SPE 149113

Methods of drilling rate increase, near bit ejector application

S. Evstifeev, Innoil LLC; V. Evenko and A. Shakirov, Drilling Innovation LLC

This paper was prepared for presentation at the 2011 SPE Saudi Arabia Section Technical Symposium and Exhibition held in AlKhobar, Saudi Arabia, 15–18 May 2011.

Abstract

Desired drilling depths are rapidly increasing i.e. extended reach and ultra deep drilling, thus sharply decreasing the performance of drill bits. The reason for this is the presence of porous, reservoir, and the variable total differential hydrostatic and hydrodynamic pressures that affect the conditions of rock destruction.

In Near Bit Ejector Pump (NBEP), we developed a new and innovative design based on the principle of using the kinetic energy of the liquid jet. This system reduces the differential pressure in the bit's work zone, thus result in mechanical drilling rate increase of up to 20% and more, mudding the borehole wall and preventing bit balling.

NBEP technology works in the partial loss of washing fluid zones, therefore preventing the phenomenon, moreover retaining the diameter of the hole close to desired nominal diameter. The technology is applicable to all rotary drilling, and in conjunction with hydraulic downhole motors, as well as with both tricone bits and PDC bits. This technology has been used and is still applied successfully in drilling operation of Russian and Libyan oil fields, allowing significant gains to the operating oil companies.

Introduction

Archive case history data show the depressing effect of increased drilling depths on drill bit performance degradation. A conclusion realized by both domestic and foreign researchers "change in downhole conditions and rock destruction influenced by such factors as the presence of pore pressure, reservoir, and the total differential of hydrostatic and hydrodynamic pressures, and mechanical properties of rocks result in rapid drill bit decline" [1].

Theory

Numerous laboratory and field studies were conducted illustrating the effect of these factors on rock destruction behavior. As result the following was observed:
1. Differential pressure is one of the main factors determining the performance of bits;
2. Intensive decrease of ROP takes place at the initial stages of differential pressure increase up to 509 psi. The further increase of differential pressure (P) is associated by stabilization of ROP (Vm)
3. Decreasing differential pressure increases ROP.
4. With increase of applied weight on the bit, increases the sensitivity of ROP to differential pressure change;
5. It is impossible to detect a common relationship Vm = Δf (P) based on results of the test drilling.

So at the present it is considered that on the current drilling modes the differential pressure, is usually the main determining factor on the cost-performance characteristics of drilling. An increase in Δ P up to 203 ... 1015 Psi, depending on drilling conditions, ROP may be reduced in 2 ... 5 times.

Addressing these issues is of importance to both the drilling operation and limiting formation damage, and subsequently swifter completion and well intervention and in oil production.

Based on recent information, differential pressure causes the static forces holding the sludge at the bottom, numerical coloration equal to the difference between hydrostatic pressure and reservoir (pore). However on the circulation of drilling fluid the hydrodynamic pressure rises, which also impacts depressant on the bottom hole. Consequently, the on bottom hole the circulation of drilling mud acts as depressant pressure, which is the sum of the differential and hydrodynamic pressures.

The most common way to reduce the differential pressure is drilling balance and or underbalanced drilling In addition to the traditional techniques to minimize hydrodynamic loss. There are other methods based on the use of some physical effects:

• **The application of the Toms's effect,** which constitutes that the addition of certain polymers into the water can reduce pressure loss in turbulent flow regimes significantly and up to 30%. Decreasing the friction substances are referred the carboxymethyl cellulose (CMC), polyacrylamide, poliizobutelen and some other polymers. There is an optimal ratio of polymer at which the maximum effect is achieved. It relative to the polymer nature, pipe size, fluid density and the Re criterion.

• **The effect of early turbulence application** - some drilling mud additives reduce Reynolds criterion Re_{kr}, changing the flow regime causing the premature turbulence.

By this sharp and improved transport and more importantly cleaning capacity of drilling fluids it was concluded that oil and carboxymethyl cellulose - 500 (CMC – 500) are active stimulators of early turbulence, and the activity of CMC-500 is significantly higher than that of oil. For example, on 0.35% content of CMC-500 in mud Re_{kr} is decreased in 14 times compared with Re_{kr} of initial mud.

Another means of helping reduce the differential pressure while drilling is drilling with the utilization of

ejector pumps. In practice this method has not found wide application because of the existing designs limitation of traditional ejector pumps that are of large dimension and can be used only for rotary drilling due to tremendous pressure build up effecting operation of ejector pumps [2].

Development

Based on the above and as a result of a patent search the Near Bit Ejector Unit (NBEU), was conceived and developed on the principle of applying the mudflow kinetic energy to increase the efficiency of the device to 60%. This design is characterized by small dimensions and can be used in as in rotary drilling, and also on drilling with downhole motors (fig. 1).
Proper application of NBEU is a selected technological mode. Under the technological mode it is realized the selection of the necessary pump flow rate, the maximum possible standpipe pressure as well as the optimal the required number nozzles and their sizes on the bit.
This calculation is based on two propositions:
• Maximum hydraulic effect is achieved at the maximum pump discharge pressure;
• Based on the drilling depth that can determine the optimal ratio of flow velocity and nozzle sizes to ensure a maximum hydraulic power supplied to the bit, or the necessary force of the jet blow.

Tests of NBEU with rotary drilling were carried out in Sakhalin's oilfield, Mirzoyev area and Saratov oilfield Mikhalkovskaya's area. The results of the tests proved that the drilling rate increase and footage on the bit dependent on the pressure, applied on the NBEU and on the bit. Empirically it was established that the minimum pressure on NBEU and bit should be at least 435 psi, which provides drilling rate increase for 15 ... 20%, and bits footage growth for 25 ... 30%. On further pressure buildup the relevant indicators are also increased: at a pressure drop on NBEU equal to 870 psi, the increase of ROP is 60 ... 80% footage - 80 ... 90%, on 1450 psi pressure, growth of factors were 80 ... 110% and 100 ... 130%.
As we see from received field tests, the gains of bit's footage slightly advances of gains of ROP. It is connected with the exception of the phenomenon of cuttings recycling in bit area, so the bit tooth is less wear out.
Also NBEU was widely tested on drilling with downhole motor in the fields of Chernogorskoe and Ershovoe (Russia). Totally NBEU was tested on 50 wells in 164 – 3280 ft and 7218 – 9186 ft intervals.
On drilling for conductor in 164 – 3280 ft interval NBEU was used with 11-5/8" MZ-GNU and SZGV bits. Interval of inclination angle changing was not taken into account on comparison. The average ROP on offset wells was 78.4 ft/hr. The average ROP on wells drilled with NBEU was 137.5 ft/hr.
The most demonstrative results were recorded while drilling in vertical sections, for example with conventional means of drilling on well # 50916, 190 – 2473 ft interval were drilled in 27 hours on the other hand and with the incorporation of NBEU on well # 41040 137 – 3323 ft interval were drilled in 24 hours.

On drilling for production string, for comparison it was considered only the 7218 – 9186 ft interval. The base for reference was taken from of set well data with the same drift and ± 30º azimuth. The mean value of the ROP in the offset wells was 28.1 ft / hr, bit's footage - 153 ft. The main value of ROP on wells drilled with NBEU was 37,4 ft / hr, for footage - 234 ft. The gains compared to the offset wells in ROP were 33% and have footage - 53%. On average the bit's savings for 7218 – 9186 ft. interval was 2 drilled

bits for each well.

On drilling with downhole motors the growth of these factors is lower because the down hole motors withdraw the main part of hydraulic power and is left only 435 ... 580 psi pressure for NBEU
While filed testing the NBEU a positive impact was observed on the borehole wall condition. As a result of these studies it was determined that the NBEU works effectively in the zones of partial loss hence curing such losses, and providing the hole size close to nominal. Figure 2 shows caliper logs of two adjacent boreholes at the Bovanenkovo field with NBEU (left) and without NBEU (right).
The NBEU was applied on on rotary drilling with 8 ½ tricone bits in Libya. The results are presented on Fig. 3 and on Table. 1. As a resut the rate of penetration (ROP) was increased to 71.5 % and 1 bit was saved in one well.
Application NBEU on another oilfield in Libya allowed to save 3 bits (Table 2) and therefore decreased the time spent for trips for 2 days. The bit after 126 hours was suitable for further drilling (Fig. 4)

Conclusions

Based on the aformentioned, we came to the following conclusions:
1. Stable operation of NBEU (resulting in drilling performance increase of 15 ... 20%) comes under 435 psi pressure applied to NBEU and bit, with a further pressure increase the ROP increses almost linearly.
2. Bit's footage also increases in proportion to pressure on NBEU, however the rate of increase of this factor is somewhat higher than the rate of ROP increase, which is explained by exception of the phenomenon of cuttings recycling in bit area. So the bit teeth wearout less due to this, hence a sharp reduction the of bit's runout.
3. Application of NBEU allows to drill the zones with partial losses with minimal losses of drilling mud.
4. Application of NBEU eliminates a bit balling and allows to reach the required depth without sticking.
5. According to the caliper logs received from the wells drilled with NBEU it was noted that hole size was close to nominal, thus reducing costs of cement jobs.

References

1. Kolesnikov N.A. Processes of rock destruction and ways to increase the drilling rate. M. VNIIOENG. Overview. Ser. Drilling. 1983.

2. Nazarov V.I., Sidorova T.K. etc. The action of high-pressure jets during the wells construction. M. VNIIOENG. Overview. Ser. Drilling. 1985.

Nomenclature

P – differential pressure
Vm – rate of penetration (ROP)

Table 1 - Comparison of drilling results on wells no. L79-65 and no. L81-65 (with NBEU)

Day	Depth		Footage		Hrs		R.O.P.		% of NBEU efficiency
	L-79	L-81	L-79	L-81	L-79	L-81	L-79	L-81	
1	7988 – 8200	7473 - 7820	212	347	14	16	15	21,0	40,0
2	8200 – 8440	7820 - 8350	240	530	21	21	12	25,0	108,3
3	8440 – 8717	8350 - 8390	277	40	22	3	12,5	13,3	6,7
4	8717 – 8800	8390 - 8436	83	46	8	6	10	14,3	43,0
5	8800 – 8975	8436 - 8830	175	394	21,5	21	8	18,7	133,8
6	8975 – 9045	8830 - 9075	70	245	10	18,5	7	13,2	89,2
7	9045 – 9075		30		3		10		
	7988 – 9075	**7473 - 9075**	**1087**	**1602**	**99,5**	**85,5**	**10,9**	**18,7**	**71,5**

Table 2 – Comparisson of bit utilization on wells no. HH99-65 & HH100-65 (with NBEU)

a) For 7415 - 9230 (1815 ft) interval at well no. HH99-65 (standard BHA without NBEU) were used 4 bits:

Item	Bit	Depth In	Depth Out	Drill ft	Drill hrs	R.O.P.	Bit Cond		
							T	B	G
RR1	ATJ-G8 347	7415	7900	485	40	12,1	4	4	I
							T	B	G
2	GT-30C 547	7900	7906	6	2,5	2,4	NEW		
							T	B	G
3	GT-20 517	7906	9160	1254	83,5	15,0	7	7	1/16
							T	B	G
RR4	GT20 517	9160	9230	70	7	10,0	2	3	I
TOTAL		**7415 - 9230**		**1815**	**133**	**13,6**			

b) For 7395 – 8583 ft (1588 ft) interval at well no. HH100-65 (with NBEU) was used only 1 bit:

Item	Bit	Depth In	Depth Out	Drill ft	Drill hrs	R.O.P.	Bit Cond		
							T	B	G
RR1	GT-30C 547	7395	8983	1588	126	12,6	4	6	I
TOTAL		**7395 - 8983**		**1588**	**126**	**12,6**			

Fig.1 - Near Bit Ejector Unit (NBEU)

Fig.2 – Comparisson of caliper logs (left – drilling with NBEU, right – drilling without NBEU)

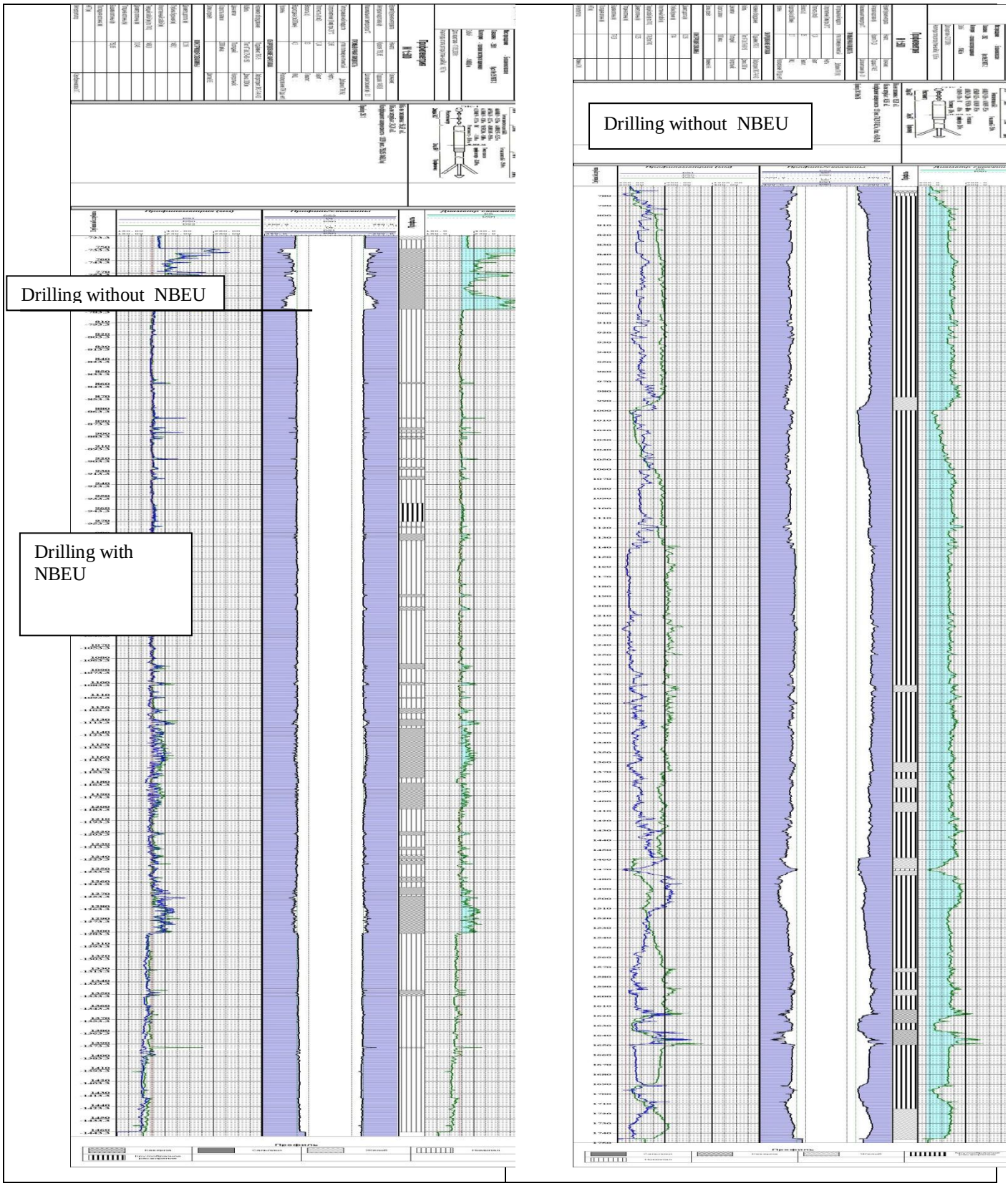

Fig. 3 - Daily ROP comparisson

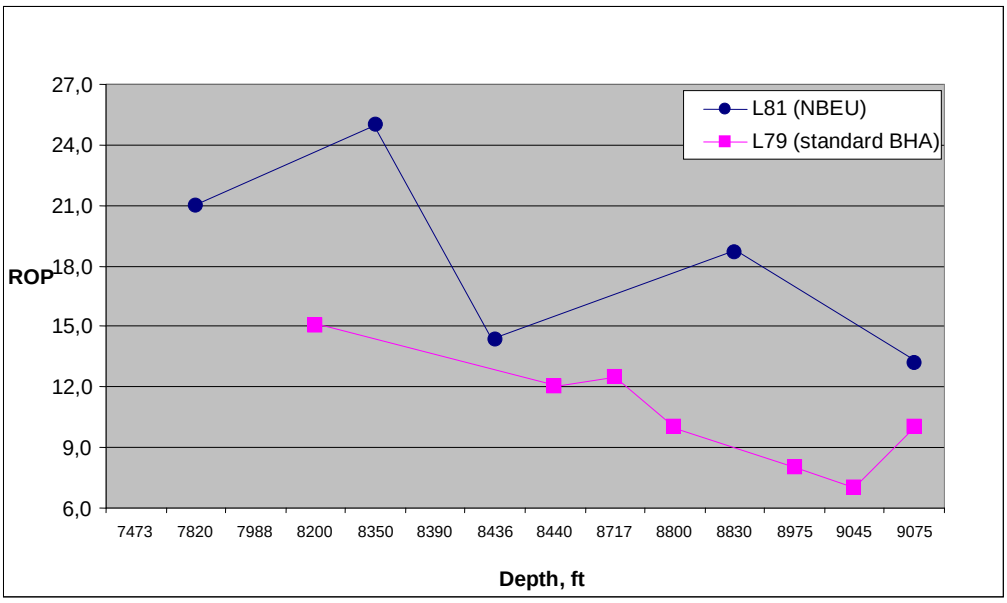

Fig. 4 – Bit after 126 hrs application with NBEU for 7395 – 8983 ft. drilling on well 100-65