Bit Record Analysis for Bits Evaluating and Selection

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ABSTRACT

The bit record is a part from the daily drilling report which is contain information about the type and the number of the bit that is used to drill the well, also contain data about the used weight on bit WOB ,revolution per minute RPM , rate of penetration ROP, pump pressure ,footage drilled and bit dull grade. Generally we can say that the bit record is a rich brief about the bit life in the hole. The main purpose of this research is to select the suitable bit to drill the next oil wells because the right bit selection avoid us more than one problems, on the other hand, the wrong bit selection cause more than one problem. Many methods are related to bit selection, this research is familiar with four of those methods, which they are: specific energy method, bit dullness way, cost per foot method, offset well bit record and geological information way. Five oil wells have been studied in Rumaila Oil Field in South of Iraq which they are R-531, R-548, R-536, R-544 and R-525. The wells R-531, R-536 and R-525 are vertical wells; the wells R-548 and R-544 are directional wells at angle of inclination 8.79° and 16.62° respectively.

Key words: bit record, selection, bit, rate of penetration.

تحليل سجلات الحافرة من اجل تقييم اختيار الحافرات

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الخلاصة

سجل الحافرة عبارة عن جزء من التقرير اليومي للحفر والذي يتضمن معلومات عن نوع وعدد وحجم الحافرات المستخدمة لحفر ذلك البئر.ويتضمن سجل الحافرة ايضا معلومات مهمة اخرى مثل مقدار الوزن المسلط على الحافرة ومقدار معدل دوران عمود الحفر في الدقيقة الواحدة ومقدار معدل الاختراق وعدد الاقدام المحفورة وضغط المضخة وايضا يتضمن هذا السجل معدل تلف او تضرر الحافرة نتيجة عملية الحفر.بعبارة اخرى يمكن القول بان سجل الحافرة هو ملخص لحياة الحافرة داخل البئر اثناء عملية الحفر.الهدف الرئيسي من هذا البحث هو لاختيار الحافرات المناسبة لحفر الابار الجديدة وذلك من خلال تحليل سجل الحافرة لابار نحفورة سابقا لانه الاختيار الصحيح لحافرة يجنبنا الكثير من المشاكل اثناء الحفروالعكس صحيح.توجد اكثر من طريقة لاختيار الحافرات منها طريقة الطاقة المحددة وطريقة تلف الحافرة وطريقة كلفة حفر القدم الواحد وطريقة سجل الحافرة والمعلومات الجيلوجية. 5 ابارفي حقل الرميلة جنوبي العراق اختيرت للدراسة ثلاثة من هذه الابار عمودية والاخران موجهان بزاوييتي 8.79درجة و 16.62 درجة على التوالي. وتم حفر تلك الابار باستخدام انواع مختلفة من الحافرات منتجة من ثلاث شركات مختلفة وتم تقييم ادائية تلك الحافرات اعتمادا على اسس طرق اختيار الحافرات

الكلمات الرئيسة :سجل الحافرة,اختيار,حافرة,معدل الاختراق.

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1. INTRODUCTION

All rig parts have one main purpose: to put a bit on the bottom of a hole and turn it to the right. Rig owners and operators want a bit that gives a good rate of penetration. They also want the bit to have longevity. The consideration that most affects bit selections the type of rock, or formation, the bit must drill. Even though many types of formation exit, it is not practical for rig operators to change bits every time. In this case, the rig operators would probably select a bit designed to drill medium-soft rock or medium-hard. Manufactures make bits to drill various formations hardness **Bela, 2012.**

This research shows how to get benefit of the data from bit record to select the suitable bit for drilling the next oil wells. These data belongs to five oil wells in south of Iraq. Since the bits that drilled those sections didn't enter to the well and get out from it without any damaging, bit dull grading is the window that from it, it can be known what happened to the bit that drilled those depths. To get most footage and fastest penetration rate, and therefore the lowest cost, the operator or contractor must choose the right bit for the job. Operators have several ways of getting information to make this decision. Dull bit records from nearby wells show wear to the bits used to drill them. For each well, the driller keeps a record of the depth, type of rock, fluids, and anything else interesting about the operation. Bit record is helpful when drilling subsequent wells in the same field**. Aswad, 1996**.

2. BIT SELECTION AND EVALUATION:

There is more than one way for choosing the best bit for drilling the oil wells, which they are:
1-specific energy way
2-bit dullness way
3- Offset well bit record and geological information way. **Allen, 1980.**
4-cost per foot way
The SE method depend on the minimum energy that is loosed at the bit to choose the bit, while bit dull grade method depending on the degree of the dull characteristic that occurred at the bit during drilling the well. A little bit damage mean good bit type and manufacturing and more bit damaging, mean bad bit manufacturing and type. Generally, not the good bit manufacturing and type effect on the bit dull grade, the drilling parameters, hydraulic and the type of formation, all of them affect in great degree on bit dull grade. This study deals with all of pervious ways **Rabia ,1982** .Depending on available data, this research is interested with the all the above ways of bit selection .

2.1 Specific Energy Method

The specific energy method gives an easy method for the suitable bits. It is defined as the demanded energy to remove one unit volume from the drilled rock.it can be taken any homogenous units. The equation of specific energy it can be derived by depending on the losses force at the bit in one minute.so,

$$E = W * 2 * \pi r * N \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad 1$$

Where:
E: The mechanical energy, lb.-inch.
W: Weight on bit, lb.
N: Revolution per minute, RPM.
R: Radius of bit, inch.
The equation of raised rock volume in one minute is:

V= $\pi r^2 * PR$ ………………………………………………………………………...2
Where:
PR: rate of penetration ft. /hr.
By dividing equation 1 and equation 2 to get the equation of specific energy
SE=E/V……………………………………………………………………………….3
SE= W*$2\pi r * N/\pi r^2 * PR$ ……………………………………………………………..4
Where:
SE: Specific Energy,lb-inch/inch^3
The equation of SE in lb-inch/inch^3 units is:
SE=10 WN/R*ROP…………………………………………………………………5
By using the diameter of bit D in equation 5 instead of R where R=D/2, the equation 5
Will be:
SE=20 WN/D*ROP…………………………………………………………………6

From equation 6, it's clear that any changeable in the value of WOB and N lead to change in the value of ROP, and that effect on the value of SE **Rabia ,1985**. It can be said that the SE method represent direct measurement for bit performance for the formation to be drilled, also it is an indicator to describe the interaction between the formation and the bit **Harold J., 2013**.

The value of SE don't represent an essential properties of drilled rock, it is depend in great degree on the bit design and type and manufacturing. The value of SE that result from drilling soft formation different completely from the value of SE that result from drilling hard formation, which mean the type of formation effect in great degree on the value of SE.it can be say that the SE method is accurate method to select the suitable bit type. The more economical bit (optimum bit), is the bit that give minimum value of SE **R.Harmer , 2013.**

Fig.1 shows the relation between the SE and the cumulative footage for three vertical oil wells which they are: R-525, R-531 and R-536, the value of SE is calculated by using eq.6. The columns 2, 3, 4 in **Table 1**,**Table 2** and **Table 3** represent the input data to get the column 4 in those tables by using eq.6.

For the vertical oil wells, the following points are found:

1- The smith bit of GS105BVC model is the best bit to drill 17.5 " ,R-531 from 454.2 ft. to 1862.22 ft. hole section by depending on the SE method.
2- From 1862 ft. to 4287.6 ft., 12.25" hole section .Comparing with the other two wells, the Baker H. Bit of HC606Z-PDC model in R-531 well is the best bit.
3- The Halliburton bit of SFD75H model that drilled 12.25 " hole section in R-536 well from 4287 ft. to 5874 ft. is the best bit.
4- From 5874ft to 7358ft, 8.5"hole section in well R-531. Baker H. bit of Q506X-PDC model gave the lowest value of SE.

Fig.2 Show the relation between the SE and the cumulative footage for tow directional oil wells which they are: R-544 and R-548, the value of SE is calculated by using Eq. (6) ,the column 2,3,4 in **Table 4** and **Table 5** represent the input data to get column 4 in those tables by using Eq.(6):

For directional oil wells, the following points are found:

1- From 454ft to 1862 ft., 17.5"hole section in well R-548. Baker bit of GTX-CG1 model gave the lowest SE value.
2- From 1862 ft. to 4000 ft., 12.25" hole section in well R-548. Baker bit of EP7199 model gave the lowest SE value.

3- From 4000ft to 6510 ft., 12.25" hole section in well R-544. SMITH bit of MSI616LPX model gave the lowest SE value.
4- From 6510 ft. to 7409ft 8.5" hole section in well R-544. Smith bit of MDi616LPX model gave the lowest SE value. As we can see above, by using the SE method, it can be make selection for the suitable bit to drill the next oil wells. The bits that gave the lowest values of SE is the preferred bits. **Fig. 3** show the relation between the SE and the cumulative footage for all the studied oil wells

For the all (five oil wells), the following points are found:

1- The R-548 well gave the lowest value of SE compared with the other studied oil wells for the 17.5"hole section.
2- The R-531 well gave the lowest value of SE compared with the other studied oil wells for the 12.25 "hole section.
3- The R-531 well gave the lowest value of SE compared with the other studied oil wells for the 8.5 "hole section.

2.2 Dull Bits Grading:

It is very important to grade dull bits properly. Grading a dull bit means estimating how much and where it has worn. Proper dull bit grading helps the operator and the contractor correct poor drilling practices, select the best type of bit for specific conditions, and make decisions that affect the cost of future drilling. It is a form of ongoing field testing that benefits all drilling contractors and operators **Nollely, 1986.** Roller cone bits and fixed –head (diamond) bits are both graded using an International Association of Drilling Contractor (IADC) dull bit classification system with eight categories as in **Table 6** Since fixed-head bits have no bearing, the column for bearing wear (B) always has an x in it when grading diamond bits. Roller con bits and fixed-head bits use the same dull bit grading system. They are grading on the basis of cutter wear, bearing wear (not for fixed-head), and gage wear **Glowka, 1983.**

Five wells have been studied each well consist of more than one section, the data that we have belong to 17.5",12.25" and 8.5" hole sections for each well. Five wells mean five 17.5" hole section and five 12.25" hole section and 8.5"hole section. Each section drilled by one bit or more than one bit, that depend on if that the bit is good and able to drill the planed footage .sometimes there are problems lead to use more than one bit. This study includes comparison each section in each well with the other same section size for the other wells. The comparing between those sections is about the degree of dullness to find the best bit from those bits to use it for drilling the next oil wells.
Table7 and **Table11** show that the 17.5"hole section in all studied wells drilled by using one bit type because this hole section is not deep and the drilled footage not more than 600ft . Also, the drilled formation in this hole section are Dibdiba, Lower Fars,Ghar,Dammam. The 17.5" hole section is drilled by using milled teeth bits in many wells. The first part from 12.25"hole section is drilled by using insert teeth bits and the second part is drilled by using PDC bits. The 8.5" hole section is drilled by using PDC bits also.
Our data show that the 12.25" is drilled by using more than one bit type because the 12.25" hole section is the longest drilled section compared with 17.5" and 8.5" hole section. From the other

hand the drilled formation in this hole section are Rus,UmmEr-Radhuma,Tayarat,Shiranish,Hartha and Sadi . In the case of directional section, the bit which drill vertical section differs from the bit which drill directional section because the directional section is drilled by using PDC bit and different BHA than those which is used in vertical section. The Roller cone bit (insert teeth bit or milled teeth bit) is just right for vertical section only, but the PDC bit is used to drill directional section and vertical section. The drilling of directional section needs special BHA like mud motor and Rotary Steerable System (RSS), PDC bit can be run with those BHA. **Table 12** and **Table 13** contain more details about the bits that was used to drill the studied oil wells.

The 12.25" hole size is drilled by using tow bit type in R-525 well and three bit in R-531well and tow bit in R-536 well and tow bit type in R-544 well and three bit in R-548 well. For the well R-525 the first bit is MDi616 bit, it was pulled due to slow ROP, Calcite stringer interbedded at top of Tayarat may have been cause of damage, the second bit MDi616E Bit was pulled at TD of 12 1/4" hole section. Bit was missing two cutters with three slightly chipped. Smith Bit of model MDI616EPX was drilled 8.5"hole section in well R-525, the bit was in relatively good condition, no chipped cutters, one nozzle lightly plugged, it can Rerun able to drill other well. This bit is used to drill the 8.5"hole section in well R-548, and as in **Table 9** Smith Bit of model MDI616EPX gave good bit dull grade, it can Rerun able to drill other well.

Depending on the degree of dull characteristic, the following points are found for vertical oil wells and as in **Tables 7, 8 and 9**:

1- From 136 ft to 1566 ft, 17.5" hole section R-536 the Halliburton bit ofEBXT08SLCmodel gave the lowest dull characteristic comparing with the others studied bits.

2- From 1696 ft to 4391 ft ,12.25" hole section R-525 Smith bit of MDi616 model gave the lowest dull characteristic comparing with the others studied bits.

3- From 4420 ft to 5723 ft ,12.25" hole section R-525 the Smith bit of MDi616Emodel gave the lowest dull characteristic comparing with the others studied bits.

4- From 5739 ft to 7327ft, 8.5" hole section R-525 the Smith bit of MDI616EPX model gave the lowest dull characteristic comparing with the others studied bits.

Depending on the degree of dull characteristic, the following points are found for directional oil wells and as in **Table 10** and **Table 11**:

1- From 136 ft. to 1566 ft., 17.5" hole section.R-544 and R-548 both of the bit have the same dull characteristic. Both of them gave good dull grade.

2- From 1696 ft. to 4391 ft ,12.25" hole section R-544 Smith bit oGFS10BVCf model gave the lowest dull characteristic comparing with the others studied bits.

3- From 4420 ft. to 5723 ft., 12.25" hole section R-544 the Smith bit of MSI616LPXmodel gave the lowest dull characteristic comparing with the others studied bits.

4- From 5739 ft. to 7327 ft,8.5" hole section R-548the Smith bit of MDi616LEPX model gave the lowest dull characteristic comparing with the others studied bits.

2.3 cost per foot method

The cost per foot method and as in Eq. depends on the cost of bit, the total drilled footage, trip time and rotating time and neglected the effect on the WOB, RPM and ROP on the bit selection.Eq.7 represent the cost per foot equation

$CPF=C_B+C_R\ (T+tr)/F$………………………………………………………………….. (7)

Where:

CPF: cost per foot \$/ft.

C_B: bit cost \$.

C_R: Rig cost \$/hr.

T: Total rotating time hr.

tr: trip time hr., t= RIH time+ POOH time…………………………………………….(8)

F: Total footage drilled.

Table 14 illustrates the cost per foot for the 17.5" hole section for all the studied oil wells, from this table it's clear that the bit that drill the 17.5" hole section in R-536 Well is the best bit compared with the other studied oil wells. This bit gave the lowest CPF compared with the other studied oil wells while the bit that drill R-544 well show the biggest cost per foot. **Table 15** illustrates the cost per foot for the 8.5" hole section for all the studied oil wells, from this table it's clear that the bit that drill the 17.5" hole section in R-531 Well is the best bit compared with the other studied oil wells. This bit gave the lowest CPF compared with the other studied oil wells while the bit that drill R-548 well show the biggest cost per foot.

Note: for the 12.25" hole section, we have no accurate data concerning to the bits price and trip time, so the studying is related only for 17.5" and 8.5"hole sections.

3. COMPARISON BETWEEN THE METHODS OF BIT SELECTION

Selecting the right bits is easier when drilling additional oil wells in the field because the operator knows what formations to expect and which bit drills them best. Many methods are used for bit selection, each way of them depending on one parameter or tow and neglected the other, so it is from important to make connection between those methods for the accurate bit selection. Sometimes tow method select the same bit type. The SE method depends on the following drilling parameters: WOB, RPM and ROP but neglected the effect cost per foot and as in Eq.6. Depending on the SE method we have the following results: the bits that drill the well R-531 is the best bits compared with the other studied wells for vertical oil wells and the bits that drill the both of wells R-544 and R-548 for directional oil wells. Depending on the cost per foot method the CPF method, the Halliburton bit of EBXT08SLC model in well R-536, 17.5" hole section has the lowest CPF value compared with the other studied oil wells. Also, depending on the cost per foot method the CPF method, the bit Baker of Q506X-PDC model in well R-531, 8.5" hole section has the lowest CPF value compared with the other studied oil wells

It is from important to put describing to the bit dull characteristic that occurs through drilling the oil wells to get the benefit from it and the bit that gave low bit dull grade, is the bit that will be used to drill the next oil wells. The bit dull grade method depends on the degree of dull grade that occurred on the bit during drilling. The bits that drill the will R-525 is the best bits compared with the other studied wells for vertical oil wells. The bits that drill the will R-544 is the best bits compared with the other studied wells for directional oil wells. Generally, it should be take all the above methods in our consideration during bit selection, which will be treated with all parameters and not one parameters and that the key for the right bit selection. In other words, it should be make combination between those methods.

Table 16 and Table 17. show the comparison between SE method and bit dull grade method for vertical oil wells and directional oil wells. It's clear that each of those methods of bit selection preferred bit model differ from the other method because each method followed specific line different from the other.

4. CONCLUSIONS

1- Halliburton bit of EBXT08SLC model that drilled 17.5" hole section in well R-536 is the best bit from the studied wells(it is gave the lowest dull characteristic compared with the other studied bit in this study), is the best bit to drill 17.5"hole section in Rumaila oil field depending on the bit dull grade method . It's drilled about 501 m in 33 hr. Also. For the same section and depending on the SE method, the Smith bit of GS105BVC model in well R-531 has the lowest SE value compared with the other studied vertical oil wells.

2- For directional well, 17.5" hole section, Smith bit of well R-544 of GFS10BVC model gave the good dull characteristic, for the same section the Baker H.in well R-548 of GTX-CG1 model gave the lowest value of SE.

3- SMITH bit of MSI616LPX model which was drilled12.25" hole section (directional part) in R-548 well and the same section in R-544 well. It's drilled about 200 ft. in well R-548 and 950 ft. in well R-544 in 99.97 hr. It gave good dull grade .It is recommended to use this bit to drill 12.25"hole sections (directional part) in this field.

4- Smith Bit of model MDI616EPX which was drilled 8.5"hole section in well R-525 and the same section in well R-548,its drilled about 447 ft. in well R-548and 443ft in well R-525 ,its drilled about 980 ft. This bit gave good dull grade, it is recommended to use this bit to drill 8.5"hole sections in this field.

5- Depending on the cost per foot method the CPF method, Halliburton bit of EBXT08SLC model in well R-536, 17.5" hole section has the lowest CPF value compared with the other studied oil wells.

Depending on the cost per foot method the CPF method, Baker H. bit of Q506XPDC -5 model in well R-531, 8.5" hole section has the lowest CPF value compared with the other studied oil wells.

NOMENCLATURES:

BHA= bottom hole assembly.

ROP= rate of penetration, ft. /sec.
RPM= revolution per minute, Rev. /min.
WOB= weight on bit, lb.
DMLR= daily Mud Logger Report.
POOH = pull out of hole.
PCD = polly crystalline diamond**.**
BT= broken teeth.
HC= heat checking.
CT= chipped cutter.
WT= worn teeth.
ER= erosion.
PN=plugged nozzle.
RIH=running in hole

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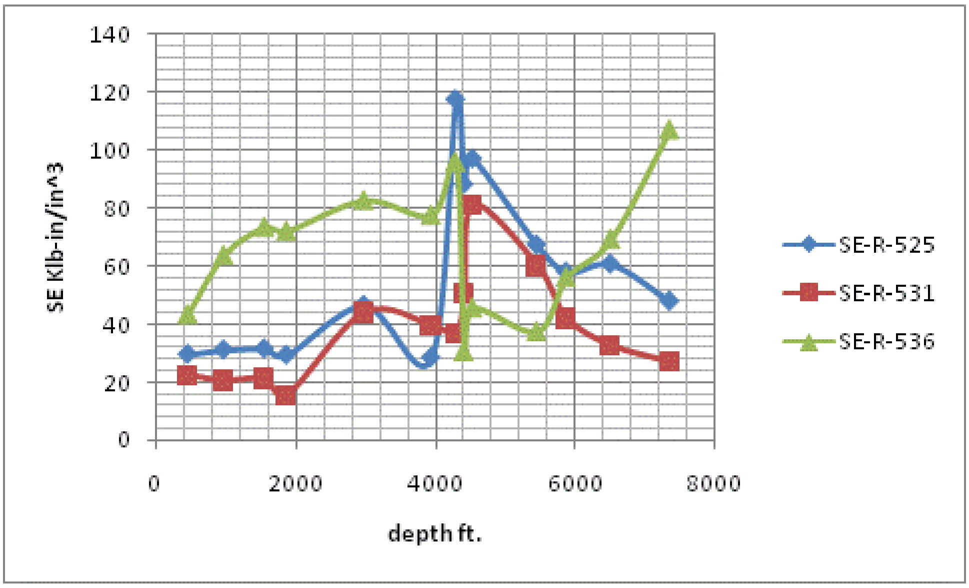

Figure 1. The relation between the SE and the cumulative footage for three vertical oil wells.

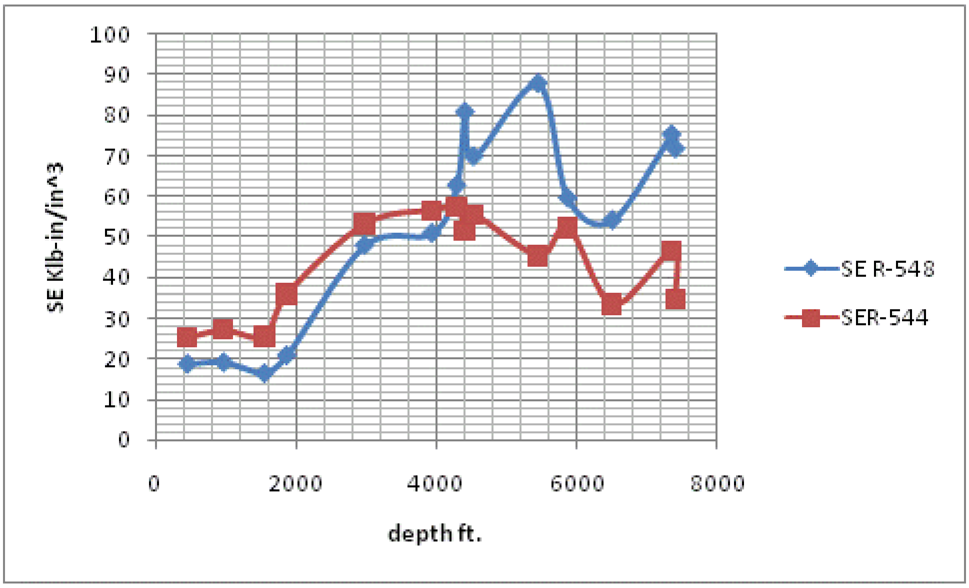

Figure 2. The relation between the SE and the cumulative footage for tow directional oil wells.

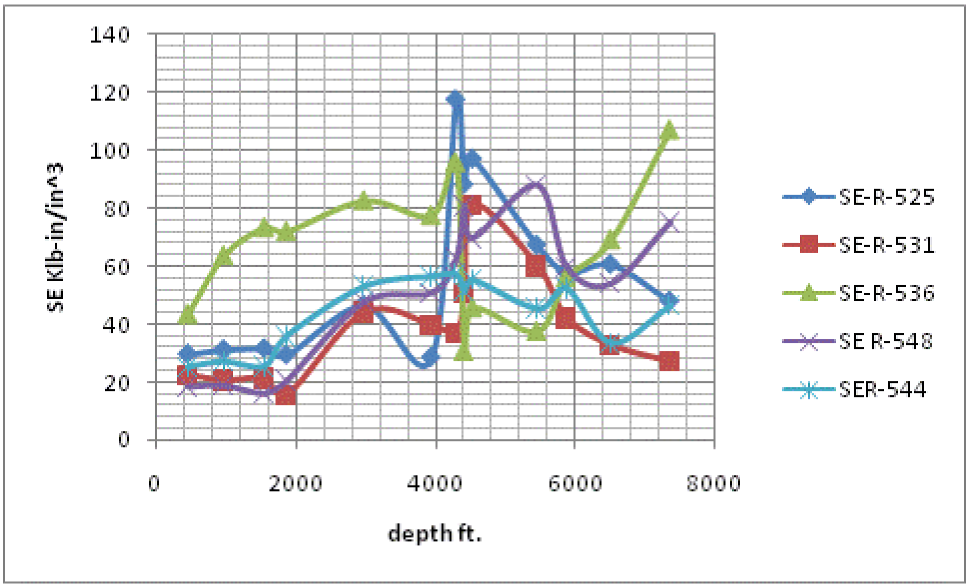

Figure 3. The relation between the SE and the cumulative footage for all the studied oil wells.

Table 1. Drilling parameter of well R-525.

cumulative footage ft.	WOB klb	RPM	ROP ft/hr.	SE klb-in/in^3	formation
454.2	13	80	40.00	29.71	Dibdiba
968.96	9.5	95	33.00	31.26	Lower Fars
1544.28	11	88	35.00	31.61	Ghar
1862.22	10	100	38.79	29.46	Dammam
2973.496	11	80	30.82	46.62	Rus
3936.4	7	90	36.00	28.57	Umm Er-Radhuma
4287.648	20	160	44.48	117.45	Tayarat
4405.74	18	120	40.00	88.16	Tayarat
4529.888	18	90	27.25	97.05	Shiranish
5450.4	12	110	32.00	67.35	Hartha
5874.32	11.5	105	34.00	57.98	Sadi
6510.2	8.5	88	29.00	60.69	Tanuma
7358.04	7	75	25.74	47.99	Mishrif

Table 2. Drilling parameter of well R-531.

cumulative footage ft.	WOB klb	RPM	ROP ft/hr.	SE klb-in/in^3
454.2	10	75	38.00	22.56
968.96	8	90	40.00	20.57
1544.28	9	80	38.50	21.37
1862.22	7.5	80	44.07	15.56
2973.496	6.4	95	22.50	44.12
3936.4	6.5	98.5	26.34	39.69
4287.648	7.5	65	21.57	36.89
4405.74	11	95	33.50	50.93
4529.888	14.5	110	32.11	81.09
5450.4	12.5	103	35.00	60.06
5874.32	10	96	37.30	42.02
6510.2	8.5	85	52.00	32.69
7358.04	9	120	65.31	27.00

Table 3. Drilling parameter of well R-536.

cumulative footage ft.	WOB (klb)	RPM	ROP ft/hr	SE klb-in/in^3
454.2	12	90	28.39	43.47
968.96	20	85	30.50	63.70
1544.28	30	75	35.00	73.47
1862.22	24	88	33.50	72.05
2973.496	18	80	28.43	82.69
3936.4	15.5	95	31.00	77.55
4287.648	19.5	110	36.50	95.95
4405.74	9.5	87	44.17	30.55
4529.888	12.5	93	41.50	45.73
5450.4	11.5	97	48.45	37.59
5874.32	13	115	43.50	56.11
6510.2	9.6	123	40.15	69.20
7358.04	14.5	131	41.70	107.18

Table 4. Drilling parameter of well R-548.

cumulative footage ft.	WOB klb	RPM	ROP ft/hr.	SE klb-in/in^3
454.2	4	77	18.80	18.72
968.96	4.5	84	22.60	19.12
1544.28	5	89	31.00	16.41
1862.22	6.8	96	35.80	20.84
2973.496	10	85	29.00	47.85
3936.4	11.6	94	35.00	50.86
4287.648	15	110	43.00	62.65
4405.74	17.4	125	44.00	80.71
4529.888	16	122	45.70	69.74
5450.4	17.7	133	43.80	87.75
5874.32	12.4	119	40.50	59.49
6510.2	9	96	37.60	54.07
7358.04	7.4	123	28.50	75.15
7409.516	6	132	26.00	71.67

Table 5. Drilling parameter of well R-544**.**

cumulative footage ft.	WOB klb	RPM	ROP ft./hr.	SE klb-in/in^3
454.2	6.6	66	19.50	25.53
968.96	7.8	75	24.50	27.29
1544.28	10	88.5	39.30	25.74
1862.22	5.5	62	15.40	36.15
2973.496	9.4	74	21.30	53.32
3936.4	6.5	155	29.00	56.72
4287.648	7	166	33.00	57.49
4405.74	6	163	31.00	51.51
4529.888	7.5	170	37.50	55.51
5450.4	7	153	38.40	45.54
5874.32	6.4	133	26.50	52.44
6510.2	5	79	27.60	33.67
7358.04	7.5	80	30.30	46.59
7409.516	5.5	78	28.90	34.93

Table 6. IADC Bit Dull Grade.

IADC : Dull Bit Grading

Example of bit grading : 2, 4, BT, M, E, X, (CT,WO), DTF.

Cutting structure							
Inner	Outer	Dull Char	Location	Bearings seals	Gauge	Other dull char	Reason pulled
1	2	3	4	5	6	7	8

1 - Inner cutting structure *(All inner rows.)*

2 - Outer cutting structure *(Gauge rows only.)*

In columns 1 and 2 a linear scale of 0 ---> 8 is used to describe the condition of the cutting structure according to the following guidelines for specific bit types.

Steel toothed bits Measure of lost tooth height due to abrasion and / or damage

0 - No loss of tooth height

8 - Total loss of tooth

Insert bits Measures total cutting structure reduction of lost, worn, & or broken inserts

0 - No lost worn and / or broken inserts

8 - 0% of inserts and / or cutting structure remaining.

Fixed cutter bits Measure of lost tooth height due to abrasion and / or damage

0 - No lost, worn and / or broken cutting structure

8 - 100% of cutting structure lost, worn and / or broken

3 - Dull characteristics

Note: use only cutting structure related codes

BC - Broken cone *	LN - Lost nozzle
BF - Bond failure	LT - Lost teeth and cutters
BT - Broken teeth and cutters	OC - Off centre wear
BU - Balled up bit	PB - Pinched bit
CC - Cracked cone *	PN- Plugged nozzle or flow by areas
CD - Cone dragged *	RG - Rounded gauge
CI - Cone interference	RO - Ring out
CR - Cored	SD - Shirttail damage
CT - Chipped Teeth & cutters	SS - Shelf sharpening wear
ER - Erosion	TR - Cone tracking
FC - Flat crested wear	WO - Wash out
HC - Heat checking	WT - Worn teeth or cutters
LD - Junk damage	NO - No dull characteristics
LC - Lost cone *	* Show cone # or #'s under location 4

4 - Location

Roller cone		Fixed cutter	
N- Nose row	G - Gauge row	C - Cone	S - Shoulder
M - Middle row	A - All Rows	N - Nose	G - Guage
State cone # or #'s I.e. 1, 2, or 3.		T - Taper	A - All areas

5 - Bearings and seals

Non sealed bearings	Sealed bearings	
A linear scale estimating bearing life is used	E - Seals effective	F - Seals failed
0 = No life used ---> 8, 100% bearing life used	N - Not able to grade	X - Fixed cutter bit

6 - Gauge

X - in gauge	1/16 - 1/16" out of gauge	1/8 - 1/8" ut of gauge	3/16-3/16" out of gauge
1/4 - 1/14" out of gauge	5/16 - 5/16" out of gauge	3/8 -3/8" out of gauge	7/16 - 7/16" out of gauge
1/2 - 1/2" out of gauge	9/16 - 9/16" out of gauge	5/8 - 5/8" out of gauge	etc.

7 - Other dull characteristics

Refer to column 3 codes

8 - Reasons bit was pulled or run completed

BHA- Change bottom hol	HR - Hours on bit
DMF - Downhole motor failure	LOG - Run logs
DTF - Downhole tool failure	PP - Pump pressure
DSF - Drill string failure	PR - Penetration rate
DST - Drill stem test	Rig - Rig repair
DP - Drill Plug	TD - Total depth / casing depth
CM - Condition mud	TW - Twist off
CP - Core point	TQ - Torque
FM - Formation change	WC - Weather conditions
HP - Hole problems	
LIH - Left in hole	

Table 7. Bit record of well R-525**.**

Size (in)	Make	Type	Inner	Outer	Dull	Location	Bearing	Gauge	Other Dull	Reason
17.50	Smith	GS105BVC	2	2	BT	A	E	0	WT	TD
12.25	Smith	MDi616	3	4	WT	A	X	In Gauge	NO	PR
12.25	Smith	MDi616E	0	1	LT	T	X	In Gauge	NO	TD
8.50	Smith	MDI616EPX	0	0	PN	A	X	In Gauge	NO	TD

Table 8. Bit record ofwell R-536.

Size (in)	**Make**	**Type**	**Inner**	**Outer**	**Dull**	**Location**	**Bearing**	**Gauge**	**Other Dull**	**Reason**
17.50	Halliburton	EBXT08SLC	1	1	No	A	E	I	No	TD
12.25	Halliburton	EQH16R	6	6	B	A	8	I	BT	HR
12.25	Halliburton	SFD75H	2	3	BT	S	*	I	RR	HP
8.50	Halliburton	FX65D	2	1	No	A	X	I	No	TD

Table 9. Bit record of well R-531.

Size (in)	Make	Type	Inner	Outer	Dull	Location	Bearing	Gauge	Other Dull	Reason
17.5	Smith	GS105BVC	1	1	BT	A	E	I	Non	TD
12.25	Baker H.	VAG - 11 - TCI	2	2	WT	A	E	I	Non	BHA Change
12.25	Baker H.	HC606Z-PDC	5	2	WT	N	X	I	BT	PR
12.25	Baker H.	HC606Z	3	2	CC	N	X	I	WT	TD
8.50	Baker H.	Q506X-PDC	1	1	WT	A	X	IN	Non	TD

Table 10. Bit record of well R-544.

Size (in)	**Make**	**Type**	**Inner**	**Outer**	**Dull**	**Location**	**Bearing**	**Gauge**	**Other Dull**	**Reason**
17 1/2	Smith	XR+VE	1	1	WT	A	E	I	NO	TD
12.25	Smith	GFS10BVC	1	2	BT	G	E	I	CT	BHA
12.25	Smith	MSI616LPX	1	2	CT	A	X	I	NO	TD
8.50	Smith	MDi616LPX	1	2	CT	A	X	I	ER	TD

Table 11. Bit record of well R-548.

Size (in)	Make	Type	Inner	Outer	Dull	Location	Bearing	Gauge	Other Dull	Reason
17.50	Baker	GTX-CG1	1	1	WT	A	1	I	NO	TD
12.25	Baker	EP7199	1	2	WT	1,2	E	I	ER	BHA
12.25	Baker	HCD505z	3	4	BT	A	X	i	CT	BHA
12.25	SMITH	MSI616LPX	1	1	WT	A	X	i	NO	TD
8.50	SMITH	MDi616LEPX	1	1	BT	G	X	I	NO	TD

Table 12. The Types of Bits which is used in directional oil wells.

Bit size in	Well	Type	Manufacturing	Nozzle size 1/32"	Bit classification	Footage Drilled	Hours
17.5	R-544	XR+VE	Smith	3*18+13C	Milled	1535.196	55.69
12.25	R-544	GFS10BVC	Smith	3*16+13C	insert teeth	1577.588	105.66
12.25	R-544	MSI616LPX	Smith	6*14	PDC	2876.6	99.97
8.5	R-544	MDi616LPX	Smith	6*12	PDC	1616.952	73.31
17.5	R-548	GTX-CG1	Baker	3*18+13C	Milled	1931.864	79.00
12.25	R-548	EP7199	Baker	3*16+13C	insert teeth	1837.996	116.7
12.25	R-548	HCD505z	Baker	6*14	PDC	1517.028	102
12.25	R-548	MSI616LPX	SMITH	6*14	PDC	605.6	13
8.5	R-548	MDi616LEPX	SMITH	6*13	PDC	1350.488	70

Table 13. The Types of Bits which is used in vertical oil wells.

Bit size in	Well	Type	Manufacturing	Nozzle size 1/32"	Bit classification	Footage Drilled	Hours
17.50	R-525	GS105BVC	Smith	4*25	Milled	1862.22	48
12.25	R-525	MDi616	Smith	6*14	PDC	2425.428	53.53
12.25`	R-525	MDi616E	Smith	6*14	PDC	1698.708	36.31
8.50	R-525	MDI616EPX	Smith	6*12	PDC	1341.404	26
17.5	R-531	GS105BVC	Smith	3*18+13C	milled	1671.456	38.6
12.25	R-531	VAG - 11 - TCI	Baker H.	2*18+1*16	insert teeth	1165.78	60.46
12.25	R-531	HC606Z-PDC	Baker H.	6*14	PDC	1556.392	44
12.25	R-531	HC606Z	Baker H.	6*14	PDC	1483.72	47.04
8.5	R-531	Q506X-PDC	Baker H.	6*12	PDC	1344.432	20.95
17.50	R-536	EBXT08SLC	Halliburton	3*16+16C	insert teeth	1517.028	33.35
12.25	R-536	EQH16R	Halliburton	3*20	insert teeth	2667.668	93.82
12.25	R-536	SFD75H	Halliburton	7*14	PDC	1026.492	43.66
8.50	R-536	FX65D	Halliburton	6*12	PDC	1603.326	39.92

Table 14. Cost per foot method for 17.5" hole section for all studied oil wells.

Parameters	**R525 ,17.5 "**	**R531,17.5 "**	**R536,17.5 "**	**R-544, 17.5 "**	**R548, 17.5 "**
Bit cost ($)	35,139	36,147	31,133	35,168	30,173
Rig cost ($/hr.)	1,208	1,208	1,208	1,208	1,208
Trip time (hrs.)	13.5 hrs.	14.5 hrs.	14.0 hrs.	15.5 hrs.	16.0 hrs.
In hole time (hrs.)	48.0 hrs.	39.0 hrs.	33.0 hrs.	56.0 hrs.	79.0 hrs.
Net Footage drilled (ft.)	1862 ft.	1671 ft.	1517 ft.	1535 ft.	1932 ft.
Cost per foot	**58.8 $/ft.**	**60.3 $/ft.**	**57.9 $/ft.**	**79.2 $/ft.**	**75.0 $/ft.**

Table 15. Cost per foot method for 17.5" hole section for all studied oil wells.

Parameters	**R-525 ,8.5 "**	**R-531, 8.5 "**	**R-536, 8.5 "**	**R-544, 8.5 "**	**R-548, 8.5 "**
Bit cost ($)	53,167	52,156	50,543	53,498	53,570
Rig cost ($/hr.)	1,208	1,208	1,208	1,208	1,208
Trip time (hrs.)	38.0 hrs.	36.0 hrs.	39.0 hrs.'	35.0 hrs.	36.0 hrs.
In hole time (hrs.)	26.0 hrs.	20.0 hrs.'	40.0 hrs.	73.0 hrs.'	70.0 hrs.
Net Footage drilled (ft.)	1341 ft.	1344 ft.	1603 ft.	1617 ft.	1350 ft.
Cost per foot	**97.3 $/ft.**	**89.1 $/ft.**	**91.1 $/ft.**	**113.8 $/ft.**	**134.5 $/ft.**

Table 16. Comparison between the bit selection methods for vertical well.

Method of selection	Bit model	Bit manufacturing	Method of selection	Bit model	Bit manufacturing	Method of selection	Bit model	Bit manufacturing	Hole size"
Bit dull grade	EBXT08SLC	Halliburton in well R-536	SE	GS105BVC	Smith in well R-531	CPF	EBXT08SLC	Halliburton in well R-536	17.5
Bit dull grade	MDi616	Smith in well R-525	SE	HC606Z-PDC	Baker H. in well R-531	Non	MDi616	Non	Non
Bit dull grade	MDi616E	Smith in well R-525	SE	SFD75H	Halliburton in well R-536	Non	MDi616E	Non	Non
Bit dull grade	MDI616EPX	Smith in well R-525	SE	Q506XPDC	Baker H. in well R-531	CPF	Q506XPDC	Baker H. in well R-531	8.5

Table 17. Comparison between the SE method and bit dull grade method for directional wells.

Section	Method of selection	Bit manufacturing	Bit model	Method of selection	Bit manufacturing	Bit model
17.5	SE	Baker H.in well R-548	GTX-CG1	Bit dull grade	Smith bit of well R-544	GFS10BVC
12.25	SE	Baker in well R-548	EP7199	Bit dull grade	Smith bit of well R-544	GFS10BVCf
12.25	SE	SMITH in well R-544.	MSI616LPX	Bit dull grade	Smith bit of well R-548	MSI616LPX
8.5	SE	. Smith bit of well R-544	MDi616LPX	Bit dull grade	Smith bit of well R-548	MDi616LEPX