Using an Optimum Bit Selection Method for Determined Wells in Northern Iraq

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Abstract

The present paper deals with optimum bit selection for determined wells in North of Iraq, specially Kirkuk wells and Bai Hassan wells by using specific energy(SE_d) method , which used to study the performance of bits drilled oil wells in North of Iraq. SE_d had been calculated for different depths and bit types.

Sketching the relation between specific energy vs. depth, best bit Performance can be indicated, where lowest value of calculated SE_d refers to the optimum bit used to drill the determined section . This technique could be used for a single well or for a field that consists more than well and the latter case shown in this paper.

الخلاصة

البحث المقّدم يتناول الاختيار الأمثل للحافرات لآبار محّددة في شمال العراق، خصوصاً آبار كركوك و آبار باي حسن بواسطة طريقة الطاقة المحددة (SE_d) و المستخدمة لدراسة أداء الحافرات لآبار نفطية حُفرت في شمال العراق. SE_d تم احتسابها لأعماق مختلفة و لحافرات متنوعة.

تم رسم العلاقة بين الطاقة المحددة و العمق، وتم تأشير أفضل الحافرات أداء" اعتمادا" على قيمة SE_d المحسوبة .هذه التقنية يمكن استخدامها لآبار منفردة أو لحقل مكّون من أكثر من بئر واحد و الحالة الأخيرة موضحّة في هذا البحث.

Introduction

The concept of mechanical specific energy has been used effectively in lab environment to evaluate the drilling efficiency of bits. Mechanical specific energy is a calculated value equal to the ratio of the input energy to the drill rate .Because of given volume of a specific rock requires a given amount of energy to destroy; this ratio should be relatively constant. Any significant increase in the mechanical specific energy ratio is taken as an indication that energy is being lost and the system has become less efficient. Specific energy allows the optimum operating parameters to be identified easily and more or less continuously for each foot of hole drilled, secondly, it provides quantitative data needed to cost-justify changes in areas such as well control practices, bit selection, directional target sizing and further more usefulness **(Fred and William 2005)** .

The specific energy was used to calculate the rotary drill process and it is defined as the work done in cutting a unit volume or mass of rock, and it provides a measure of the drilling efficiency (**Yinghui and Brian 2004)** .

The drilling specific energy SE_d is a very significant measure of drilling performance .It is directly compatible with cost/meter, because it relates the amount of energy required to penetrate rock .SE_d can also be used to quantify the efficiency of rock working processes and rock hardness during drilling .This relationships between drilling specific energy, drilling rate and the main mechanical rock character **(Erosey 2003)** . Drilling data is summarized in a common format to provide a direct comparison of drilling efficiency , jet pressure and hydraulic power **(Kolle 1999)** .It is not easy to make any logical interpretation of raw data i.e., [bit load, rate of penetration, flushing pressure, rotary speed and rotation pressure] and they represent a rather confusing picture. If however, these five parameters are combined in a formula, describing the energy from the drill bit acting on the soil. This formula represents specific energy needed to penetrate one cubic meter of the soil and the different layers of soft and hard soil are clearly visible **(Swedish geotechnical institute 1996)**.

Another definition for this energy is the energy required to remove a unit volume of rock, namely the specific energy (SE) , is a critical rock property data that can be used to determine both the technical and economic feasibility of well drilling .The most efficient rock removal mechanism would be the one that requires the minimum energy to remove a unit volume of rock**(Xu, Reed, Konercki, Gahan, Batarseh, Figueroa and Skinner 2003)** .

Theoretical background

Specific energy parameter **(Kolle 1999)** had been defined as follows:-

$$SE_d = \frac{W}{Q_r} \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(1)$$

Where, SE_d is the specific energy (J/mm^3) , W is the hydraulic or mechanical power (J) and Q_r is the volumetric rate of rock removal (mm^3)

In another words , the specific energy **(Fred and William 2005)** is defined mathematically as follows :-

$$SE_d = \frac{Energy\ \ Input}{Volume\ \ removed} = \frac{P}{d_V / d_t} \quad \cdots\cdots\cdots\cdots\cdots\cdots(2)$$

$$= \frac{\left[\frac{kW}{cm^2}\right]\cdot \sec onds}{cm} = \frac{kW}{cm^3/\sec} = \frac{kJ}{cm^3}$$

Where: - P = power Input (Watts), $\boldsymbol{d_V / d_t}$ **=** Volume time derivative (Cm3/sec)

Specific energy **(Rabia 1985)** may use any consistent set of units .It has been shown that for rotary drilling may calculated from the following equation :-

$$SE_d = \frac{E}{V} \quad \cdots\cdots\cdots\cdots\cdots(3)$$

Where: - E = mechanical power lb-in & V = a unit volume of rock in3

Mechanical power can be calculated from the following equation:-

$$E = 2\pi\ N\ W \quad \cdots\cdots\cdots\cdots\cdots\cdots(4)$$

Where N = rotary speed (rev/min), W = weight on bit (lb)

and volume of rock removed can be calculated from the following equation :-

$$V = \pi\ R^2 \cdot ROP \quad \cdots\cdots\cdots\cdots\cdots\cdots(5)$$

Where :- ROP = rate of penetration (ft/hr) , R = bit radius (in)

and now substituting equ.(4) and (5) into equation (3) produces the following :-

$$SE_d = \frac{2\pi NW}{\pi R^2 \cdot ROP} \quad \cdots\cdots\cdots\cdots\cdots\cdots(6)$$

and replacing R with D i.e.; (hole diameter) , and according to that the data are not all homogeneous to be used into equ.(6) , so conversion factors used to get the following modified equation :-

$$SE_d \quad = \quad 20 \; \frac{W \cdot N}{D \cdot ROP} \quad \cdots\cdots\cdots\cdots\cdots(7)$$

where :- N = RPM or rev / min , W = Lb , D = in , ROP = ft / hr and
SE_d = Lb – in / in^3.

Collection of data

Drilling data or ((Bit record)) had been collected from North Oil Company for selected oil wells in North of Iraq (Kirkuk wells and Bai Hassan wells).

Results & discussion

SE_d calculations:

The given Bit record data as shown in tables (1-6) must be converted to units suitable to use in equation no.(7) , specially WOB and ROP and hence bit size represents hole diameter and the last column represents calculated SE_d from equ.(7).

Table (1)

Drilling data and calculated SE_d for well ((Kirkuk no.1))

Depth (M)	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Bit size (in)	WOB (1000 lb)	SE_d [(lb-in)/in^3] *1000
135	OSC-3AJ	30.327	125	17.5	12.1	56.9977
286	X1G	8.283	105	12.25	15.4	318.727
383	X1G	5.94	105	12.25	14.3	412.698
398	X3	2.739	105	12.25	13.2	826.163
484	X3A	17.721	80	8.625	13.2	134.922

Table (2)

Drilling data and calculated SE_d for well ((Kirkuk no.2))

Depth (M)	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Bit size (in)	WOB (1000 lb)	SE_d [(lb-in)/in^3] *1000
80	OSC-3AJ	11.022	120	17.5	8.8	109.495
159	OSC2AJ	24.3375	120	26	8.8	33.376
204	OSC1GJ	21.549	100	17.5	11	58.338
400	OSC3AJ	23.1	120	17.5	13.2	78.367
700	X1G	11.781	110	12.25	11	167.686
844	J2	7.161	100	12.25	13.2	300.95
894	J3	5.775	90	12.25	13.2	335.8636
911	J2	5.445	100	12.25	13.2	395.795
915	X1G	2.904	90	8.5	13.2	962.566
951	C-20	3.3	60	8.468	13.2	566.791
1052	X1G	6.699	90	8.5	13.2	417.27
1120	X1G	13.2	100	8.5	13.2	235.294

Table (3)
Drilling data and calculated SE_d for well ((Kirkuk no.3))

Depth (M)	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Bit size (in)	WOB (1000 lb)	SE_d [(lb-in)/in^3] *1000
151	114	12.012	150	17.5	11	156.985
331.5	124	18.612	110	12.25	15.4	148.598
418	SPS	17.82	110	8.5	17.6	255.628
451	J3	13.629	100	6	11	269.034

Table (4)
Drilling data and calculated SE_d for well ((Kirkuk no.4))

Depth (M)	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Bit size (in)	WOB (1000 lb)	SE_d [(lb-in)/in^3] *1000
400	SPS	37.62	120	17.5	26.4	96.2406
670	SPS	17.82	120	12.25	26.4	290.249
842	SPS	20.625	120	12.25	26.4	250.775
949	SPS	19.602	120	8.5	26.4	380.273
973	DKG	13.2	100	6	13.2	333.333

Table (5)
Drilling data and calculated SE_d for well ((Bai Hassan no.1))

Depth (M)	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Bit size (in)	WOB (1000 lb)	SE_d [(lb-in)/in^3] *1000
300	DKG	13.761	100	17.5	22	182.71
500	SPS	12.012	100	17.5	22	209.314
628	DKG	10.56	100	12	22	347.222
785	DKG	6.27	100	12	22	584.795
913	DKG	5.28	100	12	22	694.444
1038	SPS	4.488	100	12	22	816.993
1099	DKG	2.871	100	12	22	1277.139
1187	DKG	4.587	85	12	24.2	747.402
1224	DKG	1.551	90	12	22	2127.659
1246	SPS	2.145	90	12	22	1538.461
1349	SPS	2.97	90	8.5	17.6	1254.901
1369	SPS	5.28	90	8.5	17.6	705.882
1378	DKG	0.825	80	6	15.4	4977.777
1450.5	J4	5.28	90	6	15.4	875

Table (6)
Drilling data and calculated SE_d for well ((Bai Hassan no.2))

Depth (M)	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Bit size (in)	WOB (1000 lb)	SE_d [(lb-in)/in^3] *1000
388	DKG	22.44	110	17.5	13.2	73.95
450	DKG	20.46	110	17.5	13.2	81.105
747	SPS	16.17	100	12	11	113.378
972	SPS	8.91	100	12	15.4	288.065
1065	SPS	3.696	70	12	4.4	138.889
1207	SPS	6.336	100	12	15.4	405.092
1267	SPS	5.214	100	12	15.4	492.259
1345	SPS	4.29	70	8.5	15.4	591.251
1371	SPS	3.894	70	8.5	15.4	651.379
1454	J3	4.62	70	6	13.2	666.666
1485	J3	17.16	70	6	13.2	179.487

Now after SE_d calculations, SE_d plotted vs. depth for Kirkuk wells. The obtained graph shown in figure 1.

We notice that each point on the graphs above represents bit performance regardless of trip time, rig cost, and other parameter that affects the cost per foot (CPF).We will show later how the best bit performance carried lowest values of SE_d values.

Relation of ROP with SE_d :

The relation between rate of penetration vs. SE_d is a reverse relation i.e. when ROP increased SE_d decreased.

Well no.(1)in Kirkuk for example ,we notice very low value of SE_d i.e. 56.9977 lb-in / in^3 at depth 135 m .

If we return to penetration rate at that depth , it was 30.327 ft / hr which it is a high value, while at depth 398 m , the calculated value of SE_d was 826.163 lb-in / in^3 which it is simply high value corresponding to rate of penetration equals to 2.739 ft /hr which it is so low .

Bit performance:

Plotting SE_d vs. depth from data of tables (1) , (2) , (3) , (4) ,(5) and (6) will produce fig.(1) and fig.(2) as shown below:-.

Well (Kirkuk no.1):

For this well it is remarkable that minimum value of SE_d was equal to 56.9977 lb-in / in^3 at depth 135 m which represents the lowest value and according to that the bit which used at that depth is the best i.e. (OSC-3AJ) as shown in Fig.(1).

Well (Kirkuk no.2):

For this well it was occurred that OSC2AJ bit carried minimum SE_d i.e. 33.376 lb-in / in^3 at depth 159 m which that means it is the best as shown in fig.(1) below.

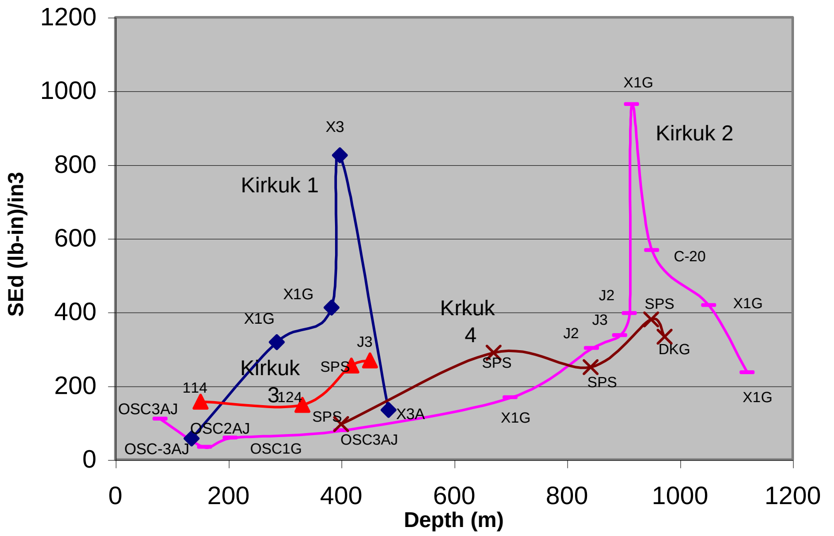
Well (Kirkuk no.3):

From fig.(1) we notice that minimum value for SE_d i.e. 148.598 lb-in / in^3 corresponded to bit type 124 , which means that it is the optimum bit for this well.

Well (Kirkuk no.4):

For this well the best bit was SPS because it carried lowest value of SE_d i.e. 96.2406 lb-in / in^3 at depth 400 m as show in fig.(1) .

Fig.(1) Relation of SEd vs. depth for Kirkuk wells



Well (Bai Hassan no.1):

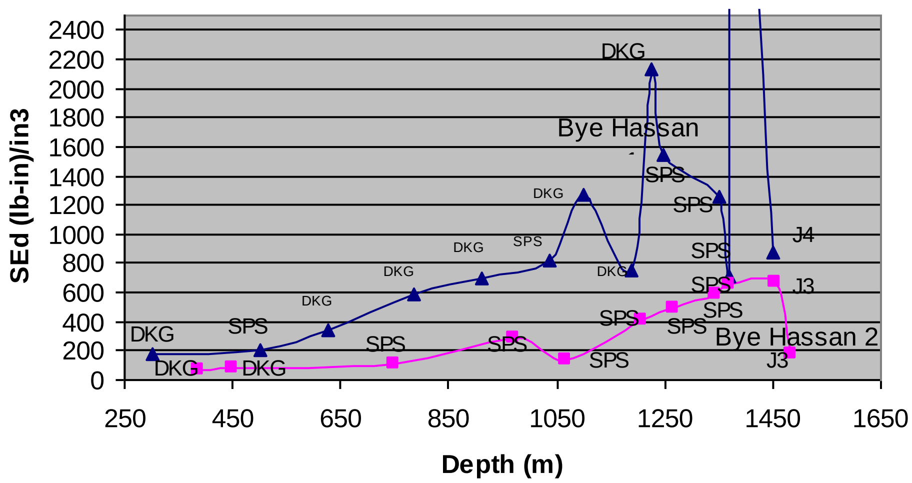
For this case the best bit used was DKG because it carried lowest value of SE_d i.e. 182.71 [(lb-in) / in^3] at depth 300 m as shown in fig.(2) .

Well (Bai Hassan no.2):

For this case the best bit was DKG that had lowest value of SE_d i.e. 73.95 lb-in/ in^3 at depth 388 m as shown in fig.(2) below:-

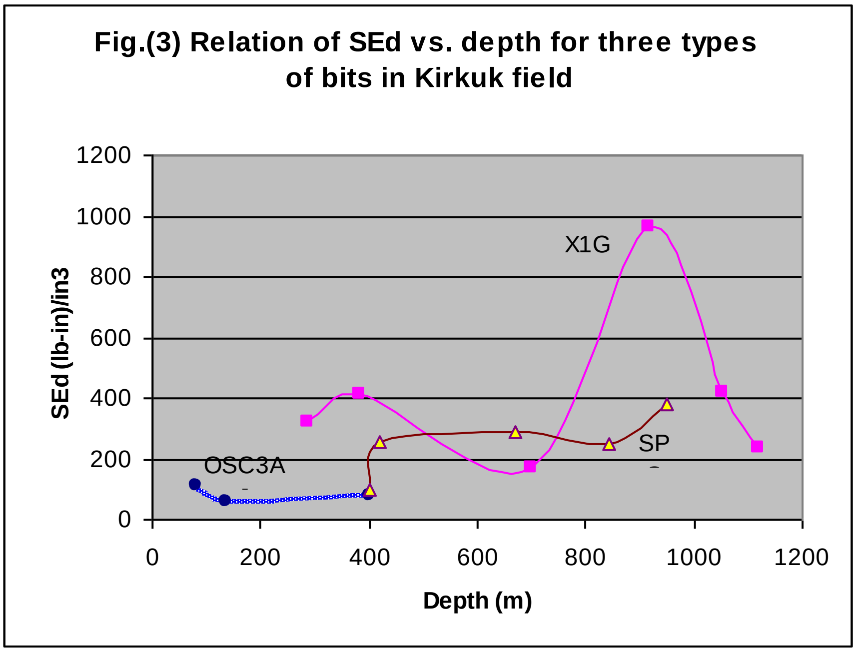
Selecting best bit performance for Kirkuk wells:

Fig.(2) Relation of SEd vs. depth for Bai Hassan wells



Because all types of bits were not participated to drill the four Kikuk wells, so the study will be confined on OSC3AJ, X1G and SPS bits only which were used to drill more than one well in Kirkuk field .

When plotting SE_d vs. depth for OSC3AJ bits for all Kirkuk wells and also the same for X1G and SPS bits we will obtain fig.(3) and by using the concept of specific



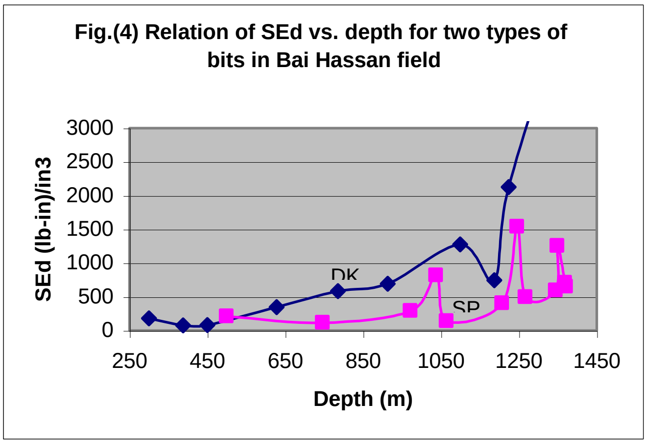
energy the decision of optimum bit selection will be determined as shown in table (7)below :

Table (7)
Optimum bits for Kirkuk wells

Depth (m)	Optimum bit
0-500	OSC3AJ
500-800	X1G
800-1100	SPS
1100-1200	X1G

Selecting best bit performance for Bai Hassan wells:

Plotting the results of SE_d versus depth for DKG and SPS bits which drilled the two wells in Bai Hassan field & without using other bits for drilling the both wells in Bai Hassan we will obtain fig.(4) which through it, the decision of selecting optimum



bits will be determined as shown in table (8) below:

Table (8)
Optimum bits for Bai Hassan wells

Depth (m)	Optimum bit
0-475	DKG
475-1400	SPS

, while for depths from 1400 to 1500 m the optimum bit selection will be difficult, because DKG and SPS bits were not participated to drill this depth for both wells in Bai Hassan field .

Conclusions

1- drilling parameters such as weight on bit , rotary speed and bit size had slightly effect on SE_d rather than rate of penetration .
2- Optimum bits can be selected for each formation by plotting SE_d vs. depth , for each well , where bits which carried lowest SE_d are the best or optimum bits.
3- Optimum bit selection for a whole field could be done by plotting SE_d vs. depth for each type of bit that drill more than one well , then by correlating the resulted figure, the bit which carried lowest SE_d for certain depths represents the optimum drilling bit as illustrated in figures 3 and 4.
4- Since the cost of drilling is becoming increasingly greater as deeper and harder rock formation, so it is highly desirable to apply specific energy method for all drilling wells to reduce drilling costs to the minimum besides using the technique of cost per foot.

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