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Jan Macuda*, Sławomir Wysocki*, Magdalena Gaczoł**

WATER WELL ACTIVATION WITH APPLICATION OF CLAY MINERALS DISINTEGRATION AGENT***

1. INTRODUCTION

During drilling through aquifer layers using rotary drilling method with drilling mud application, phenomenon of formation clogging in near-well zone takes place. It leads to physical changes in pore spaces in consequence of particles deposition of solid phase originated from drilling mud. Due to this fact, filtration velocity in clogged zones of aquifer formation decreases, what results in increased pressure drawdown and decreased well hydraulic efficiency. Therefore, it causes reduction of well total capacity [3, 7, 14].

Likewise, drilling mud circulating in the well generates clay deposit on wellbore wall and similarly impacts hydraulic resistance of water stream flowing into the well by increasing it [1, 2, 5, 20]. While hydrogeological drilling, besides formation clogging in near-well zone, there also take place clogging of filter active surface during its installation in the well filled with drilling mud. It is additional factor which increases resistance of water flow into the well and depends significantly on type and size of the filter active surface [15].

Currently in industrial practice, there is no effective method for substantial limitation of near-well zone clogging during well drilling, especially in the view of wide use of bentonite muds treated with various kinds of polymers. One of key method is low-head drilling through aquifer formations. However, this method may be used only for drilling in compacted formations where do not occur problem related to wellbore wall instability [10, 11].

* AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland

** AGH University of Science and Technology, Faculty of Drilling, Oil and Gas, Krakow, Poland, PhD student

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Loose aquifer formations, to preserve the stability of wellbore wall, require to be drilled with maintenance of mud column overpressure in the well in relation to hydrostatic pressure of water column. Abroad, in countries where rigorist criteria of well hand over are in force, for reduction of formation permeability damage in near-filter zone, there is obligatorily used activation treatment before hydrodynamic tests. Cleanout of filtrate and solid phase in near-filter zone, besides enhancement of well hydraulic efficiency, have a significant impact on well capacity increase and exploitation time extension [2, 4, 18]. For improvement of near-well zone damaged permeability, in particular the one caused by clay solids, at the Drilling, Oil and Gas Faulty of AGHUST Krakow it was developed agent for disintegration of clay minerals called SKINAUT, which is in a process of obtaining patent rights. For this reason, its formula is kept secret and cannot be presented in the article. In order to confirm its effectiveness authors conducted, additionally to laboratory studies, industrial tests that established its meaningful usefulness.

2. CHARACTERISTIC OF GEOLOGICAL AND HYDROGEOLOGICAL CONDITIONS OF DRILLING OPERATIONS

Area of water intake within which tests of SKINAUT agent for clay minerals particles disintegration were undertaken, is characterized by simple geologic structure. Quaternary formations occur from the bottom of ground surface, directly under them at 23–29 m depth underlie Tertiary clays. In the Quaternary formations roof down to 3–5 m occurs layer of sandy clayey silt (alluvial soils). There are fluvial deposits in the floor of this layer. In the roof, luvial deposits appears in form of medium and coarse grained sands and in its floor as gravels with pebbles.

In the area of water well, groundwater occurs at the same level of aquifer being sandy-gravel Quaternary sediments. Water table of this level depth is 3.5–4.0 m and on the main part of area being discussed has freedom of movement. In case of occurrence of loam of thickness above 3 m, its movement is pressured. Aquifer layer is composed of medium and coarse grained sands and gravels with pebbles located on impermeable Tertiary clays. Filtration coefficient of aquifer layer varies from 0.39 to $1.63 \cdot 10^{-3}$ m/s. Therefore, it proves that hydrogeological conditions are diverse, but very advantageous. In Quaternary aquifer, the water is supplied by rainwater infiltration process.

3. CONSTRUCTION AND TECHNOLOGY OF THE WELL COMPLETION

Well, that was treated for its activation with application of new clay mineral disintegration agent SKINAUT, has been drilled to 34.0 m depth by rotary drilling method with right circulation of the mud. Drilling of the well was achieved with Wirth B3A drill rig.

From the ground surface down to 4.0 m depth, the well has been drilled with a cone bit of 0.56 m diameter and conductor pipe of 0.508 m diameter has been installed. After cementing abovementioned pipe to the top and successful bonding of cement, further drilling was continued with cone bit of 0.4445 m diameter to the planned depth. Next, filter column of PVC-U pipe with 0.35 m nominal diameter was installed in the well. Its construction was designed as followed:

- upper part of the filter column 20.0 m long, outer ϕ 0.33 m, wall thickness $t = 0.0145$ m,
- filter 8.0 m long, outer ϕ 0.33 m and slot perforation (slot of 1.0 mm width),
- lower part of the filter column 4.0 m long, outer ϕ 0.33 m.

Annular space between wellbore wall and filter column was filled with gravel pack of grain size 3–5 mm.

4. TYPE OF THE DRILLING MUD

Drilling of the well has been performed with application of bentonite mud with addition of cellulose derivative (CMC) that enables completion of the process without break--downs and drilling complications. However, this mud, during drilling through loose formations, creates compacted mud cake on the wellbore wall and causes mechanical clogging of the pore spaces in near-well zone of the aquifer layer. In result, diminished permeability of aquifer layer in near-well zone and increased water flow resistance in direction to the well can be observed [1]. For the improvement of water filtration in this zone, it should be performed treatment of activation with application of agents causing clay mineral disintegration and its removal during cleanout pumping. Formula of bentonite mud with CMC addition used for well drilling is presented in Table 1, its technological parameters are presented in Table 2.

Table 1

Formula of bentonite mud with CMC addition used for well drilling

Material/reagent	Concentration, %
Bentonite	4
CMC	0.5
Na_2CO_3	0.4
Na_2HCO_3	0.1
NaOH	0.25

Table 2

Technological parameters of bentonite mud with CMC

Density	Plastic viscosity	Apparent viscosity	Yield point	Geles	API filtration	pH
kg/m^3	cP	cP	$lb/100\ ft^2$	$lb/100\ ft^2$	ml	–
1 025	17.9	27.5	4.5	3.7/8.8	9.7	10

5. EVALUATION OF WELL HYDRAULIC EFFICIENCY

To rate a quality of a completed wellbore and an effectiveness of activation treatment which should improve water flow conditions in the near-filter zone, Jacob and Hantush [9, 13, 16] mathematically described components of total pressure drawdown. Components represent resistances of laminar flow in aquifer formation and resistances of turbulent flow in the near-filter zone and inside the well with the following formula:

$$s = BQ + CQ^2 = s_w + \Delta s \tag{1}$$

where:

- s – total drawdown of the well at water pumping capacity Q, m;
- Q – well pumping capacity, m^3/h;
- B – coefficient of resistance of laminar flow in aquifer layer, h/m^2;
- C – coefficient of resistance of turbulent flow around well, in filter and in filter column, h^2/m^5; coefficient C is called well resistance coefficient;
- BQ – actual pressure drawdown due to water laminar flow in aquifer layer;
- CQ^2 – well losses;
- s_w – actual pressure drawdown described by equations of well inflow, expressed as BQ;
- Δs – additional pressure drawdown (well losses) – could be described by C coefficient and expressed as $\Delta s = CQ^2$.

Jakob (1947) assumed in his model that area of turbulent flow where flow type change from turbulent to laminar is permanent and does not rely on pumping capacity.

This theory was introduced to industrial practice after Bruin and Hudson has greatly simplified it [6, 8, 9]. According to the new methodology the initial Jacob's formula (1) was transformed to the following form:

$$\frac{s}{Q} = B + CQ \tag{2}$$

After transformation, the following formula was obtained:

$$C = \frac{s - BQ}{Q^2} = \frac{\frac{s}{Q} - B}{Q} \tag{3}$$

The graphical solution of this formula is a chart in a rectangular coordinate system with: unit pressure drawdown s/Q versus capacity Q (Fig. 1), which allows to draw from it B and C factors [6, 12, 16].

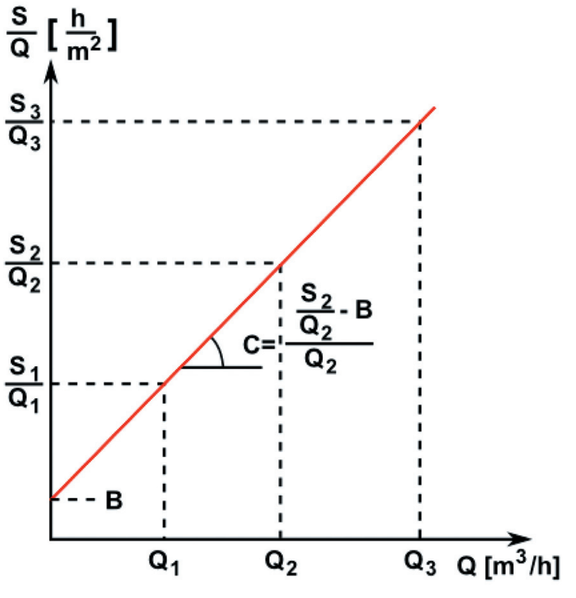

Fig. 1. Graphical method for hydraulic capacity of the well assessment due to Bruin and Hudson method [16]

Results of multistage pumping allow to put on an ordinate axis of a chart values s_1/Q_1; s_2/Q_2; s_3/Q etc. of the further steps of pumping with corresponding to them well capacities Q_1; Q_2; Q_3 on shaded axis. Points should designate a straight line and its extension to ordinate axis is specifying numerical value of aquifer layer hydraulic resistance coefficient B. The value of a tangent of the angle between the line and shaded axis is specifying numerical value of well hydraulic resistance coefficient C:

$$C = \frac{\frac{s_2}{Q_2} - B}{Q_2} \tag{4}$$

The C factor value is an indicator of hydraulic resistances values in the near-filter zone and inside the well, thus it can be used as indicator of a borehole technical condition in terms of hydraulics. The evaluation of a borehole technical condition is made through comparing the value of C factor from Bruin and Hudson methodology with criteria values presented by Walton [19] (Tab. 3).

Table 3

Assessment of well improvement depending on C coefficient [19]

Well condition	C, h^2/m^5
Properly designed and constructed well	< 0.00015
Moderately contaminated or clogged well	0.00015–0.00030
Advanced contaminated or clogged well	0.00030–0.0012
Significantly contaminated or clogged well	> 0.0012

6. CLEANOUT PUMPING

After installation of filter column in the well and placement of gravel pack, drilling mud was removed from the well with air-lifting device. Afterwards, it was performed 24 h cleanout pumping using pump aggregate at three stages of pressure drawdown. This pumping was aimed at cleaning of pore spaces, aquifer layer near-filter zone, gravel pack and filter out of clogging material deposited from the mud in the form of fine particles of cuttings and clay minerals. Results of the well cleanout pumping are presented in Table 4.

Table 4

Summary of the cleanout pumping results

Pumping stage	Pump capacity Q, m^3/h	Pressure drawdown s, m	Unit pressure drawdown s/Q, h/m^2
I	18	0.70	0.0390
II	37	1.73	0.0470
III	57	2.90	0.0510

On the basis of the calculations of efficiency coefficient $C = 0.00038\ h^2/m^5$, it was concluded that constructed well classifies as III class well i.e. advanced contaminated. Therefore, completed well absolutely necessary requires activation treatment performance in order to improve its efficiency.

7. WELL ACTIVATION WITH SKINAUT AGENT APPLICATION

In order to counteract clogging of aquifer layer near-filter zone and improvement of conditions of water inflow into the well, it was performed activation treatment with application of agent called SKINAUT that disintegrates particles of clay minerals. For this purpose, solution of abovementioned agent was injected by gravity through drill string, in the volume allowing its infiltration into aquifer layer near-filter zone at distance up to 1 m. After injection of the solution of SKINAUT agent disintegrating particles of clay minerals into near-filter zone, it was ordered 24 h downtime, subsequently after installation of pump aggregate next cleanout pumping was conducted with three stages of pressure drawdown. Obtained outcomes of repeated cleanout pumping are presented in Table 5.

Table 5

Summary of the cleanout pumping results after disintegration of clay minerals

Pumping stage	Pump capacity Q, m^3/h	Pressure drawdown s, m	Unit pressure drawdown s/Q, h/m^2
I	19.55	0.85	0.04348
II	41.38	1.95	0.04712
III	58.06	3	0.05167

The analysis of obtained results of cleanout pumping, after conducted treatment of well activation and mathematical calculation of well efficiency coefficient $C = 0.000028\ h^2/m^5$, confirm that well should be considered as I class well i.e. properly designed and constructed. Findings of repeated cleanout pumping prove high effectiveness of agent for clay mineral particles disintegration and its applicative aspects in hydrogeological drilling.

8. CONCLUSIONS

Groundwater drilling using rotary drilling method with application of drilling mud causes formation permeability damage in near-well zone in result of pore spaces clogging of drilled aquifer layer by solid phase originated from the mud. The usual symptom for this phenomenon is decreased hydraulic efficiency and exploitation capacity of the well.

In industrial practice for the improvement of formation permeability in near-well zone, there are used various mechanical and chemical treatments of well activation.

In Polish conditions, the most recently used treatment for this problem is clean out pumping, running for 24 hours at three pressure drawdown stages. This treatment is simple to conduct, however it is low effective and in most cases does not allow efficient counteraction against formation clogging in near-well zone, especially created by clay minerals.

For the purpose of effectiveness increase of treatments for activation of well drilled using rotary drilling method with application of drilling mud, new disintegration agent for clay minerals called SKINAUT was developed at the Drilling, Oil and Gas Faculty of AGHUST Krakow. In order to confirm its effectiveness in industrial conditions, it was conducted test for clogging limitation of recently drilled well, which primarily was classified as III class i.e. advanced contaminated or clogged well. Application of the agent allowed significant improvement of its hydraulic efficiency and reclassification of the well from III class to I class i.e. properly designed and constructed well.

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