USING SPE TECHNIQUE FOR STUDYING BIT PERFORMANCE FOR A SELECTED WELL IN SOUTH OF IRAQ

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Abstract

The present study deals with drilling specific energy technique used to study the performance of bits drilled an oil well in southern Iraq and exactly in oil well (west Qurna no.15 in Basrah).

SE_d had been calculated for different depth and bit types.

Using the relationship 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 and consequently reduces highly drilling costs.

Introduction

In order to break by mechanically or by thermally induced stresses, a sufficient force of energy must be applied to the rock, such that the induced stresses will exceed the rock's strength. Similarly, when fusing rock sufficient heat must be applied to produce local temperatures that exceed the melting temperature at the rock. Once these threshold values of force or energy are exceeded, the amount of energy required to break or remove a unit volume of rock remains nearly constant. This energy parameter, which is a measure of the efficiency of the rock destruction technique, is defined as specific energy [1].

Cutting experiments were carried out to quantify the dependence of the specific energy on the bottom hole pressure and on the pore pressure in shales. The experiments were conducted with an instrument cutting device specially designed to operate inside triaxial cell .This preliminary experimental investigation support the theoretical findings that the specific energy depends only on bottom hole pressure and not on the differential pressure in shales under conditions when the rock is shear-dilatant .In such cases, specific energy can indeed be expressed as $SE_d = SE_0 + mp_{an}$, where SE_0 denotes the specific energy under atmospheric conditions, p_{an} denotes to bottom hole pressure, and m is a coefficient which is a function of the drilled angle and the internal friction angle of the shale [2].

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. Drilling data is summarized in a common format to provide a direct comparison of drilling efficiency, jet pressure and hydraulic power [4].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 [5].

Theoretical background

Specific energy parameter has defined as follows [4] :-

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

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 is defined mathematically as follows [1] :-

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

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

where :- P = power Input (Watts) , dV/d_t – Volume time derivative (cm3/sec)

Specific energy may use any consistent set of units .It has been shown that for rotary drilling may calculated from the following equation[6] :-

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

where :- E = mechanical power lb-in & V = a unit volume of rock in^3 mechanical power can be calculated from the following equation :-

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

where N - rotary speed (rev/min) , W = weight on bit (lb) and volume of rock removed can be calculated from the following equation :-

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

where :- ROP = rate of penetration (ft/hr) , R = bit radius (in) and now substituting equ.(4) and (5) into equation (3) produces the following :-

$$SE_d = \frac{2\pi N W}{\pi R^2 \cdot ROP} \qquad \cdots\cdots\cdots(6)$$

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 :-

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

where :- N RPM or rev / min , W = ib, D = in, ROP = ft / hr and

SE$_d$ = ib – in / in^3 .

Collection of data

Drilling data had been collected from Baroid oil company for a selected oil well sample in South of Iraq (west Qurna no.15 in Basrah).

Table (1) showed the data which includes depth, rate of penetration, rotary speed, hole diameter, weight on bit, bit type and lithology .

Table (1)
Drilling data collected from Baroid company

Depth	Bit type	ROP (ft/hr)	Rotary speed (rpm)	Hole diameter (in)	WOB (1000 lb)	Formation	Lithology
2932	JD4	2.874	90	12.25	20	Nahr Umr	Interbeded shales & sandstone
3005	JD4	4.921	90	12.25	19	Shuaiba	Dolomite with minor limestone
3102	JD4	5.624	90	12.25	18	Zubair	Limestone with minor shales
3187	533	4.233	80	12.25	18	Zubair	Shales with minor sandstone
3312	J33	3.185	60	12.25	18	Zubair	Interbeded mudstones and shales
3338	JD4	2.66	65	12.25	18	Zubair	Shales & interbeded sandstone
3407	JD4	2.73	80	12.25	21	Ratawi	Shales with limestone
3417	J33	2.813	65	12.25	20	Ratawi	Shales with limestone
3455	J33	4.921	60	12.25	20	Ratawi	Shales with limestone
3475	J33	3.227	70	12.25	20	Ratawi	Shales with limestone
3502	J33	2.97	70	12.1875	20.25	Ratawi	Limestone
3550	C20	3.579	85	12.1875	9	Yamama	Limestone with interbeded shales
3622	C20	2.008	80	12.1875	10	Yamama	Limestone
3637	C22	2.316	104	8.437	9.5	Yamama	Limestone
3713	JD4	5.625	104	12.25	9	Yamama	Limestone
3857	FS5 KJ	2.316	85	8.375	20	Sulaiy	Limestone with thin interbeds of anhydrite
3896	LM6	1.848	50	8.375	14	Sulaiy	Limestone with thin interbeds of anhydrite
3932	J33	1.405	50	8.375	14	Sulaiy	Limestone with thin interbeds of anhydrite
٣٩٨٢	J33	1.839	50	8.375	17	Sulaiy	Limestone with thin interbeds of anhydrite
4000	J3	2.073	50	8.375	17	Sulaiy	Limestone with thin interbeds of anhydrite
4100	J3	2.187	50	8.375	17	Sulaiy	Limestone with anhydrite
4117	J3	4.825	55	8.375	19	Sulaiy	Limestone with thin interbeds of anhydrite
4200	J3	1.357	60	8.375	13	Gotnia	Anhydrite with thin interbeds of limestone & salt
4210	J3	24.607	55	8.375	13	Gotnia	1st cycle of salt
4247	J3	26.25	65	8.375	13	Gotnia	1st cycle of salt
4275	J3	1.789	45	8.375	18	Gotnia	Anhydrite with limestone and salt
4302	J3	13.124	100	8.375	18	Gotnia	2nd cycle of salt
4307	J3	3.281	100	8.375	15	Gotnia	2nd cycle of salt
4315	J3	10.35	100	8.375	15	Gotnia	2nd cycle of salt
4320	J3	13.1	100	8.375	13	Gotnia	2nd cycle of salt
4372	F4	1.383	60	5.625	5.25	Gotnia	Anhydrite with limestone & salt
4387	F4	3.937	59	5.625	7.3	Gotnia	3rd cycle of salt
4387	F4	21.8	75	5.625	7	Gotnia	3rd cycle of salt
4392	F4	1.789	42	5.625	5.5	Gotnia	Anhydrite with limestone
4402	F4	5.403	42	5.625	6.5	Najmah	Limestone
4443	F4	1.405	55	5.593	5.7	Najmah	Limestone
4451	HTC J33	1.48	55	5.875	4.5	Najmah	Limestone
4463	J33	1.640	64	5.875	6	Najmah	Limestone
4493	LM 9J	2.072	65	5.875	6	Najmah	Limestone with sandstone
4512	J33	2.46	64	5.875	6	Najmah	Limestone with salt & anhydrite
4563	OVB	1.613	120	5.843	6	Najmah	Limestone with salt & anhydrite
4615	OVB	6.057	110	5.843	6	Najmah	Limestone

Results & discussion

SE_d calculations:

The data collected used to calculate SE_d using equation (7).

The obtained values of SE_d shown below in table (2)

Table (2)
SE_d calculated vs. Depth

Depth (m)	SE_d [(lb-in)/in^3] *1000	Depth (m)	SE_d [(lb-in)/in^3] *1000
2932	1022.538	4117	517.21
3005	567.27	4200	1372.7
3102	470.246	4210	69.38
3187	555.341	4247	76.873
3312	553.619	4275	1081.297
3338	662.881	4302	327.531
3407	1004.724	4307	1091.782
3417	754.5	4315	345.761
3455	398.089	4320	236.984
3475	708.322	4372	809.872
3502	788.85	4378	388.981
3550	350.764	4387	85.626
3622	653.808	4392	459.107
3637	700.063	4402	179.658
3713	394.429	4443	797.81
3857	1184.307	4451	569.292
3896	904.568	4463	796.854
3932	1189.869	4498	640.709
3992	1103.322	4152	531.395
4000	979.206	4563	1527.689
4100	982.747	4615	372.909

Now after SE_d calculations, we sketch SE_d vs. depth. The resulted graph shown in fig.(1).

Fig.(1) Relation of SE_d vs. depth
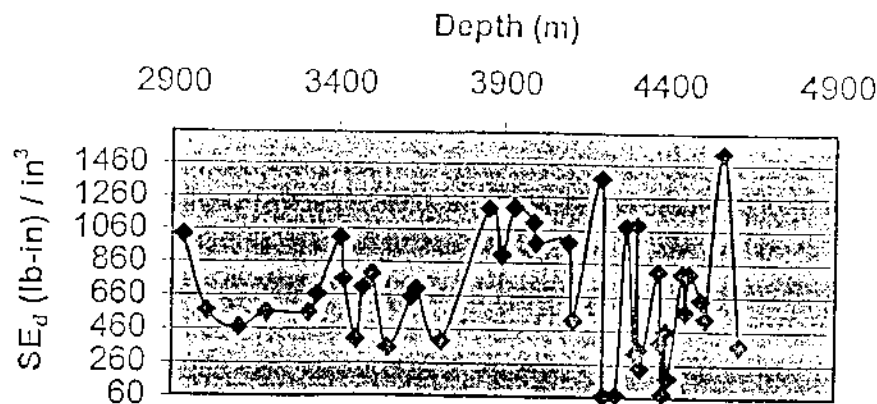
We notice that each point on the graph represent bit performance regardless the trip time, rig cost, and other parameters that effects the cost per foot (CPF).We will show later how the best bit performance carried lowest values of SE_d values .

Relation of ROP with SE_d :

First of the distinguished part of the graph is that we notice very low value of SE_d i.e. 69.38 lb-in / in3 at depth 4210 m .

If we return to penetration rate at that depth, it was 24.607 ft / hr .

The same thing, it has been realized at depth 4247 m, the calculated SE_d was 76.873 corresponding to rate of penetration equals to 26.25 ft /hr .

If we get benefit of the lithology at depth between (4120-4400 m), it refers to Gotnia formation, and particularly at depth between (4204-4252 m) the 1st cycle of Gotnia salt encountered . The presence of salt at that formation increases the rate of penetration & consequently decreases the value of SE_d calculated according to equ.(7).

Also we realize the same thing at depth between (4300-4358 m) & particularly at depths 4315 &4320 m where, the second cycle of Gotnia salt, but SE_d here are so low like the first Gotnia salt i.e. 345.761 & 236.984 (lb-in) / in^3 respectively .
Final effect of Gotnia salt encountered at depth 4387 m where the third series Gotnia salt and the value of SE_d at that depth was 85.625 (lb-in) / in^3, so we realize that at very high ROP SE_d will be low.

Bit performance:

Using various bits to drill each formation as shown in table1 (1) produces various graphs of SE_d vs. depth as following :-

Nahr Umr and Shuaiba formations:

For both above formations, we have only one point of readings for bit record and consequently one point of SE_d for each formation, so it is insufficient to apply SE_d technique for these formations .
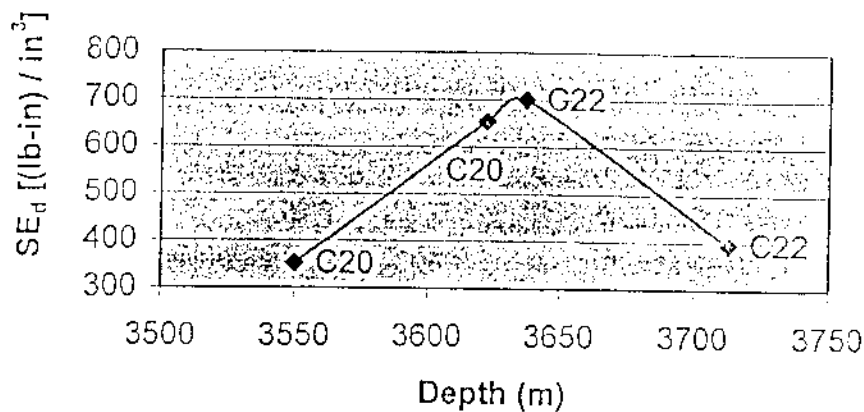
Zubair formation:

For this formation, and according of it's lithology, which most of it is limestone with little bit of shale, so we see that optimum (best) bit used to drill this section is JD4 because it carries lowest value of SE_d.This conclusion is identical to which used by bit comparison chart [7] where JD4 bits classified under insert medium bits where, medium refers to medium formations i.e. between soft to hard formations & here limestone represent this formation .Fig.(2) illustrates values of SE_d vs. depth for Zubair formation.

Fig.(2) SE$_d$ vs . depth for Zubair formation
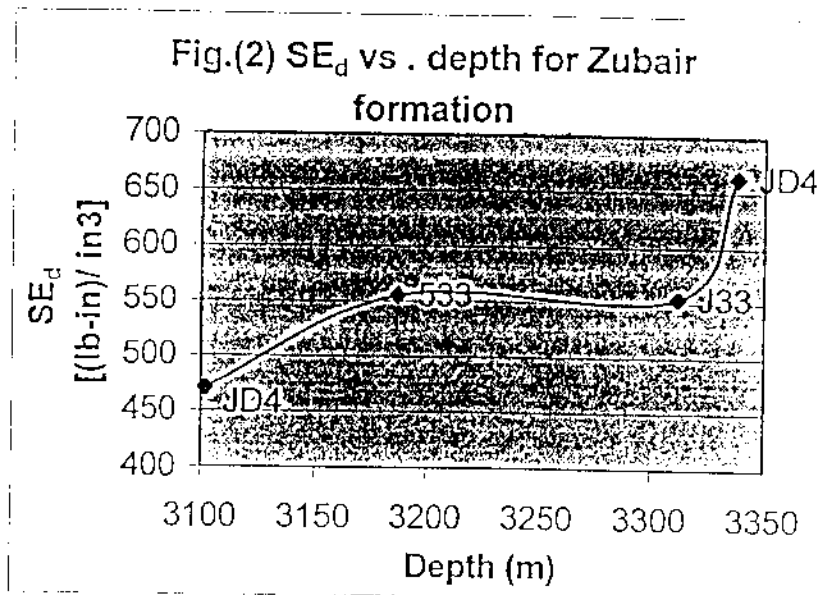
Yamama formation :

For this formation we notice that C20 bit carried minimum SE$_d$ which that means it is the best , but unfortunately the bit comparison chart that
we used does not include c20 bits into it in order to confirm our choice to use these bits.Fig.(3) illustrates SE$_d$ vs. depth for Yamama formation .

## Fig.(3) SE$_d$ vs. depth for Yamama formation

Sulaiy formation :

From the lithology for this formation, we realize that most of it is limestone plus Anhydrite , and from fig.(4) we notice that minimum value for SE_d corresponded to FS5 KJ bits, which it is classified according to bit comparison chart under insert hard bits where, hard refers to hard formations such as limestone and anhydrite and this is identical to our formation i.e. (Sulaiy formation) .

Fig.(4) SE$_d$ vs. depth for Sulaiy formation

Gotnia formation :

For this formation the best bit is J3 because it carried lowest value of SE_d and according to bit comparison chart these bits classified under milled tooth soft bits which it is used for soft formation, and this is true because most of Gotnia formation is salt and soft anhydrite which considered soft formation .Fig.(5) illustrates his reality

Fig.(5) SE$_d$ vs. depth for Gotnia formation

Najmah formation :

For this case the best bit used is F4 because it carried lowest value of SE_d i.e. 179.658 [(lb-in) / in^3] and according to bit comparison chart these kinds of bits

classified under insert medium bits, and from the lithology of Najmah formation which most of it is limestone .

And as known that Limestone considered as medium formation, so it confirms the reality of bit comparison chart. This reality shown in fig.(6)

below.

Fig.(6) SE_d vs. depth for Najmah formation
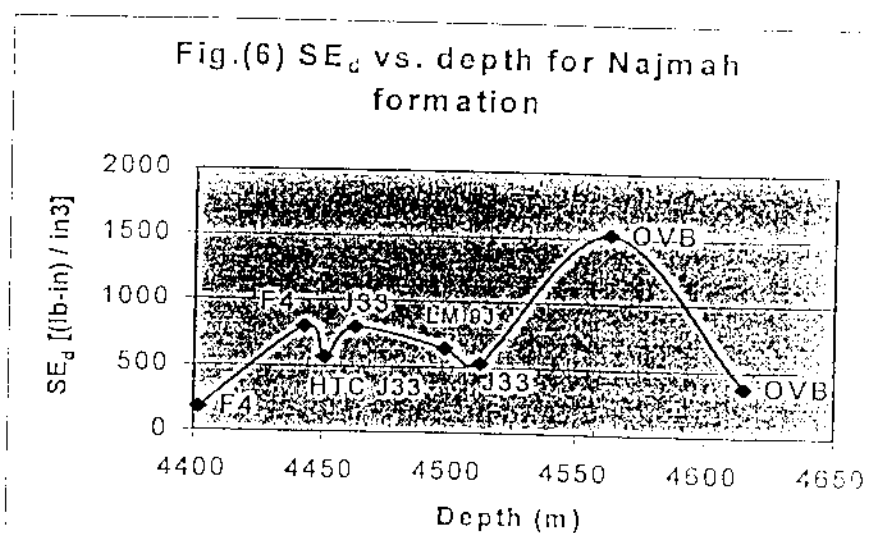
Conclusions

1- SE_d technique is so useful and economical method to evaluate the drilling bits and bit performance by optimum bit selection .

2- Lowest SE_d occurred at highest rate of penetration .

3- The drilling parameters such as weight on bit, rotary speed and bit size have slightly effect on SE_d rather than rate of penetration .

4- Optimum bits can be selected at each formation by plotting SE_d vs. depth, where bits which carried lowest SE_d are the best or optimum bits and consequently reduces drilling costs .

5- Optimum bit drilled Zubair formation was JD4 bit, while C20 bit for Sulaiy formation, J3 bit for Gotnia formation and F4 for Najmah formation .

6- We can apply this technique for the adjacent wells to get optimum bits use to drill similar formations and consequently reducing drilling operation costs.

SECURITY ROCK BIT COMPARISON CHART

Bit Comparison Chart [7]

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الخلاصـة

الدراسة المقدمة تتناول تقنية الطاقة المحددة المحفورة و المستخدمة لدراسة ادائية الحافرات لبئر نفطي في جنوب "العراق و(بالتحديد البئر النفطي غرب القرنة رقم ١٥) ، حيث تم احتساب لـ SE لأعماق مختلفة و لحافرات متنوعة .

و باستخدام العلاقة بين الطاقة المحددة و العمق تم تأشير افضل ادائية للحافرات.

و ان أدنى قيم لـ SE المحسوبة تشير إلى امثل حافرة تم استعمالها لحفر المقطع المحدد و بالتالي يمكن التقليل من تكاليف الحفر الباهضة .