Well extension in fractured and broken rocks by wire-line tool (SSK-59)

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Abstract. Conditions of increasing the drilling rate per run, which influence wire-line tool application efficiency, are analyzed. Decreasing of drilling rate is usually caused by alarm initiation which indicates core blocking. Producing of longitudinal and lateral vibrations during drilling process and initiation of fluid upward flow inside the inner core pipe, significantly increases the drilling rate. For initiating an upward flow inside the inner core pipe it is suggested to install the bottom hole pump inside the wireline inner core barrel to be applied as a mechanical motor of downhole vibrator which starts to operate only in a case of core blocking. It was found out that the bottom hole pump provided the necessary speed of upward flow (0.3 – 0.5 m/s) at the rotation speed of more than 150 rpm. Field test was carried out to drill siltstone and sandstone formations of 9 -10 drilling category and their alternation with the formation dip angle of more than 70º (rough and disintegrated rocks). The upward flow inside the inner core pipe SSK-59 allowed increasing the drilling rate by 10% as well as to increase core recovery ratio. Besides, it was noted that a large amount of the cuttings (sized 8 – 10 mm) were accumulating inside the inner core pipe during downhole pump application, that in its turn, proved the initiation of upward flow inside the inner core pipe.

1. Introduction

Drilling rate is a key factor defining the efficiency of wire-line tool application. 15-30% of total drilling operation time is spent on auxiliary operations connected with core pipe tripping depending on geological conditions [4].

Besides, during wire-line tool drilling the useful length of the inner core pipe is not fully put in operation. As a rule, a lot of drill operations stop because of core blocking inside the inner core pipe. Depending on drilling conditions the admission coefficient of the inner core pipe (average drilling ratio to useful length of the wireline core barrel) in rough and disintegrated rock formations can decrease up to 30% and less.

At the same time a number of the complete runs (core recovery ratio - 100%) are not more than 25-50%, at that 10-20% of runs have a length of less than 1 meter. These numbers show that the increasing of drilling rate per run is one of the essential factors which prove the efficiency of wire-line tool application. In most cases the reason for decreasing of run length is connected with alarm initiation indicating core blocking inside the inner core pipe. Usually core blocking occurs during fractured and disintegrated rocks drilling due to getting of small rock pieces between the core plug and pipe or at core cleavage under sharp angle to borehole axis and splitting of core.

2. Methods

The following factors influence the increasing of drilling rate per run and length of run: operating parameters (rotation rate, weight on the bit), stability of outer core pipe (cementing while drilling), quality of inner core pipe inner surface (surface condition and hardness), influence of longitudinal and lateral vibrations on inner core pipe during drilling process (or occasionally at the beginning of core blocking), initiation of upward fluid flow inside the inner core pipe, etc.

Relative influence of weight on the bit and centrifugal force, caused by tool rotation, can lead to instability of outer core pipe and its bending inside the borehole [6]. The bending of core pipe while drilling, negatively influence the core keeping conditions. Due to the small distance between outer and inner pipes (δ = 1.7 mm) an inner core pipe touches the walls of a core pipe and bends. This leads to its rotation and vibration. These processes result in core disintegration and blocking.

The investigations have shown [2], that in a range of applied weights (from 600 to 2000 daN) and rotation rate (from 200 to 1200 rpm), the rotary rate influence on the stability of core retrieving barrel is greater than the influence of weight on the bit. Only one core retrieving barrel (among all SSK-59 assembly) with the length of 2.5 m saves the stability during the whole range of researches.

Increasing of core pipe stability is either possible by the application of centralizer with hard facing, installed in such a way so that the length of separate parts of outer core pipe will not exceed the collapsing length or by the application of equipment with higher hardness resource as the outer core pipe [9]. Rigid structure allows applying rational operating parameters. This results in reaching of maximum mechanical drilling speed and increasing of core recovery ratio. Increasing of mechanical speed reduces core keeping period inside the core pipe as well as core disintegration and blocking.

It has been noted [4], that increasing of mechanical speed from 2 to 8 m/h leads to the increasing of inner core pipe filling per run from 31 to 76%.

The possibility of core blocking inside the inner core pipe depends on the quality of its inner surface (surface condition and hardness) i.e. from core moving resistance. The less is friction between the core and the pipe, the less is the possibility of core blocking.

Produced inner core pipes for wire-line tool SSK-59 have inner surface with average roughness height of 0.4-8 um. During exploitation the quality of inner surface worsens: appearing of scratches, increasing of bending; all these reduce drilling rate per run.

Russian Federation Research Institute of Exploration Technique (VITR) [3] has researched the influence of post operating inner core pipe application on the drilling rate. Two inner core pipes – new one and with the run rate of 400 – 500 m were compared. It was proved that the application of new inner core pipe with undisturbed inner surface leads to the increase of drilling rate per run by 1.5 times in comparison with post operating inner core pipe.

Consequently, the increasing of inner core pipe inner surface hardness and its condition, positively influence the drilling rate. For that purpose, it was advised to treat the inner surface of inner core pipe with the steel rod pulled by drawing bench.

After treating the quality of inner surface improved: roughness grade raised to 10 (average roughness height 0.10 – 0.12 um). Due to cold work hardening of inner surface, hardness increased by

10%. Drilling rate per run increased in average from 3.05 to 4.55m with the application of treated pipes during the process of weak and rough formations drilling.

Influence of longitudinal and lateral vibrations on inner core pipe significantly raise the drilling rate. Small core particles which usually block core plugs or large pieces could be considered as friable material. If they are treated by vibration, friction force between core and the inner surface of inner core pipe will decrease. This will provide free passing of friable material through core and increase drilling rate due to eliminating of core blocking. At that, core recovery ratio reduces due to its disintegration during inner core pipe vibration [7].

3. Results and Discussion

To raise the length of the run and to get high core recovery ratio, a core wire-line tool (SSK-59EB) was invented [5]. It allows initiating of upward flow inside the inner core pipe with a help of ejector through lateral vibrations. However vibrations destruct the core and reduce its recovery. At the same time according to the research, at the minimum charge of fluids Q = 15 and 19 l/min, flow resistance between a core barrel and inner core pipe exceeds the permissible rate for ejector operating. As a result, ejector "turns up side down" and the fluid starts to flow into the inner core pipe. This leads to the decrease of core recovery or core blocking.

For creating an upward flow inside the inner core pipe it is suggested to install the bottom hole pump inside the wireline wireline inner core barrel to be applied as a mechanical motor of downhole vibrator which starts to operate only in a case of core blocking [8].

Wire-line tool (fig.1) assembly includes drill string 1 with outer pipe 2 and bit 3. Inside of the outer pipe 2, a wireline inner core barrel 6 with locking coupling and mechanic vibrator in the form of upper and lower coupling 8 and 9 are assembled to stop ring 4.

Upper coupling 8 is fixed to locking coupling 5, the lower coupling 9 is spring-loaded by spring pins 10 and 11 through lower coupling housing 12 interacting with them through bearings 13 and 14. Lower coupling 9 is attached to the wireline inner core barrel 6 through housing 15, at that housing 15 is a housing of the piston pump having valves 16

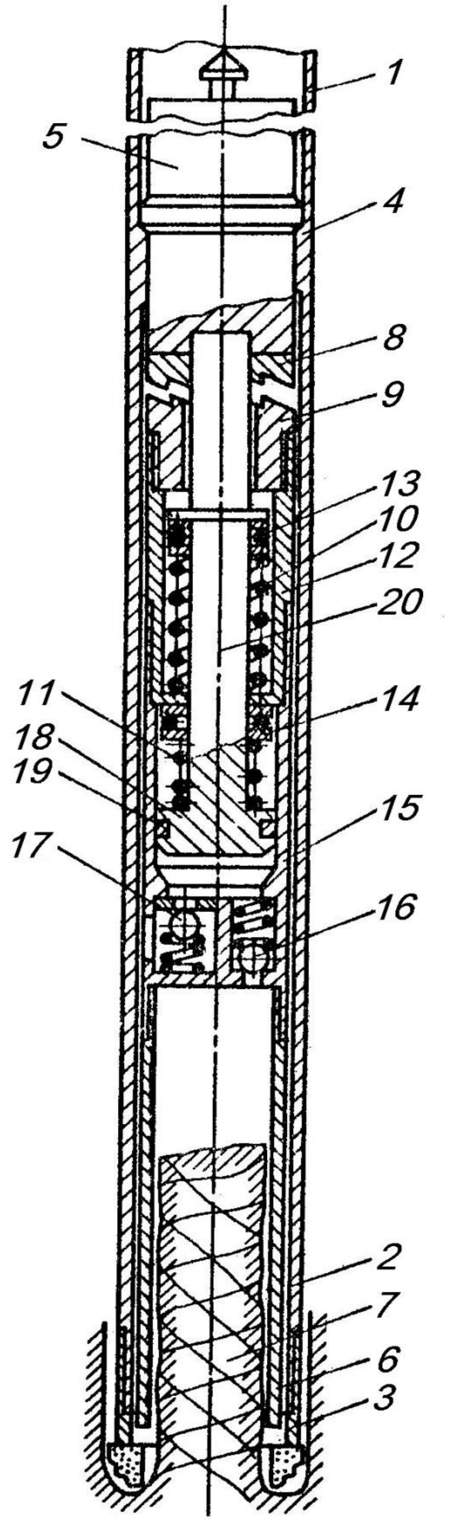

Figure 1. Wire-line tool assembly
1 – drill string; 2 – outer pipe, 3 – bit, 4 – stop ring, 5 – locking coupling, 6 – wireline inner core barrel, 7 –core, 8 – upper coupling, 9 –lower coupling, 10, 11 – spring pins, 12 – lower coupling housing, 13, 14 –bearings, 15 – piston pump housing, 16 – suction valve, 17 – discharge valve; 18 – pump piston, 19 – pump cup, 20 – rod

and 17. Inside the housing, a pump piston 18 with pump cup 19 is installed which is joint to locking coupling by rod 20.

After running of wire-line tool to the bottom hole, the fluid is injected through drill string 1 and casing between outer pipe 2 and wireline inner core barrel to the bottom hole and then through casing to the surface. After that, the drill rod starts to rotate and weight on the bit is created. This results in realizing of core drilling operations. Core 7 gets into inner core pipe 6. During rough and disintegrated rocks drilling, core blocking may occur due to the accumulation of core particles inside the inner core pipe 6. However, bit 3 together with core pipe 2 runs deeper destroying the rock, at that the inner core pipe 6 does not rotate. The locking coupling 5 is fixed inside the core pipe 2 and limit the wireline inner core barrel run to the surface. Spring 10 is compressed and lower coupling 9 contacts with upper coupling 8 rotating with core pipe 2.

At joining of rotating and non-rotating couplings, slipping or jumping may occur. This results in longitudinal vibrations of the wireline inner core barrel joint to mechanical vibrator through coupling 9. Due to these longitudinal vibrations of inner core pipe, the cuttings are shaken inside the wireline inner core barrel partially eliminating the core blocking. Besides, relative motion of piston pump housing 15 and pump piston 18 creates discharging in piston part of the pump (during run down of the pump 15). As a result fluid from inner core pipe 6 flows through suction valve 16 into the underside part of piston pump. When piston pump 15 runs up, the fluid is dispersed through discharge valve 17 from underside part of piston pump to casing. This relative motion of piston pump 15 provides the fluid upward flow inside the inner core pipe 6.

The purpose of laboratory testing was to estimate the basic parameters - pump inlet capability and speed of upward flow inside the inner core pipe at various pump response speed, which is defined by wire-line toolrotation speed at operating vibrator. The results are given in table 1.

Table 1. Results of pump parameters tests considering wire-line toolrotation rate.

Parameters	RPM		
	155	390	680
Fluid flow rate inside core pipe, l/min.	2.3	4.6	8.9
Upward fluid flow speed between inner walls of inner core pipe and core (nominal core diameter - 35 mm), m/sec.	0.34	0.68	1.31

According to table 1, pump with mechanical vibrator has provides the required speed of upward flow (0.3 – 0.5 m/sec.) at wire-line tool rotation rate of ≥ 150 rpm.

4. Conclusion

Laboratory tests have proved the efficiency of wire-line tool with piston pump and mechanical vibrator as a motor.

After laboratory tests, the piston pump (PVN-01) was produced for field testing carried out in Ognevskaya party by Ust-Kamenogorskaya geological survey expedition. The purpose of field testing was evaluation of piston pump (PVN-01) performance reliability, detection of weak details, comparative analysis of SSK-59 and PVN-01 operating parameters.

Drilling was conducted in siltstone of 9th drilling category, sandstone (10th category) and their alternations. Formation dip angle was 70º. Rock formations were from fractured (5-15 pieces per core meter) to rough and disintegrated (more than 15-70 pieces per meter).

Drilling was realized out by wire-line tools (ZIF-650M, SSK-59) with drill bits (К-01-2).

A bottom hole vibration pump was installed between inner core pipes and mechanical vibrator of the wireline inner core barrel. Core pipe was joined by special connector with centralizer.

Drilling modes were kept within the limits applied during drill operations without piston pump (PVN-01) operation: weight on the bit 460-1000 daN, rotation rate - 800 rpm, fluid flow rate – 10 l/min, fluid pressure rate 1.0 – 1.6 MPa. Water was used as fluid.

Table 2. Results of comparative analysis

Drilling interval, m	Type of tool	Drilling depth, m	Average length of the run, m	Average core recovery, %
135,5-166 203-207,2	Wire-line tool (SSK-59) with a vibrator	34.7	2.07	84
166-203	Wire-line tool (SSK-59) with pump (PVN-01)	37	2.3	87

According to table 2 the installation of pump (PVN-01) which initiates the upward flow inside the inner core pipe of SSK-59 allows increasing the drilling rate by 10% at relative core recovery rate increasing. Besides, it was noted that a large amount of the cuttings sized up to 8-10 mm had been accumulated in the inner core pipe at PVN-01application during drilling operations. When drilling operations were conducted by wire-line tool SSK-59 without PVN-01pump, the cuttings were not accumulating. That was proved due to creation of upward flow inside the inner core pipe by the bottom hole pump.

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