625
0.75	0.04871	0.025
0.77	0.05724	0.016
0.80	0.07162	0.00625
0.82	0.08229	0.00225

Table(3) liquid- gas Relative Permeability Data.

Sl%	K_{rg} md	K_{rog} md
0.67	0.08181	0.02844
0.70	0.06856	0.04444
0.72	0.06017	0.05709
0.75	0.04829	0.07901
0.77	0.04087	0.09560
0.80	0.03054	0.12346
0.83	0.02127	0.15486
0.85	0.01574	0.17778
0.87	0.01080	0.20227
0.90	0.00467	0.24198
0.92	0.00165	0.27042
0.94	0.0	0.30044
0.1	0.0	0.4

2- Well Specifications The producing period has been constant for all the scenarios at almost one year. first constrain had been to increase the both steam rate with temperature and leave the soaking period constant, second constrain had been to increase the injection period and keep the soaking period constant, third constrain had been to change in soaking period and keep injection period constant, forth constrain had been increase the steam quality and keep injection period and soaking constant.

Results and Discussion.

I.Analysis both steam rate with temperature:

In this scenario From the table (4) below, being changed the steam rate with temperature, while the steam quality(0.7) have been fixed, soaking (4day) and injection(10 day) period time. In this process several changes had been followed in steam rate with temperature that obtained the high oil recovery of (4.4%), at the high temperature of (1000F), with the high steam rate of (6500BBl/days), and the rate of production could be increased as much as both steam rate with the steam temperature. See Fig 3.

Table (4) shows oil recovery from analysis both the steam rate with temperature

Steam rate bbl/day	Stem ,,temp F	Oil Recovery%	Incremental Oil recovery
300	250	3.836	------
500	300	3.838	0.002
700	350	3.854	0.016
900	400	3.921	0.067
1200	460	4.012	0.091
500	550	4.015	0.0031
2500	750	4.270	0.225
3500	850	4.380	0.110
6500	1000	4.482	0.102

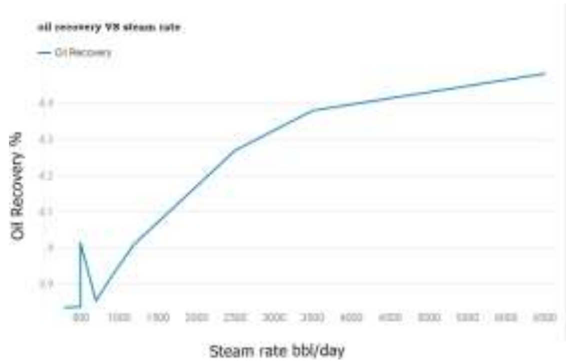

Fig (3) oil recovery VS steam rate with temperature

II Analysis injection period:

In this scenario From the table (5) below, the change in the injection period being done , while the steam quality (0.7) being fixed, soaking (3day) , temperature (650 F°), steam rate (2000bbl/day),In the first case when the days of injection (5 days) had been the factor of oil recovery (2.898), after increasing the days of injection to (30 days) increased by (3.985),After several changes in the days of injection, being found that the more days of injection, the higher the rate of recovery, meaning that the relationship between them is a direct, . See Fig 4.

Table (5) shows oil recovery from analysis

Injection Day	Oil Recovery Factor	Incremental Oil recovery
5	2.898	------
10	4.011	1.113
15	4.944	0.983
20	5.443	0.499
25	6.148	0.705
30	6.883	0.735
50	9.929	2.409
100	15.946	6.017

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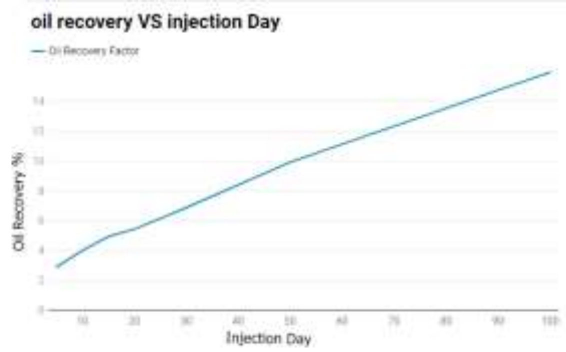

Fig (4) oil recovery VS injection Day

III. analysis for soaking period:

In this study soak interval sensitivity. Short soak periods is useless because steam distribution will not be sufficient, However long soak intervals will result in oil recovery drop and bottom hole temperature would be reduced due to heat losses . In this scenario From the table (6) below, the change in soaking period being applied , while being fixed the steam quality(0.7), soaking(3day) , temperature (450 F°), steam rate (1000bbl/day) and injection(10day) period time, in first case when day of soak was (3day) the factor of recovery oil (3.968) , when increased day of soak to (5day) obtained an increased in oil recovery while was (3.998), after that increased day of soak to (7day) for obtained on high recovery oil while was (4.011) ,when increased day of soak to (10day) to obtain the highest oil recovery but decreased where it was (3.971) ,mentioned before the main reason in decrease long soak intervals will result in oil recovery drop and bottom hole temperature would be reduced due to heat losses. In finally result increasing the day of soak to (10day , 15day, 20day, 25day) founding that there is no increasing in recovery factor. The oil recovery at the end of production period first increases then decreases, so the soaking period with maximum oil recovery (7 days) will be chosen as optimized soak interval for CS I well. . See Fig 5

Table (6) shows oil recovery from analysis soaking period

Soaking Day	Oil Recovery%	Incremental Oil recovery
3	3.968	------
5	3.998	0.03
7	4.011	0.013
10	3.971	-0.04
15	3.968	-0.003
25	3.898	-0.07

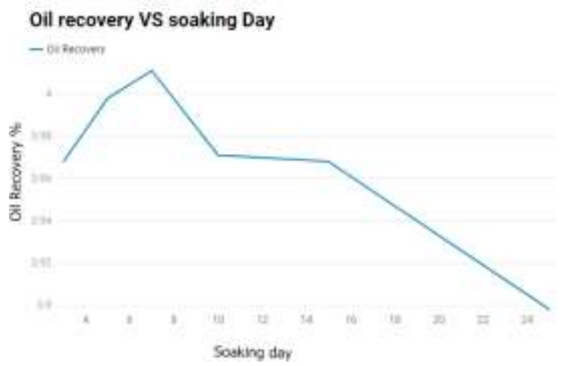

Fig (5) oil recovery VS soaking Day

IV. Analysis Injected Steam quality:

The optimized temperature is high enough to provide surface steam quality up to 80 % (maximum boiler quality can provide). The high steam quality as can be seen from plotting c oil recovery at different steam qualities, the higher quality give the higher oil recovery.

When steam quality is high the enthalpy carried by steam is greater this will ensure high oil recovery. In this scenario From the table (7) below illustrate the effect of steam quality changes under fixed the soaking(4day) , temperature (550 F°), steam rate (1000bbl/day) and injection(10day) period time, After several changes in the steam quality from (0.2 to 0.9),

The Oil recovery increased by increasing the steam quality of (3.330 to 4.195) , meaning that it was a direct relationship between them.

From steam quality figures and the boiler quality limitation, the steam quality optimum value is 0.8 but it is recommended to use high insulation tube to avoid heat losses. . See Fig 6.

Table (7) shows oil recovery from analysis steam quality

Steam Quality	Oil Recovery %	Incremental Oil recovery
0.2	3.330	------
0.3	3.493	0.163
0.4	3.652	0.159
0.5	3.816	0.164
0.6	3.974	0.157
0.7	3.981	0.007
0.8	4.123	0.142
0.9	4.195	0.072

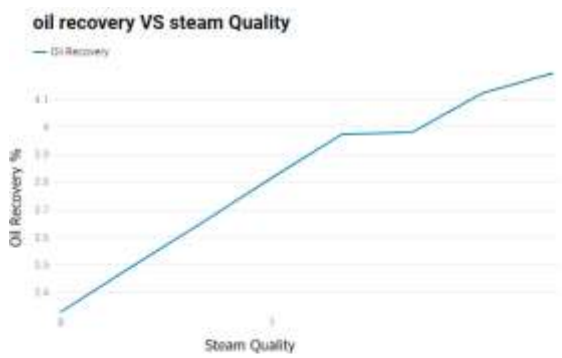

Fig (6)) oil recovery VS steam Quality

V. Analysis cumulative oil VS time over different steam injection volumes:

Steam injection volume had not been definable to CMG software since there had no entry to injected fluid volume. However the volume had been entered in term of injection duration as long as there had a known **injection rate.**

(Equation) injection volume.

$injection\ volume$ (bbl/day) = $injectionrate$ (bbl/day)$*injectionduration$ ($days$)

the producing period in all of the cases had been almost constant ,as well as the injection duration (30 day) fixed in three cycles of steam stimulation for the field. From the table (8) below constant in steam quality (0.7) , injection day(10 day) and soaking period(4day),different values of steam volumes and temperature of steam rate, note in this scenario the cumulative rate of oil increases as the steam volume increases ,meaning that it had been a direct relationship between them. . See Fig 7.

Table (8) shows cumulative rate and incremental cumulative oil

Steam rate bbl/Day	Steam volume bbl	Steam. . Team F°	Cumulative Oil bbl/Day	Incremental cumulative oil
300	9000	250	19264.4	------
500	15000	300	19276.2	11.8
700	21000	350	19356.7	80.5
900	27000	400	19692.2	335.5
1200	36000	460	20149.2	457
1500	45000	550	20167.7	18.5
2500	75000	750	21446.9	1279.2
3500	105000	850	21997.9	551
6500	195000	1000	22360.7	362.8

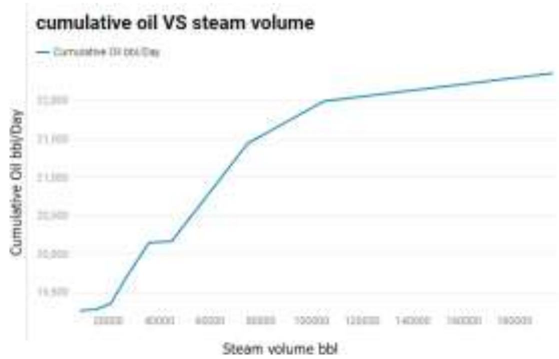

Fig (7) cumulative oil VS steam volume

Conclusion

As a final summary of the five best scenarios worked on, found that:

In the First scenario there is a positive relationship between increasing of temperature and steam rate with the increase of the recovery factor and we get the highest amount of (4.482%) recovery factor at temp of (1000F) and (6500 bbl) steam rate .

In the second scenario there is a positive relationship between the increase of injection period with recovery factor and we got the highest recovery factor (15.946%) at (100 days), and it's the highest recovery factor we have achieved in our work .

In the third scenario there is a positive relationship between increase of the soaking period with recovery factor until 7 days of soaking period then it reverses to a negative relationship and decreased after increasing soaking period more than 7 days .

In the fourth scenario After several changes in the steam quality from (0.2 to 0.9) we find increases of recovery factor at all points and was the highest recovery factor is (4.195%) .

In the fifth scenario we performed a cumulative oil calculation in 3 cycles as well the injection cycle duration (30 day) fixed in three cycles of steam injection for the field. we find that cumulative rate of oil increases as the steam volume increases.

Recommendation:

1-Recommendation for using cycle steam injection for 4 wells or more instead of 1 well, for more version of result.

2- Recommendation for analysis of production rate , production duration, oil steam ratio ,water cut, oil profit ,steam cost, production cost, and Net profit, for better oil recovery and lower cost.

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