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DRILLING FLUIDS DIFFERENTIAL STICKING TENDENCY DETERMINATION

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Abstract

Differential sticking is defined as stuck pipe caused by the differential pressure forces from an overbalanced mud column acting on the drillstring against filter cake deposited on a permeable formation. It is in uenced by drilling uid properties and characteristics of rock formations and has major impact on drilling efficiency and well costs respectively. Differential sticking tendency of two drilling uids were determined in laboratory using sticking tester as well as in uence of lubricant and increase of solids content on uid properties. Results of the testing are presented in the paper.

Sažetak

Diferencijalni prihvat definira se kao prihvat bušaćih alatki prouzročen diferencijalnim tlakom koji se javlja uslijed djelovanja stupca isplake na niz bušaćih alatki, a uzrokuje "ljepljenje" bušaćih alatki za isplačni oblog kojim su obložene stijenke kanala bušotine u području propusnih naslaga. Uvjetovan je svojstvima bušotinskih uida i karakteristikama naslaga stijena kroz koje se buši i ima veliki utjecaj na učinkovitost bušenja i troškove izrade bušotine.U laboratoriju je pomoću instrumenta za određivanje koeficijenta ljepljivosti ispitana sklonost odabranih uida diferencijalnom prihvatu odnosno utjecaj količine čvrstih čestica i podmazivača na svojstva uida i koeficijent ljepljivosti. Rezultati ispitivanja prikazani su u radu.

Introduction

Differential sticking is one of the most common and serious drilling problems that always increase drilling costs. It can range in severity from minor inconvenience to major complications, which can have significantly negative results, such as loss of the drillstring or complete loss of the well. If the drillstring becomes stuck, every effort should be made to free it as quickly as possible because the probability of freeing stuck pipe diminishes rapidly with time. Also, early identification of the cause of the sticking problem is crucial, since each cause must be remedied with different measures. An improper reaction to a sticking problem could easily make it worse.

Stuck pipe problems are generally divided into two categories – mechanical sticking and differential sticking. The proportion of incidents classified in each category varies with the type of well and the geographical area. Mechanical sticking is caused by physical obstruction or restriction in wellbore. Some reasons of mechanical sticking can be cuttings settled in wellbore, unstable formations of shale, cement or junk dropped into the hole, undergauge hole, stiffness of drilling assembly, doglegs, casing failures etc. Mechanical sticking usually occurs when drillstring is moving, and in most cases obstructed circulation is noted. Occasionally, however, a limited amount of up/down mobility or rotary freedom is evident.

Differential sticking is caused by differential pressure forces from overbalanced mud column acting on the drillstring against a filter cake deposited on a permeable formation. This type of pipe sticking usually occurs while pipe is stationary such as when connections are being made or when a survey is being taken. It is indicated by full circulation and no up/down mobility or rotary freedom.

Mechanism of differential sticking

According to Gray and Darley (1), a portion of the drillstring will always be in contact with the side of the hole, especially in deviated wells. The drillstring is lubricated with a film of drilling uid as long as the string is moving, and the distribution of pressure around the drill string is equal. A differential pressure develops when motion ceases, and the filter cake between the drillstring and a permeable zone is isolated from the drilling uid column and begins to lose pore water to the formation. Friction increases between the drillstring and the dehydrating and compacting cake, resulting in increasing torque and drag. Once drag exceeds the power of the rig, the drill string is stuck. The situation becomes worse with time as filter cake builds up around the stuck pipe section, thus increasing the area of contact between the pipe and filter cake, and most importantly, increasing the force required to pull the pipe out. The force required to free the pipe is a function of the differential pressure, the contact area, as well as the friction between cake and pipe and is given by equation (1):

$$F = A \cdot (p_h - p_f) \cdot f \qquad (1)$$

where:

F – force to pull drillstring free, kN

A – filter cake contact area, m^2

p_h – hydrostatic pressure, Pa

p_f – formation pressure, Pa

f – friction coefficient (from 0,07 for invert emulsions to 0,40 for low solids mud)

Experimental work

As stated earlier, the main cause of differential sticking is the difference between hydrostatic and formation pressure. However, there are direct or indirect in uences of other factors such as mud formulation, mud properties, characteristics of the filter cake, type of lubricant etc. Their relationship, as well as pipe sticking probability and appropriate way of prevention, can be evaluated through continous laboratory research.

Two uids were tested in laboratory - lignosulphonate mud (mud A) and polymer mud (mud B). Formulations of tested muds are shown in Table 1. To determine in uence of solids content on mud properties, especially on differential sticking tendency, amount of Rev-Dust in base lignosulphonate mud was varied. The number included in the mud sign implies Rev Dust concentration in grams per 1 dm^3 of mud. In uence of different lubricants was tested, too. Two lubricants (sign as P1 and P2) were added in every mud formulation in concentration of 2% vol. Rheological properties, filtration and lubricity of tested uids were determined according to API Recommended Practice Standard Procedure for Testing Drilling Fluids, API RP13B. Differential sticking tendency of the tested uids was evaluated using differential sticking tester marketed by OFI Testing Equipment International. The sticking coefficient is defined as the ratio of the force necessary to initiate sliding (or rotation) of the plate in contact with a filter cake under differential pressure, relative to the normal force on the plate. The test device consists of a filtration cell capable of holding 200 cm^3 of uid, a perforated bottom capable of holding filter paper and screen, a plate (on a plunger) and a torque wrench.

Table 1 Formulation of the tested muds

Tablica 1. Sastav ispitivanih isplaka

MUD													
	Units	A0	A0P1	A0P2	A35	A35P1	A35P2	A70	A70P1	A70P2	B	BP1	BP2
Water	ml	974	974	974	974	974	974	974	974	974	1000	1000	1000
Bentonite	g/l	60	60	60	60	60	60	60	60	60			
PAC - LV	g/l	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5			
Cr - free lignosuphonat	g/l	4	4	4	4	4	4	4	4	4			
Barite	g/l	100	100	100	100	100	100	100	100	100			
NaOH	g/l	1	1	1	1	1	1	1	1	1			
Lubricant P1	%		2			2			2			2	
Lubricant P2	%			2			2			2			2
REV - DUST	g/l				35	35	35	70	70	70			
Xanthan gum	g/l										5	5	5
Starch	g/l										15	15	15
Calcium carbonate	g/l										50	50	50
Defoamer	as needed										Yes	Yes	Yes

The cell with filter paper in place is filled with uid, pressurized with 3291 kPa and filtrate is collected for 30 minutes (to get appropriate filter cake thickness). The plate (on a plunger) is then pushed down on the filter cake for 2 minutes to stick the plate and left 15 minutes in that position. After that time, collected filtrate volume is noted. The plate is then rotated with the torque wrench and the torque necessary to break the plate free is measured. Filtrate is then collected for another 15 minutes and the plate is then pushed down again on the filter cake for 15 minutes to stick the plate once more. The torque necessary to break the plate free is again measured and the process is repeated once more.

The sticking coefficient is calculated by the following equation:

$$K_{sc} = 0{,}001 \cdot T_u \quad (-) \tag{2}$$

T_u – torque, Nm

Values of rheological properties, uid loss, mud cake thickness and friction coefficients of mud A are shown in Table 2 and in Figure 1.

Table 2 In uence of solids content and lubricants on the properties of mud A

Tablica 2. Utjecaj čvrstih čestica i podmazivača na svojstva isplake A

	Lignosulphonate mud								
	A0	**A0P1**	**A0P2**	**A35**	**A35P1**	**A35P2**	**A70**	**A70P1**	**A70P2**
Plastic viscosity, Pa·s	0,015	0,018	0,017	0,017	0,020	0,018	0,020	0,023	0,022
Yield point, Pa	3,57	3,57	3,06	4,0	5,10	3,06	5,61	6,63	5,1
Consistency index, Pa·s^n	0,105	0,097	0,081	0,099	0,155	0,080	0,180	0,216	0,148
Flow index, -	0,750	0,782	0,798	0,772	0,737	0,807	0,718	0,713	0,755
Fluid loss volume, ml	7,6	6,7	6,3	6,6	7,0	6,6	6,0	7,0	6,6
Filter cake thickness, mm	1,15	0,55	0,86	0,95	0,36	0,88	0,74	0,59	0,68
Friction coefficient, -	0,183	0,177	0,046	0,186	0,200	0,092	0,213	0,214	0,083

It can be seen from Table 2 that values of the rheological parameters were slightly increased with the added amount of solids. Filtrate volume and filter cake thickness were generally decreased when the solids content increased. Addition of lubricants decreased filter cake thickness but that decreasing is much more noticeable when lubricant P1 is added. The effect of lubricant P1 on the friction coefficient is negligible contrary to the lubricant P2 that greatly reduces friction coefficient for every mud formulation (Figure 1).

To determine the in uence of the time on the sticking coefficient three measurements of torque were done and the coefficient was calculated according to equation 2. Results of measurement are shown in Figure 2.

From Fig. 2 it can be seen that addition of the lubricant P2 greatly increased sticking coefficient. It should be noted that in the case of addition of the lubricant P2 plate sticking is achieved after force acting on the plate 4 minutes (in testing procedure that time is 2 minutes). From that can be concluded that lubricant P2 reduce the risk of differential sticking, but if sticking occurs, the force needed to free stuck pipe will be larger than if the lubricant P1 is used.

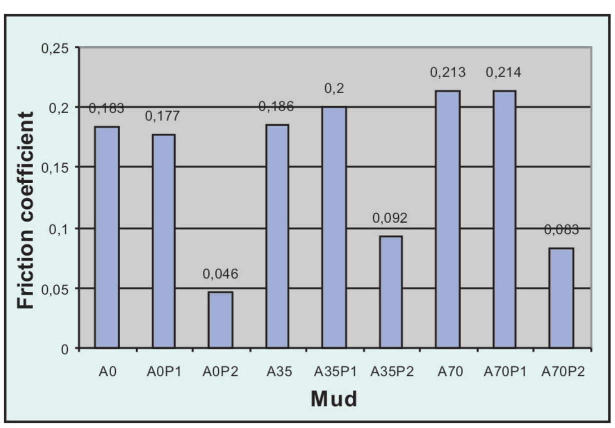

Figure 1 Friction coefficients of mud A

Slika 1. Koeficijenti trenja isplake A

Values of rheological properties, uid loss, mud cake thickness and friction coefficients of the mud B are shown in Table 3. Since mud B is a polymer mud characterised with low solids content, comparisons of that mud and the mud A0 (formulation without REV-DUST) were done. From comparison of the friction coefficients of muds A0 and B the same conclusions as for the mud A can be done - lubricant P2 greatly reduces friction coefficient while in uence of the lubricant P1 is almost negligible (Fig. 3).

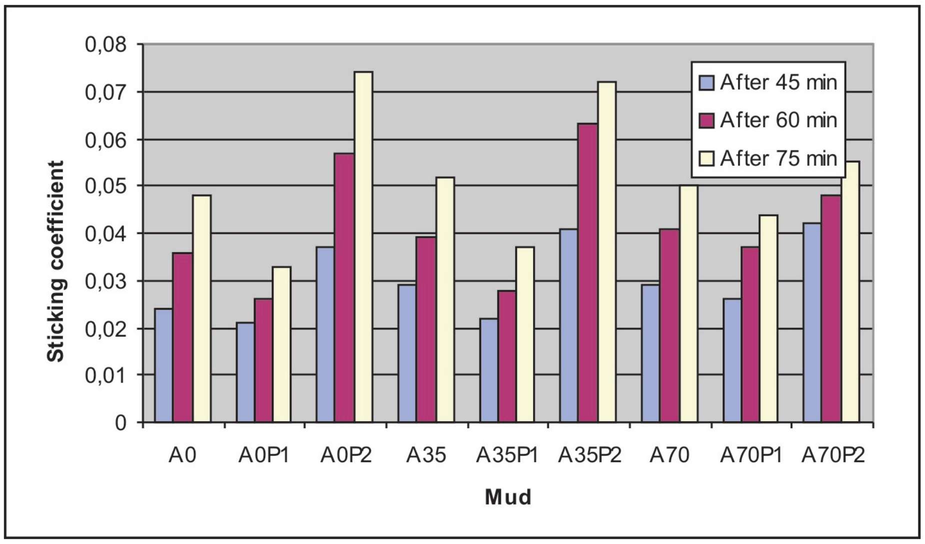

Figure 2 Sticking coefficients of mud A

Slika 2. Koeficijenti ljepljivosti isplake A

Table 3 In uence of lubricants on properties of the basic mud formulation

Tablica 3. Utjecaj podmazivača na svojstva osnovnih isplaka

	Polymer mud		
	B	**BP1**	**BP2**
Plastic viscosity, Pa.s	0,012	0,012	0,009
Yield point, Pa	15,18	15,96	14,43
Consistency index, Pa·s^n	2,07	2,255	2,549
Flow index, -	0,376	0,369	0,324
Fluid loss volume, ml	7,3	7,3	8,0
Filter cake thickness, mm	0,15	0,25	0,12
Friction coefficient, -	0,193	0,184	0,038

A comparison of filter cake thickness is shown in Fig. 4 while sticking coefficients of tested muds are shown in Figure 5.

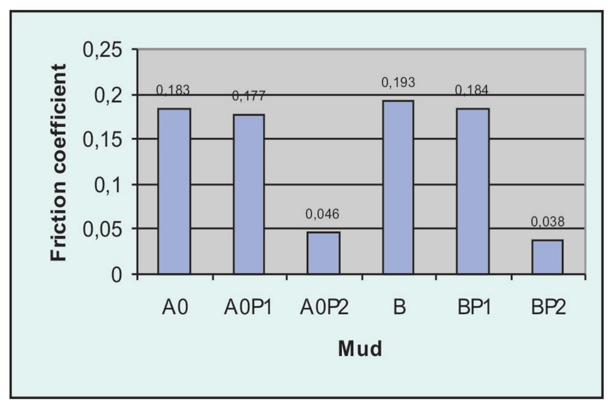

Figure 3 Comparison of friction coefficients of muds A0 and B

Slika 3. Usporedba koeficijenta trenja isplake A0 i B

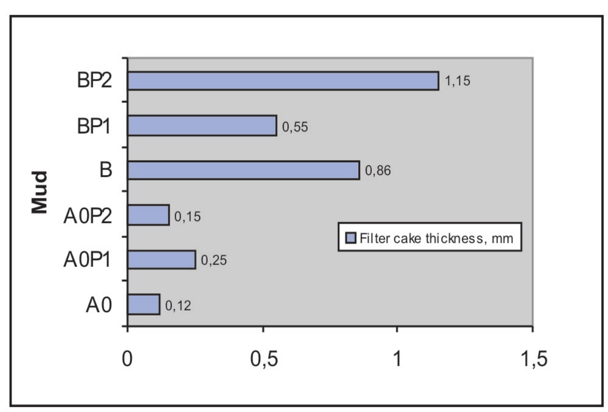

Figure 4 Comparison of filter cake thickness of muds A and B

Slika 4. Usporedba debljine isplačnog obloga isplake A i B

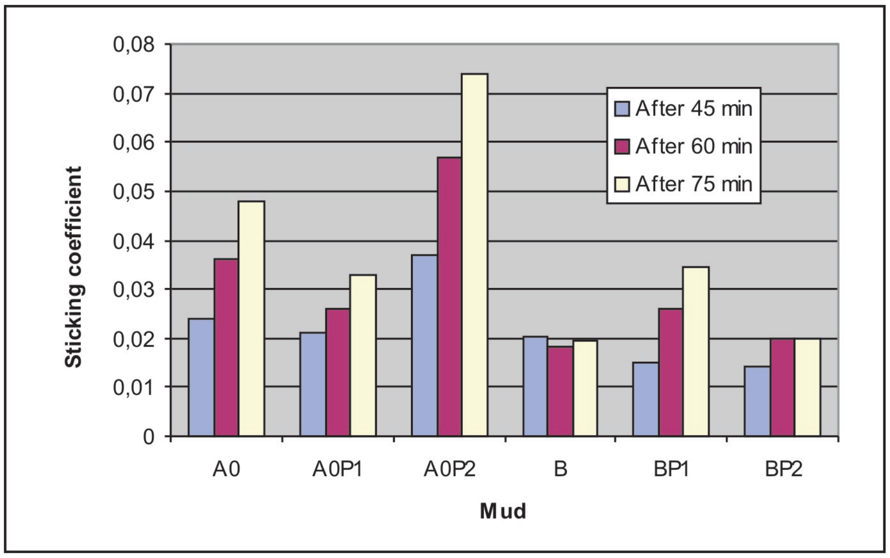

Figure 5 Comparison of sticking coefficients of muds A and B

Slika 5. Usporedba koeficijenata ljepljivosti isplake A i B

If figures 4 and 5, are compared, increase of the sticking coefficient with an increase of filter cake thickness is obvious. A comparison of the muds sticking coefficients (Fig. 5) shows that the polymer mud has lower sticking coefficient values than the lignosulphonate mud.

Conclusions

From performed tests the following conclusions can be made:

- Sticking potential of the lignosulphonate mud is greater than the polymer mud.
- Filter cake thickness has a direct in uence on value of the sticking coefficient.
- In uence of lubricants on mud differential sticking tendency should be determined in laboratory because a lower friction coefficient of the tested mud does not mean necessarily a lower sticking coefficient.
- The sticking tendency of muds cannot be easily estimated from data acquired from API standard mud tests, so using differential sticking tester on well-site should be considered.

Results of the testing presented in the paper have shown that trends of sticking mud potential should be determined in laboratory during the process of mud design. Use of the test at the well-site not only allows the mud engineer to identify the problem before the sticking occurs, but also allows for the most effective treatment option to be selected and implemented. That is the right way to avoid differential sticking problems and to reduce drilling costs substantially.

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