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Selection of High Performance Roller Bits Suitable to Specific Well Cases

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Abstract

Depending on the purpose envisaged (proper drilling, enlarging, correction, deviation), on the drilling method (rotary table or submersible engine drilling), on the well conditions (as for diameter, depth, circulated fluid, rock type, tectonics) and by using all the available information, the bit shall be selected from among all existing types and methods so that to be the most suitable depending also on the constructor's provisions and previous performances under the same conditions.

Key words: *roller bit, well conditions, constructor's provisions*

Introduction

In soft rocks having bit balling-up trend such as marl rocks, milled-teeth bits shall be used having high pitch and height with adequate washing system (central nozzle, possibly combined) for efficient disposal of cuttings, while in hard rocks such as abrasive rocks, thrown off balance bits in which both teeth and gauging faces get worn; therefore the use of inserted teeth bits is recommended with hard-faced gauging faces in order to get mechanical strength and necessary wear strength.

Fixed cutter bits are preferable for small diameter boreholes while roller bits having low resistance bearings but for large diameter boreholes, compared to diamond or PDV bits that are too expensive and therefore not cost efficient. Should drilling be done to high depths, then sealed bearing and inserted teeth bits, diamond bits although expensive usually prove to be efficient as their working time is longer than that of the standard bits (non-sealed bearings) and the number of trips is much decreased so that they are recommended in such cases. Given their high rotative speeds that do not influence much the bearings' service life, in submersible engine drilling tools are preferable to be with fixed elements, because the bearing service life decreases with rotative speed. If roller bits are used, bearings can stand higher rotative speeds than journey bearings, however journal bearings stand higher loads than bearings.

Should drilling be done with air, then roller bits shall be used preferably with tungsten carbide insertions and air blowing cooled bearing; diamond and PDC bits are not properly cooled therefore the most suitable selection stays for roller bits as the thermal coefficient of heat transmission is lower in air than in drilling fluid.

In order not to diminish the bit feed rate in some porous-permeable rocks, given that the oil based muds decrease the roller bit feed rate by retarding the reduction in the well – bottom pressure difference, this is avoided by using diamond and PDC bits that due to the scraping effect do not lead to such diminution as beforehand mentioned. Should there be any fractured rocks or rocks with hardness alternation, then roller bits are preferred as diamond ones are sensitive in fractured rocks or hardness alternations being only recommended in hard and homogeneous rocks. In cases when there are severe trends of deviation on a certain fields the PDC bits are preferred as they need thrust loads lower than the other bits therefore lower mechanical stress on the stratum. Summing up, a bit shall be chosen depending on the rock resistance or hardness which is an approximate strength to be determined by drilling tests or by means of sonic logging.

The actual strength like other mechanical features defining the bit work would need laboratory trials on cores sampled out of the concerned rock formation. If there is the case, the required trials should be conducted.

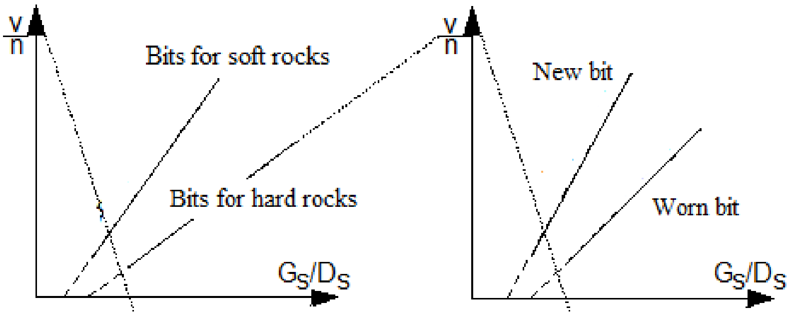

Fig. 1. Bingham Representation [5]:
a – effect of rock hardness; b – effect of bit wear degree

If by a drill-off test the feed is represented onto rotation depending on the thrust load versus the bit diameter, under adequate conditions of bottom washing, a line can be obtained by extrapolation that is called performance line [5]. In hard rocks, the abscissa to origin is larger while the line slope is smaller than in soft rocks (fig. 1,a). As the bit teeth get worn, the contact area with the rock gets larger: the abscissa to origin increases and the line slope decreases (fig. 1,b). The expression:

$$K_s = m_c \cdot \left(\frac{G_{s0}}{D_s} \right)^{\frac{1}{2}} \tag{1}$$

is practically independent from the rock in which drilling is conducted and stands for the bit capacity of displacing; it decreases with the bit wear degree. With m_c the line slope was noted and with G_{s0} – the abscissa to origin. The values of K_s are shown in Table 1.

Table 1. Roller Bit Displacement Capacity

Bit Type	**Constant K_s (mm^3/kN)$^{1/2}$/rot**				
	New Bit	**Worn 1/4**	**Worn 1/2**	**Worn 3/4**	**Fully Worn**
For soft rocks	4.47	3.73	3.11	2.60	2.17
For medium rocks	2.56	1.87	1.56	1.30	1.09
For hard rocks	1.60	1.33	1.11	0.93	0.77
Insertion bits	1.60	-	-	-	-

Analysis of Roller Bit Performances

The analysis of roller bit performances (diameter 8 ½ in) across interval 3, on the three geological formations and related wells resulted in the following performances on the three geological fields:

Caragele Field:

Well 8 Caragele, on the interval 2296-3863 m, made use of two types of bits: IADC117 and IADC417 among which the highest performer is **the rock bit s7** IADC117 that drilled on the interval 2296-2632, H_s = 336 m, t_s = 67.46 h with V_m = 12.8 m/h; **the rock bit s11**, IADC417, on the interval 3447-3863 m, H_s = 416 m, t_s = 58.9 h, V_m = 7.06 m (see fig. 2.).

Well 4 Făurei, on the interval 1676-2189 m made use of two types of bits, IADC117 among which the highest performers are: **the rock bit s5,** on the interval 1711-2051 m, H_s = 340 m, t_s = 29 h, V_m = 10.8 m/h; **the rock bit s4,** on the interval 1676-1711 m, H_s = 35 m, t_s = 4.2 h, V_m = 8.2 m/h.

Although the rock bits IADC117 are designed to soft rocks, or slightly consolidated rocks that lie at the surface and are used up to 2000 m depth, in this case the rock bit s7 at the well 8 Caragele outclassed its condition by drilling up to 2632 m depth, with mechanical velocity V_m of 12.8 m/h. Therefore the choice of these bits proved to be the best.

Colibaşi Field:

Well 256 Colibaşi, on the interval 500- 2470 m made use of a single type of bit that proved to be the best, namely: IADC117: **the rock bit s3,** on the interval 1326-2130 m, H_s = 818 m, t_s = 46 h, V_m = 17.8 m/h has the best performance.

Well 261 Colibaşi, on the interval 2530- 2781 m, although made use of three types of bits (IADC137, IADCM223), it was still IADC117 that proved to be the best by the following: **the rock bit s10,** on the interval 2530- 2781 m, H_s = 251 m, t_s = 31 h, V_m = 8.1 m/h. Again, this type of bit exceeded by over 780 m the limits of depth (see fig. 4).

Piscuri- Filipeşti Field:

Well 111 Filipeşti, the rock bit s2, on the interval 602- 1040 m made use of the type of bit IADC223 with H_s = 1038 m, t_s = 86 h and V_m = 12.2 m/h, standing for the bit record on the field.

Well 112 Filipeşti, on the interval 482-1396 m made use of the type of bit IADC117, H_s = 914 m, V_m = 11.6 m/h, the rock bit number 2 standing for a second choice (see fig. 3).

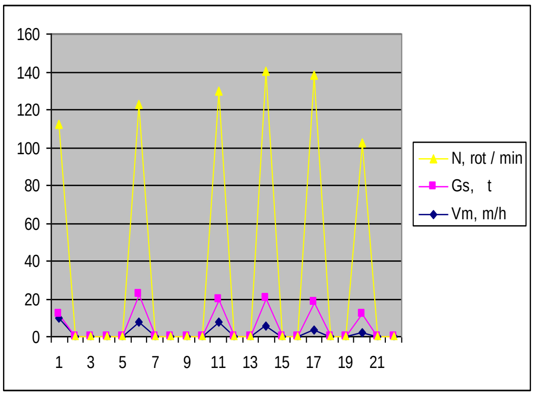

Fig. 2. Well 8 Caragele

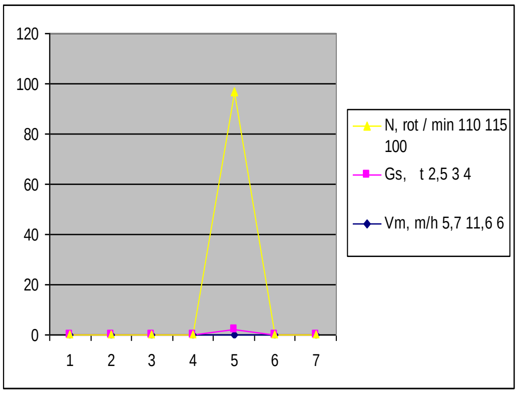

Fig. 3. Well 112 Filipeşti

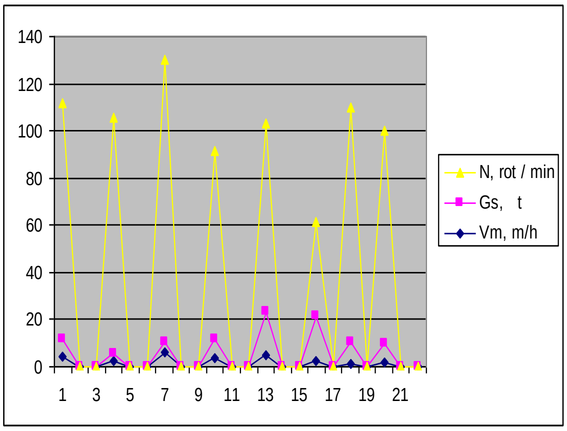

Fig. 4. Well 261 Colibaşi

Bit performances may be established also within a same well, as shown in Table 2. Situation of bits in this table is presented from 374-3000 m. In the gaps there are data missing or not significant. From among the 12 bits of 17 ½ in, the first got the best V_m: 2.63 m/h, compared to the lowest velocity of bits having the same diameter 0.82.

The first bit had also the highest mechanical velocity of all bits in the well. The 4 bits featured 12 ¼ in had velocities within 0.89 (a 15 a) and 2.01 (a 16 a), while bits featured 8 ¼ had within 1.12 (bit 19) to 1.86 (bit s17).

Figure 5 shows the manner how mechanical velocity V_m depends on the thrust on bit G (fig. 5,a.), respectively on the bit rpm N (fig. 5,b.).

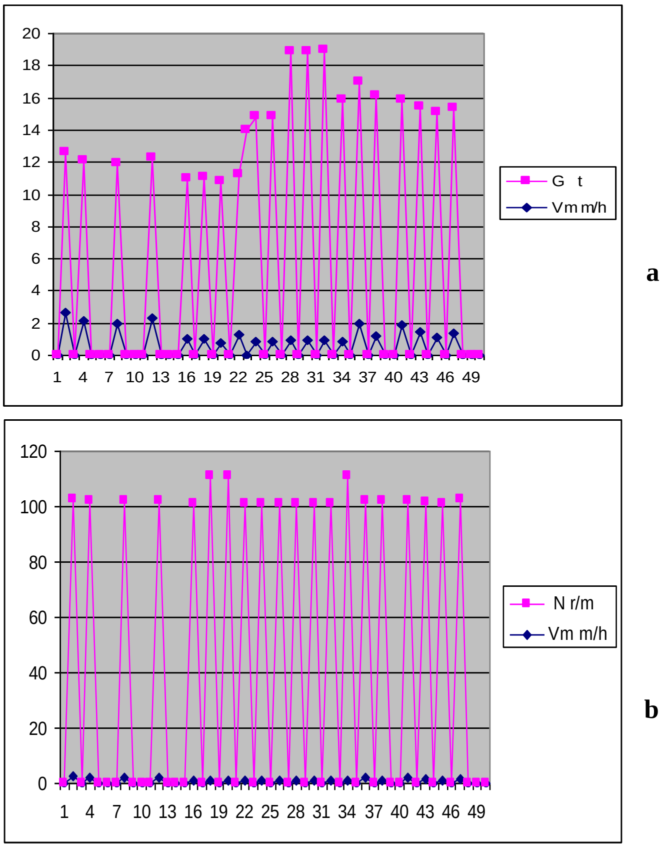

Fig. 5. Mechanical Velocity Reliance: a. V_m = f (G) b. V_m = f (N).

Table 2. Performances of Bits and Drilling Fluids on a same Well: 5Traian S.

Bit No.	**Brand**	**ID**	**Bit Type**	**Series no.**	**Nozzle 1/32**	**H_i m**	**H_f m**	**t_s hrs.**	**H m**	**V_m m/h**	**ρ, kg /dm^3**	**G t**	**N r/m**	**Q l/s**	**V_j**	**IADC Wear**
1	SD BS	17 ½	XN1C-111	1069515	3x22/32	374	550	67	176	2,63	1,3	10	100	54	76	
2	SD BS	17 ½	XT1G SC111	10616362	3x24/32+1x16/32	660	655	49,5	105	2,12	1,3	10	100	54	66	
2	SD BS	17 ½	XT1G SC111	10616362	3x24/32+1x16/32	655	720	33,5	65	1,94	1,3	10	100	54	66	
2	SD BS	17 ½	XT1G SC111	10616362	3x24/32+1x16/32	720	847	56,5	127	2,29	1,3	10	100	54	64	
3	SD BS	17 ½	XT3-135M	10662886	3x28/32	847	881	34,5	34	0,99	1,35	10	100	48	43	
4	SD BS	17 ½	XT1G S-115	10702309	3x28/32	881	941	56,7	60	1,06	14	10	110	50	44	
4	SD BS	17 ½	XT1G S-115	10702309	3x28/32	941	943	2,50	2	0,80	139	10	110	50	44	
4	SD BS	17 ½	XT1G S-115	10702309	3x28/32	943	1093	94	120	1,28	139-146	10-14	100	50	44	
3	SD BS	17 ½	XT3-135M	10662866	3x28/32	1063	1090	32,7	27	0,82	147	14	100	48	43	
3	SD BS	17 ½	XT3-135M	10662866	3x28/32	1090	1112	32	22	0,89	148	14	100	46	40	
5	SD BS	17 ½	XT-135	10708829		1215	1394	162	149	0,92	155	18	100	46		
6	SD BS	17 ½	XTGS-115	10702308		1964	1465	110	101	0,92	157	18	100	46		
7	SD BS	12 ¼	XS3G-137	10876945		1557	1750	111	103	0,93	157	18	100	34		
8	SD BS	12 ¼	XS3G-137	10678942	3x14	1798	1801	37	33	0,89	160	15	110	34	115	No major wear
9	SD BS	12 ¼	EBX SC1	10706258	1x14+3x17	1852	2061	99	209	2,01	165	15	100	34	151	
10	SD BS	12 ¼	XSC1-1168	10672848	3x17,4+1x14	2067	2103	31	36	1,16		15	101	34		
11	SD BS	8 ¼	XSC1-117	10706283	3x 14,29	2249	2448	107	199	1,86		14	100	24		No major wear
12	SD BS	8 ¼	XS3G-137	10711227	3x 14,29	2448	2648	140	200	1,43		14	100	24		No major wear
11	SD BS	8 ¼	XSC1-117	10706281	3x 14,29	2648	2781	119	133	1,12		14	100	24		No major wear
13	SD BS	8 ¼	XS3G-137	10695794	3x 14,29	2761	2964	133	183	1,38		14	101	24		No major wear
14	SD BS	8 ¼	XS3G-138	10695793	3x 14,29	2964	3000?		36							

Another parameter useful for the selection of rock bits both of roller bits and of the other type is represented by the gamma logging curves of density and neutron porosity, capacity of cationic exchange of clayish rocks that may also be used for the selection of its, including of diamond bits.

Upon due interpretation of sonic logging charts the total porosity can be established (effective and total for the rock) depending on its strength. With sonic logging the entire porosity in a rock can be measured that is engaged by water – including the water fixed onto the laminar marls and discrete solid particles dispersed in the water, both effective porosity – like in sandstones and the absolute one – like in marls.

The correlation between total porosity and rock strength depends on the type of rock and break them down into three big categories: sandstones, limestone and carbonates. Depths at which there are carbonate rocks are known and differences between marls and sandstones shall be established by gamma logging. Practically the logging line shall be broken down into intervals (100-500 m), and then the minimum value shall be determined for interval (a) and the maximum value (b). Interval shall be divided into subintervals, i.e.: for subinterval 1 value (c) and for interval 2 value (d). T/he percentage of marls will be:

- for the subinterval 1; % marls = (c-a)/ (b-a); ex.: (30-10)/(90-10) = 0.25%;
- for the subinterval 2; % marls = (d-a)/ (b-a); ex.: (20-10)/80 = 0.125%.

In front of these minimum values, on subintervals the minimum values are read on the sonic logging. TY/he percentage of marls and the sonic logging give information about the rock strength, high values for sonic logging and low values for the percentage of marls show utilisation of bits for harder rocks and reversely. In view of selecting the due bits, also the bit comparative tables built in on a same field formation can be used (Tables 3 and 4).

Selection of Bits for Directional Drilling

Selection of Bits for Directional Drilling [2] has two main aspects: slant direction - which means change of well direction/slant and keep on the well direction. Slant direction is achieved by using as technical means the rock bit and the bottom hole assembly made of drill collars with 1-4 stabilizers fixed at certain distances, in order to allow the bit to act towards the wall.

In the rotary drilling, the rock bit is determined to act towards the wall by the operational regime applied by operator, especially by the thrust on bit. Directing depends on routine – that may decide on the number of stabilizers and, given the experience on a field, work can be done with single stabilizer placed immediately above the bit, or with two or three stabilizers, provided that one should be placed immediately above the bit and the other at a distance sufficient against the bit in order to facilitate the development of the bending-deflection in drill collars between each other. The first stabilizer close to the bit plays the role of a pivot, resting point for the action of the drill collar bent onto the bit.

Should drilling be done by means of bottom engine then directing from the bit and the two stabilizers placed on the engine shall be achieved by an assembly of three non-collinear points, because the upper section of the motor may develop an angle with the internal section. Due to the design of such engines, the distance between the first stabilizer placed down and the bit is much smaller than the distance between the first stabilizer and the second one. This design forces the rock bit to work towards the well wall. Therefore, bits shall be as short as possible, because their body and the shaft between the first stabilizer and the bit stands for the short arm of a lever pushing the rock bit towards the wall. Given that the rock bit is forced to work with the outside of its active part, it is very important that it is very resistant in that area, and even protected and for directing bits shall be selected with protected gauge and pin, and their body should be short in order to push it towards the wall.

Fixed cutting edge bits shall have the outside area – nose, outside taper lengthening, shoulders and gauge very resistant, and the gauge length as short as possible. The whole bottom-hole assembly keeps also the path but their feature is that of composing together with the rock bit a straight mechanical system – points belonging to it shall be collinear – across 20 –40 m length.

Table 3. Comparative Table for Wells 215, 249 and 228 Colibaşi

Well no. and bottom, data:	Lithology, limits, m	Bit Dia., in.	Density /interval kg/dm^3	Issues of Drilling, Action, Remedial, Proposals, Comparison Analyses
Well 215	Mi/D = 746	17 ½ + 26	1.22-1.20	- mud losses (15m^3) – no drilling difficulties.
2420m	D/P = 1308	17 ½	1.20-1.24	- drill string stuck at 561-647m; instrument.
Production Well				Oil bath and vibrations; disengaged the rock bit after 3 days; - corrected interval 476-72.
	P/M= 2005	12 1/4		Increased the salt contents up to 75%;
Deviated path	M/Mi=2132 Mi/O=2189 OI/OII 2250	8 ¼	1.21-1.54	- drill string stuck at 1246m, on withdrawal; drilling fluid overweighed; disengaged after 3 days, corrected 830-840m and 1222-1225m, trends of being stuck at 1328m; treated, overweighed up to ρ = 1.38
Well 249,	M/D = 733	17 ½	1.2	- mud losses (10 m^3)
2326m				- contaminated mud with gypsum 485-520 m - cavitation (0,03m^3) to 529 m
Production Well	D/P = 1300	12 ¼	1.21-1.4	- increased the salt contents up to 680.718 and 870 m
				- changed the accumulated mud with salt saturated mud at 870m;
Deviated path	P/M = 1986	8 ½	1.15-1.34	- mud treated and corrected at 590-990m, ρ= (1.28-1.4)
				- the rock bit stuck on correction at 1068-1085m, with ρ= 1.28, disengaged after 28 days;
				- light mud losses 794-1106m, ρ= 1.32-1.37, corrected 8 days, no result.
	M/Mi = 2146			- lining of casing decided with 9 5/8 in at 1106 m, cavitation at 125 m 0.03 m^3
	Mi/O = 2136			- trends of being stuck at: 1280-1165, 1330-1275, 1304-1250 and 1280-1125 m
	OI/OII 2193			- corrected interv.1170-1180, 1720-1748 2034-2030, ρ=1.21-1.33, cavit. 0.05 - trends of being stuck at 2055-2015 m
				- increased density of mud to 1.33 - increased contents of gas to 7.9 % - decreased dens of mud from 1.33 to 1.31 - drill.fluid treated and overweighed to 1.34
Well 228, 2350m	M/D = 733	17 ½	1.1-1.2	- massive losses of mud on the interval 0-87 m, 30m^3 ρ=1.2; cement plug done across 18 m length, with no result; mud to cellar
	D/P = 1308	17 ½	1.19-1.2	- no drilling difficulties
Production Well	P/M= 2005	12 ¼	1.2-1.37	- drill string stuck at 561-647m; instrum. wt. vibrations and oil baths; disengaged after 3 days, overweighed mud to1,3; corrected interv.476-721m; increased salt contents; corrected 752-1200m
Deviated path				- stuck the rock bit at 1246m, released after 3 days (oil bath and vibrations); corrected interval. 830-840 and 1252-1222m; - trends of being stuck at 1328 m; - increased density of drilling fluid to 1.32 kg/dm^3
	M/Mi=2132	8 ½		- no drilling difficulties

Table 4. Correlations between Wells: 54, 61 and 49AR Filipeşti

Well no.and bottom, data:	Lithology, limits, m	Bit Dia., in.	Density /interval kg/dm^3	Issues of Drilling, Action, Jobs, Recommendations, Proposals
Well 54AR Filipeşti H= 3500 m, Drilling year ’43 Drilling time 60 days	D=350 m, N/A P=980 m, N/A M=1527,N/A H=1527, N/A M3=3500 m, Crude oil + gas	17 ½ 12 ¼ 8 ½	1.26-1.28 1.28-1.3 SG 1.21-1.2 SG 1.18-1.2 SG	All wells have the same operation depth: 3500 m but two of them (54 and 61) had no drilling difficulties. The shortest operation time S54: 60 days.
Well 61AR FILIPEŞTI H= 3500 m, Drilling year ‘44 Drilling time 77 days	D=350 m, N/A P=1050m,N/A M=3500 m, Crude oil + gas	17 ½ 12 ¼ 8 ½	1.24-1.28 SG 1.30-1.34 SG 1.21-1.25 SG	Coal interlayers (Drader 714-975m) were crossed more quickly at 54 AR by treating the drilling fluid with materials specific to the three sandy packs: I up, II and III down.
Well49AR FILIPEŞTI H= 3500m, Drilling year 1987 Drilling time 89 days	D=100 m, N/A P=600 m, N/A M=3500 m, Crude oil + gas	17 ½ 12 ¼ 8 ½	1.15 1.25 1.15-1.28	Hold on hole on almost ½ of the well depth increased the operation time by 29/12 days versus wells 54/61AR; 29 days were employed for circulation and correction which increased the well costs as we as downtime for repairs of rigs by 324 hours.

So also the bits belonging to this system shall be as long as possible. To such respect, fixed cutter bits shall be built with very long gauges in order to keep by “embedment” the well path to be achieved.

For bit selection and optimization of rock bit sequence numerous compromises are accepted caused by several variables: alterable – mud (type, contents of solids, viscosity, filtrate, density); hydraulics (discharge pressure, jet velocity, flow rate, speed in annulus); type of bit (thrust on bit, rotative speed); non-alterable – metrological (site, condition of drilling system, bottom hole temperature, presence of sour gas, round trip time, rock properties, quality of the drilling crew, depth).

Centralized, among the methods allowing for the bit selection and the optimization of the rock bit sequence by the most important factors are: price per metre drilled; bit wear; statistic study of datasheet for bits in previous wells; method of specific energy; etc.

Depending on lithology and on the manner of building this bit sequence the specialty companies recommend certain bit sequences to the oil societies and companies or, eventually even to wells, with proposals concerning: bit diameter, type and IADC code, withdrawal depth, drilled interval, hours/bit, mechanical velocity, weight on bit and bit rotative speed, combinations of nozzles, flow rates, bit price, nozzles, etc. Selection of bits can be achieved also depending on faults and wear of bits withdrawn to the surface from a same geological formation, from a same well or neighbouring wells, from the same types of rocks, same conditions or working conditions alike, etc.

Proposals for Adaptation of the Letter Code Signification of Some Bit Designations to Bits Withdrawn before the Term

In the following table we tried to adapt significations and explanations from English language for some codes, by using words having identical letters, close to or at least half meaning versus the letters in the codes. We have achieved it to a percentage of 71-74%:

Table 6. Proposed Signification

It.	Code	Code Signification / Proposed Signification	Signification in English
2	CM	Conditioning of drilling fluid/ Conditioning of mud	Condition Mud
3	CP	Sampling of boring core / Sampled core	Core Point
5	DP	Building of cement plug / Plugging (cement)	Drill Plug
6	DSF	Drill string failure/ Drilling system damaging	Drill String Failure
8	DTF	Operating tool failure / Damaging of tool kits	Down Hole Tool Failure
9	FM	Change of geological formation lithology / Altered formation	Formation Change
10	HP	Drilling difficulties/ Drilling problems/ Oilfield malfunctioning	Hole Problems
11	HR	Achievement of keeping the bit on bottom hole/ Hours achieved	Hours on Bit
12	LOG	Completion of geophysical surveys / Running logging	Run Logs
13	LIH	Metallic remains on bottom hole / Metal left in hole	Left in Hole
14	PP	Increase in pumping pressure/ Increased pumping pressure	Pump Pressure
15	PR	Decrease of bit feed rate/ Less dense penetration (rates)	Penetration Rate
16	RIG	Repairs to the drilling rig / Repairs of drill string system	Rig Repairs
17	TD	Reaching final or casing depth/ Completed bottom hole/ casing hole	Total Depth/ Casing Depth
19	TW	Breaking of pipes due to torsion / Pipe cutting	Twist Off
20	WC	Unfavourable weather conditions/ Severe weather! / Weather conditions	Weather Conditions

The best selection of bit shall be immediately confirmed after drilling resuming and bit running-in by conducting a drill-off test using Bingham representation (shown beforehand) to be achieved with the test results, get the bit performance line resulting in indications about its consistency with the rock in which drilling and on the efficiency of t5he working regime applied; the best verification shall be done after the bit has been withdrawn, by analysing its wear and one of the drilling parameters, such as cost/m drilled.

Conclusions

As a conclusion, selection of roller bits shall be done depending on the following:

- the purpose envisaged: enlarging, proper drilling, correction, deviation;
- the drilling method: rotary table, or submersible engine drilling;
- the well conditions: as for diameter, depth, circulated fluid, rock type, tectonics
- and by using all available information.

The bit shall be selected from among all existing types and methods to be the most suitable depending also on the constructor's provisions.

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Alegerea sapelor cu role performante pentru situaţii concrete de sondă

Rezumat

Alegerea sapelor se face în funcţie de scopul urmărit (foraj propriu-zis, lărgire, corectare, deviere), de metoda de foraj (cu masa rotativă sau cu motoare submersibile), de condiţiile de sondă (diametru, adâncime, fluid circulat, tip de rocă, tectonică) şi, folosind toate informaţiile disponibile sapa se alege dintre toate tipurile şi modelele existente, cea mai potrivită, şi în funcţie de prescripţiile constructorului şi, chiar de performanţele anterioare, în aceleaşi condiţii.