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Issues Regarding the Drilling Fluid's Circulation into the Well

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Abstract

Circulation of the drilling fluid from surface rig to dril bit is done through cylindrical section that prints a laminar or turbulent motion to the fluid. Present paper is theoretical presentation of pressure loss during circulation and an experimental study of hydraulic power and the pressure required to defeat friction during circulation.

Key words: *pressure loss, hydraulic power, circulation system, drilling fluid*

Introduction

The circulation of the drilling fluid into the well is, alongside the screeding of the drill's foot and handling the equipment inside the probe, a basic operation conducted by the rig, which provides down hole rock advancing and deepening of the probe. The debris resulting in the dislocation is removed out of the probe like this. In the same way rock particles detached from the walls of the well penetrated fluids from the geological crossed layers (gas, water, oil, etc.), salts and other contaminants from the open rocks, fragments of cement, scrap metal; all are brought to the surface and eliminated, however disturbing they are for the drilling process. Submersible motors receive their energy required to rotate the drill and the close monitoring of the circulated fluid out of the probe with all that it brings up is an important source of information for conducting the drilling process.

The process is defined by a long list of parameters, each with greater or less participation, many of them with mutual conditions, many of them more or less dependent on the operator.

The two mud pumps of the rig determine the energy input into the system, respectively hydraulic power, P_p driven by pressure pumps, p_p and circulation flow, Q.

$$P_p = p_p \cdot Q \tag{1}$$

In the design phase, the operator chooses the pumps and, because usually there are only two, must do all that is necessary in order to cover requirements for the entire probe. Along with the hook load, the hydraulic power installed is a criterion under which the rig is chosen for a particular probe.

In the drilling process, the operator decides the maximum possible pressure of the pumps, by equipping them accordingly, i.e. through the pistons' diameter. But the parameter most available for the operator through which he can adjust the circulation process of the drilling fluid into the well is the flow, which can have values in the ranges associated with the same equipment mounted on the pumps.

The circulation system, starting with the pumps, is made up from: through the surface installation (pipes, fittings, charger, hose drilling, hydraulic head / topdrive rod drive etc), the interior of the transom drill pipe, of the section rods crossing (heavyweight), of the section of the collar's drill, in the submersed engine, in drills and in the annular space between the well's walls (free hole or the casing) and the drill string, etc. Apart from the installation's surface there are many other auxiliary elements for the circulation of the drilling fluid (reducers, stabilizers, etc.) with a negligible participation in the development process, however dimensionally assimilated and included in the base, neighboring embodiment.

The listed order relates to a composition commonly used. There may be two different sections of the drill pipe size, drill collars may be absent or may be two separate sections from a section of drill pipe passage, etc. The submersible motor is commonly used to conduct the probe on a certain trajectory and rarely at the drilling of the wellbore without such requirements.

From the energy supplied by pumps, the one consumed in the dig is considered to be really useful. It is followed by the one consumed by the motor when it is used, and then the energy consumed in the annular space for cleaning the probe. Whatever energy consumed by the remaining components of the circulation system can not be avoided but it should be minimized as possible.

The Circulation of the Drilling Fluid in the Annular Space between the Drill Rod Assembly and Well

It is the area with the modest participation in terms of consumption of which the wells provide in the overall process of movement but, it is the area where the process' parameters are more difficult to assess and the most sensitive by the restrictions that may occur in the process, especially if we consider the free hole, bordered by crossed dig rocks.

The pressure fall depends on the length and it is assessed by the relationship [2]:

$$\Delta p_{si} = \lambda \cdot \frac{v_m^2}{2} \cdot \frac{L}{D_c} \cdot \rho = \lambda \cdot \frac{8}{\pi^2} \cdot \frac{Q^2 \cdot L}{\left(D_g - D_p\right)^3 \cdot \left(D_g + D_p\right)^2} \cdot \rho \tag{2}$$

For a more rigorous calculation of local pressure drops by the joints, the following should be taken into consideration:

$$\Delta p_{siL} = \zeta \cdot \frac{v_m^2}{2} \rho \tag{3}$$

where Q is the circulation flow, λ – hydraulic resistance coefficient, dependent on flow, dimensions of the flow line/space and identity and rheological properties of the drilling fluid, ζ – local resistance factor, dependent on he strangulation's diameter, D_g – probe diameter, D_p – gasket diameter, D_c – equivalent flow diameter, ρ – drilling fluid's density, L – length section.

The probe's diameter, hole free zone, at a first assessment is considered equal to the diameter of the drill. A real scenario is tried out by increasing this diameter by a factor of caliper (1.1 - 2.5) but the real shape of the probe may be far from reach [1,2]. Areas with rocks consolidated can be calibrated at drill's diameter, areas with poorly consolidated rocks can be widened, even transformed in cavernous areas, areas with flowing or swelling rocks may have a smaller diameter than the subfloor/screed's, which explains a category marked by gasket grips or the necessity of repeated corrections at the introduction or the extraction of the drill. Sometimes even the circular form of the cross section is disputed, which theoretically should make any digs in a consolidated rock.

Significant errors exist in terms of knowing the properties of the drilling fluid circulating in this range. Drilling fluid pumped from the surface is clean and with measured properties. Probe temperature and pressure cause some changes in properties but their extent and effects seem to be insignificant and therefore neglected.

In the annular space, however, the drilling fluid is loaded with debris washed from the base drives, calls the debris in areas with loose rocks, drives the fluids flowing from the layer into the well, which may be gases, salt water, oil, integrates salts dissolved in the probe's walls or fine particles dispersed from crossed clay sections etc. The density and rheological parameters can be significantly affected, particularly when there is an incompatibility between what nature has penetrated and drilling fluid's type, respectively when the fluid becomes contaminated and this could lead to serious consequences.

The presence of rocks with very diverse physicochemical parameters introduces restrictions on movement parameters. Apart from the present studies and extensive researches in the literature that relate to this area, there are two issues that cannot be neglected.

The bushing and the increasing risk of gasket clamping risk grow by the number of solids in the upstream of the well's annulus. The concentration of solids in the annular space is defined as the ratio of the volume of the rock base product, measured by mechanical speed, v_{mec}, and the volume of the annulus [1, 2] in which rock fragments are brought to surface by high flow traffic.

$$c_{si} = \frac{D_s^2 \cdot v_{mec}}{\left(D_g^2 + D_p^2\right) \cdot v_r} \tag{4}$$

The speed of lifting the solids into the annular space, v_r is less than the ascending speed, v_{as}, of the fluid stream due to the phenomenon of sliding of the particles in the fluid, a phenomenon dependent on the shape, size and density of the particles, on the properties of the drilling fluid, etc.

The recommended value for the concentration of solids in the annulus is of 2% up to 5%, beyond which the risk of injuring the probe significantly increases.

Any additional pressure with a value over the hydrostatic one, which occurs in the probe into the free hole means increasing the risk of cracking of the band with all the deriving consequences. The drilling fluid's flow with its properties measured at the surface determines relatively modest pressure drops in the annulus compared with other areas. The risk is higher when the presence of solids increases the equivalent density of the circulated fluid, when overpressure appears at the handling of the gasket, when the fluid's rheology changes due to the contaminants.

Theoretically, the sole level is the most exposed. The pressure drop for overcoming friction in the annular space is treated as a hydrostatic component and the equivalent density of the drilling fluid on the sole is determined.

$$\rho_{ech} = \rho + \frac{\Delta p_{si}}{g \cdot H} \tag{5}$$

Size is important but mostly from a theoretical point of view. The presence of solids with a density of ρ_p in this area amend the drilling fluid's properties, especially its density.

$$\rho^{+p} = \rho + \Delta\rho^{+p} = \left(1 - c_{si}\right) \cdot \rho + c_{si} \cdot \rho_p \tag{6}$$

where ρ^{+p} is fluid density in the presence of solids particle, $\Delta\rho^{+p}$ – surplus of fluid density due of the presence of solids particle.

In addition to the values recommended for concentration, the upper limit of the present solids is also recommended by the density's surplus, at mostly 30 kg/m^3.

What is happening in the free hole in the annulus often exceeds the assessments of the type shown. For example, accumulation of detritus/debris in caves or on the wall below the inclined hole can sometimes drastically change the alleged uniform and continuous behavior of the models.

In horizontal inclined probes, the cleaning requirements are more stringent. The form of the flow path is further away from the annular supported shape for vertical wells, which drastically changes the movement of solids to the surface. In such cases, increased flow may not be sufficient and should be accompanied by a vigorous rotation of the gasket, by the pumping of intermittent packages of drilling fluid with greater viscosity etc. There are now devices that allow more control of the phenomena in this area. Devices integrated in the gasket, in the vicinity of the flange/sole, provide in real-time the value of the actual pressure in the annulus, and at surface equipment which allows the monitoring of outputs of solids from the probe can be installed [3].

It is obvious that this area imposes severe restrictions on the flow of traffic due to costly consequences, which might occur when those restrictions are exceeded.

The Circulation of the Drilling Fluid within the Drill String

It is the area that consumes a lot of what the pumps give and with no other gain then that of bringing energy to the drill and to the submersible engine, if it exists. It introduces few restrictions in the process and even if they are present, they are difficult to achieve, such as resistance to internal pressure.

The objective is to consume as little as possible in this area and to decrease, sometimes even eliminate, bottlenecks (for example in connections); is noted in the constructive evolution of rods. If the inner diameter of the rods is d_p, the linear presure drop, along the section with given measurements, is evaluated by the same relationship (2) as the one for the annular space. Local pressure drops, by the joints, are evaluated with the help of the same formula as in the annulus.

In a similar way, pressure drops are measured at the surface of the installation, from the pump to the rods. No significant values are recorded, but they cannot be overseen either, especially when assessments are made in order to find explanations for undesirable situations in the drilling process.

Obtained Results and Discussions

The IADC Drilling Manual proposes a simplified approach. In accordance to the rig is enough to choose a type of structure for the surface rig with the dimensions from table 1 [4].

Table 1. Types of structure for surface rig

	Type 1		Type 2		Type 3		Type 4	
	Inner diameter	Length	Inner diameter	Length	Inner diameter	Length	Inner diameter	Length
	mm	m	mm	m	mm	m	mm	m
Manifold and charger	76,20	12,2	88,90	12,2	101,60	13,7	101,60	13,7
Drilling hose	50,80	13,7	63,50	16,8	76,20	16,8	76,20	16,8
Drive rod	57,15	12,2	82,55	12,2	82,55	12,2	101,60	12,2
Hydraulic head	50,80	1,2	63,50	1,5	63,50	1,5	76,20	1,8

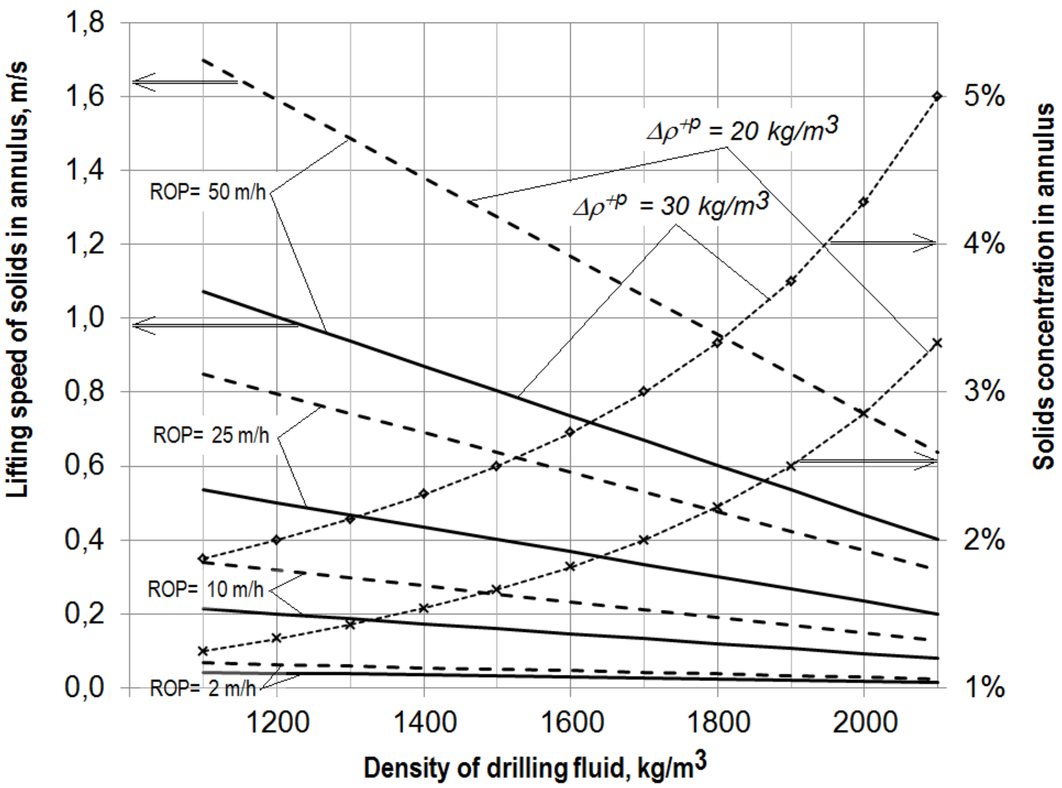

Fig. 1. Dependence of solids concentration, lifting speed of solids in annulus and density of drilling fluid

The concentration of solids in the annular space depends on density of drilling fluid and the increase of density due to the presence of solids. Lifting speed of solids is a lower severe restriction for ascending velocity of the fluid stream, also for the flow, and the amount that should have secured by the debit has to be correlated with the speed of advancement. Restrictions can be imposed of speed of advancement, if necessary. Solids larger in size will be discharged first if the uppward velocity is higher.

Figure 2 shows the pressure loss and hydraulic power in the circulation system of a well at final depths requirements of each phase of drilling. Values are estimated with calculation models established [1, 2] and the data presented in Table 2.

Table 2. Well design and fluid properties

Construction phase		1	2	3
Flow rate	L/s	72	46	28
Bit, D	in	17_1/2	12_1/4	8_1/2
PDM, OD	in	-	-	6_3/4
Drill colars, OD * length	in * m	8 * 200	8 * 50	$6^{1/4}$ * 40
Heavy Weight, OD * length	in * m	-	5 * 150	5 * 450
Drill pipes, OD	in	5	5	5
Hole, D	mm	450	312	215
Casing string, OD * depth	in * m	$13^{3/8}$ * 800	$9^{5/8}$ * 3000	-
ρ	kg/m^3	1050	1350	1700
η_{pl}	cP	17.3	21.4	-
τ_0	N/m^2	1,1	4,5	-
K	Ns^n/m^2	-	-	0.2
n	-	-	-	0.81

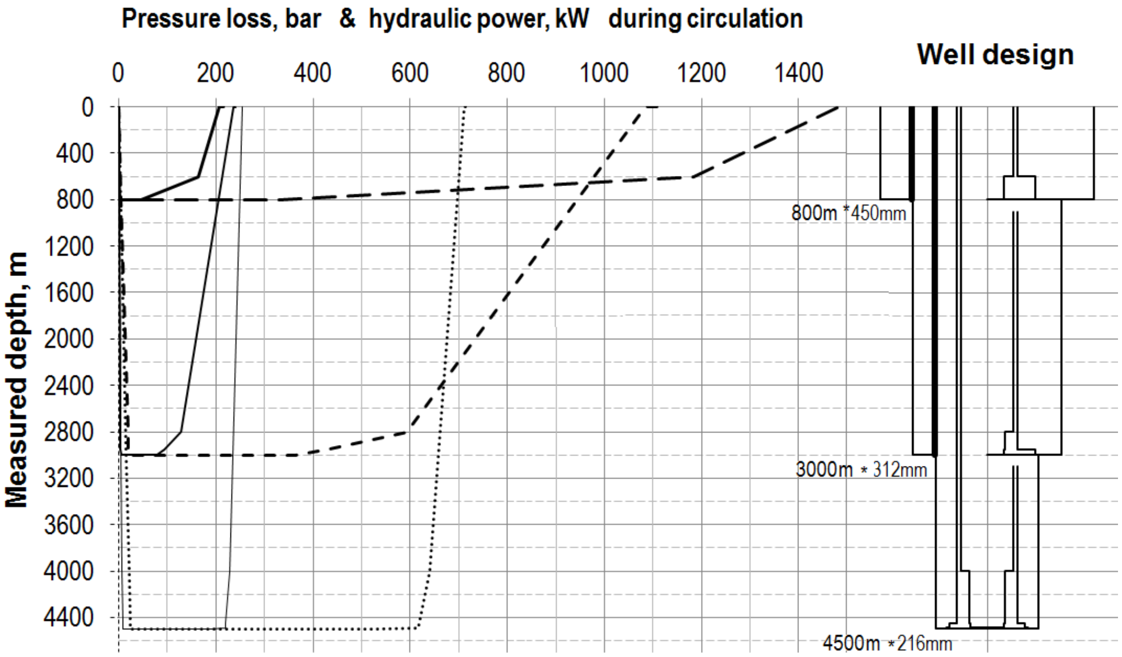

Fig. 2. Maximum values for pressure loss and hydraulic power for a 4500 m well

This well requirements is covered with two pumps each 1500-1600CP.

An analysis of how and where they consume consume circulation system can provide process optimization solutions.Very much is consumed within the garniture.

For example, the structure of pressure drop for the end of Phase 2 looks like Figure 4.

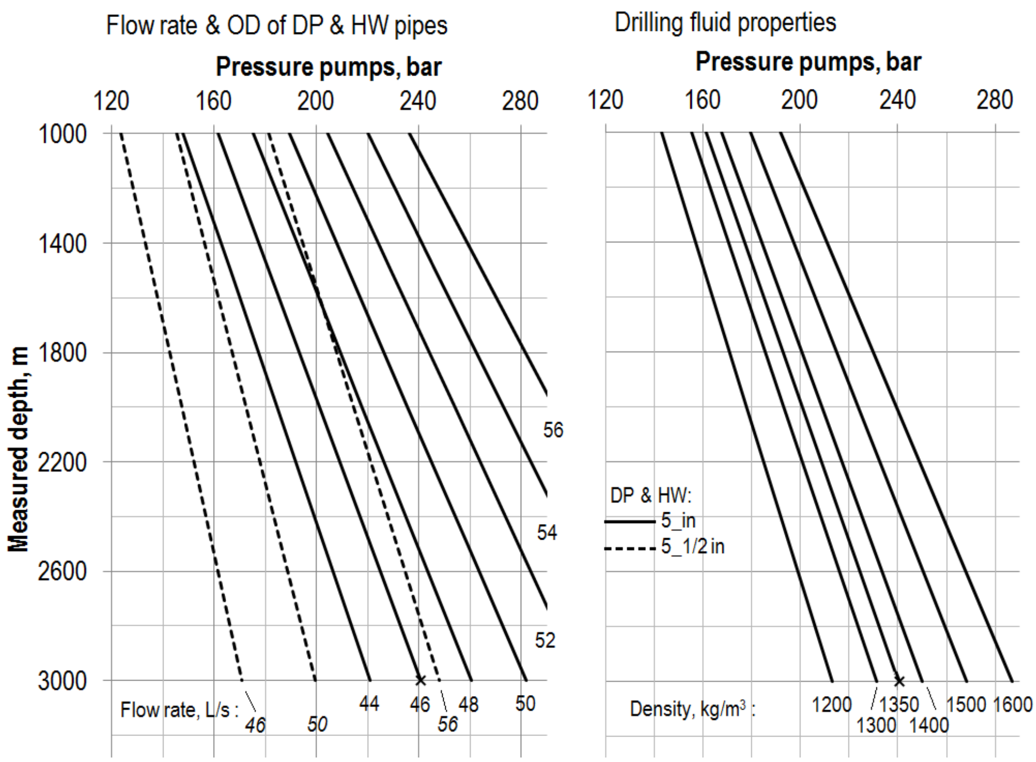

Fig. 3. The influence of depth well on pressure pumps

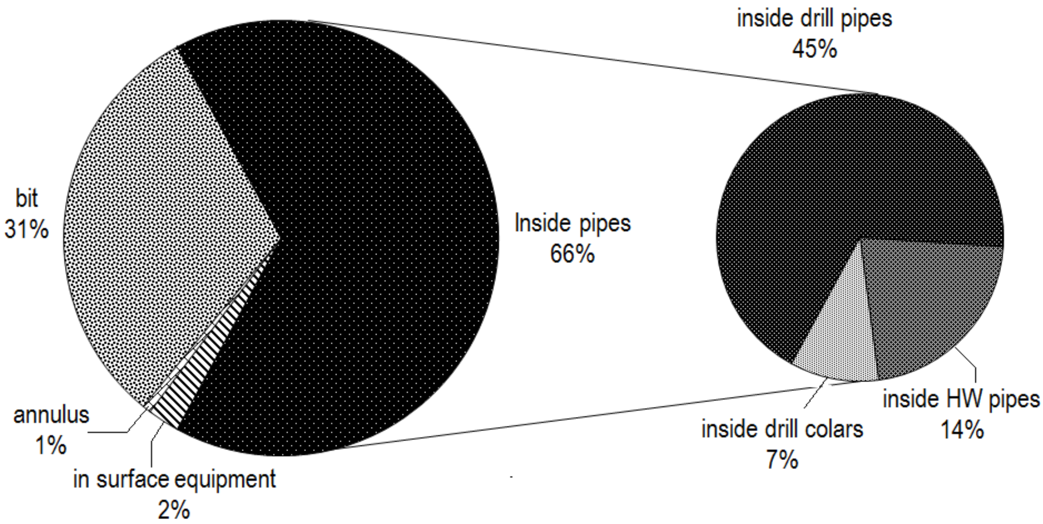

Fig. 4. Pressure loss during circulation at the end of phase 2

Conclusions

The submitted information does not cover all possible situations. Many components within the structure of the circulation system do not have a noticeable contribution to assessments but, any additional element integrated in the circuit should be so treated, with a minimum effort for its analysis. For example, some MWD systems take their energy, more or less, from the down flow of the drilling fluid or the 10 ... 20 bars of pressure drop in the degasser connected at the output of the probe; at the surface they can change the conditions on the sole or even within the pumps themselves etc.

Using the upper limits of what the pumps can give, the most common approach can lead to outstanding performances, especially when the rig exceeds the probe's requests. When these come in close range with what the probe could produce/give, optimization can still provide effective solutions.

Restrictions imposed on the circulation system, especially those severe ones in the free hole, should never be neglected; drilling difficulties and accidents, as in any other field, are easily and cheaper to prevent than to combat.

It is also important to carry and consume as much as possible, for as long as necessary, at the drill and then at the engine, to ensure safe conditions in the annulus, focusing on the free hole, to minimize power consumption in the rest of the system.

Pressure loss inside the drill string, especially in drill pipes have the largest share of consumption for which pumps give. This explains the occurrence and wide spread of 5 ½ in even 5 $^{7/8}$ in drill pipes. Only in this way the increased requirements for inclined or horizontal wells have been satisfied. With increasing depth, requirements are increasing (section of drill pipe lengthens) and frequently make concessions on performance to limit the speed of advancement because it has reduced traffic flow.

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Aspecte privind circulatia fluidului de foraj

Rezumat

Fluidul de foraj circulă de la instalaţia de suprafaţă până la talpa sondei prin secţiuni cilindrice care imprimă acestuia o mişcare laminară sau turbulentă. Lucrarea de faţă prezintă aspecet teoretice cu privire la căderile de presine ce apar în timpul circulaţiei fluidului de foraj şi studiul experimental al puterii consumate şi al presiunii necesare pentru învingerea frecărilor în sistemul de circulaţie.