Principles of selection ofdrilling mud stream volume when drilling with a stream pump

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Princípy selekcie objemu vŕtneho výplachu pri vŕtaní s prúdovým čerpadlom

The reverse mud circulation induced by a stream pump is most frequently applied for large diameter drilling. This system is treated as auxiliary in all design solutions. It is implemented to drilling wells from the surface to the depth of deposition of the preliminary column. It enables performing wells in loose sands, gravel, clays clayey shales, marls, limestones, sandstones and other sedimentary rocks.

A principle of selecting a drilling mud stream volume for various bit diameters and drilling rates in loose rocks are presented in the paper. A special attention has been paid to the drop of efficiency of cuttings removal with an increasing depth of the borehole.

***Key words**: Large diameter drilling, reverse mud circulation, stream pump.*

Introduction

The reverse mud circulation enhanced with a stream pump can be used for drilling large diameter hydrogeological wells from the surface to a depth of tens of meters. This method lies in a suction action of a stream pump, which can be disposed on a string below or above the mud level in the borehole. A scheme of drilling a well with a reverse mud circulation induced with a stream pump is presented in Fig. 1. This method is also frequently applied as a supplementary action of drilling mud caused by an airlift.

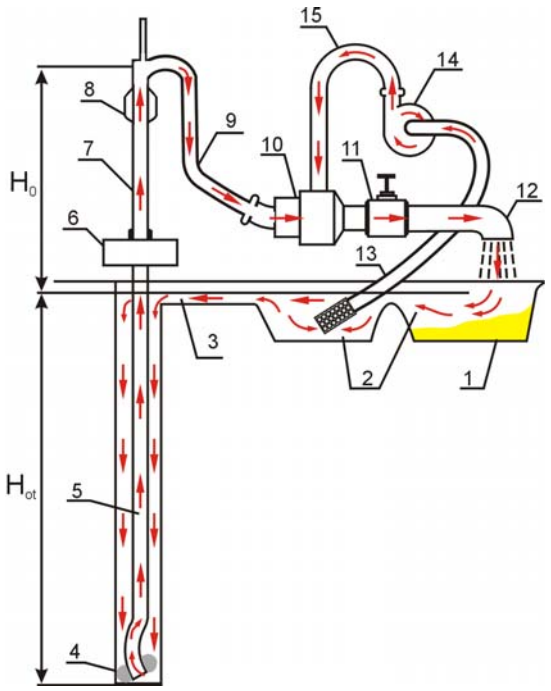

Fig. 1. Scheme of reverse drilling mud circulation induced by a stream pump disposed over the mud level in a borehole. 1 – cuttings, 2 – pit, 3 – inflow trench, 4 – bit, 5 – string, 6 – drilling table, 7 – kelly, 8 – mud wellhead, 9 – suction hose, 10 – stream pump, 11 – valve, 12 – discharge hose, 13 – suction hose of a spin pump, 14 – spin pump, 15 – injection hose.

Hydrogeological large diameter wells drilled by this method, create a possibility to dispose large-diameter well filters and to use suitable gravel packers. This method also makes efficient drilling of wells in loose sands, gravel, clays, clayey shales, marls, limestones, sandstones and other sedimentary rocks.

The cuttings must be efficiently removed from the bottom of the well to provide a correct operation of the drilling procedure. Thus, it is necessary to pump a mud having specific rheological parameters and a volume rate enabling a good cleaning of the bottom and a transport of the cuttings inside the string to the surface. The efficiency of the cuttings removal depends on a number of parameters, e.g. the density

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and shape of the cuttings, the density of the drilling mud, the Reynolds number of the flowing mud, the well's diameter and the mud volume rate [1, 2, 4].

When designing the hydraulic parameters of drilling, limitations resulting from the technical characteristic of the suction (stream) pump must be taken into account, especially its maximal suction pressure which in the end phase of the bit cycle must overcome the flow resistance between the bit and the uttermost point of the mud circulation.

Calculation of the maximal height of the stream pump suction

When designing hydraulic parameters of drilling large diameter wells with reverse mud circulation induced with a stream pump, the pressure balance is used in the form [2]:

$$p_s = p_o - p_p - p_g - p_t - p_a - p_k \tag{1}$$

where:

p_s – suction pressure of a stream pump,
p_o – atmospheric pressure,
p_p – water evaporation pressure,
p_g – pressure losses caused by the increased density of mud discharged from the well,
p_t – pressure losses resulting from the friction of mud circulating in the string,
p_a – pressure losses caused by the mud acceleration in the string,
p_k – pressure losses resulting from a change of the flow direction of mud in the mud wellhead.

These losses are defined with the formulae:

$$p_g = H_o \cdot (\rho_w - \rho_p) \cdot g \tag{2}$$

$$p_t = \frac{k\left(H_{ot} + H_o\right) \cdot v_p^2 \cdot \rho_w}{2 \cdot d_w} \tag{3}$$

$$p_a = \frac{\rho_w \cdot v_p^2}{2} \tag{4}$$

$$p_k = \frac{w \cdot \rho_w \cdot v_p^2}{2} \tag{5}$$

where:

H_{ot} – depth of well,
H_o – height of mud rise over its level in the well,
ρ_p – density of mud injected to the well,
ρ_w – density of mud discharged from the well,
g – acceleration of gravity,
k – coefficient of losses caused by friction,
v_p – mud flow velocity in the string,
d_w – internal diameter of the string,
w – coefficient of losses caused by the friction dependent on the mud wellhead design.

By substituting eqs. (2) through (5) to eq. (1), the maximal suction height of a stream pump could be determined:

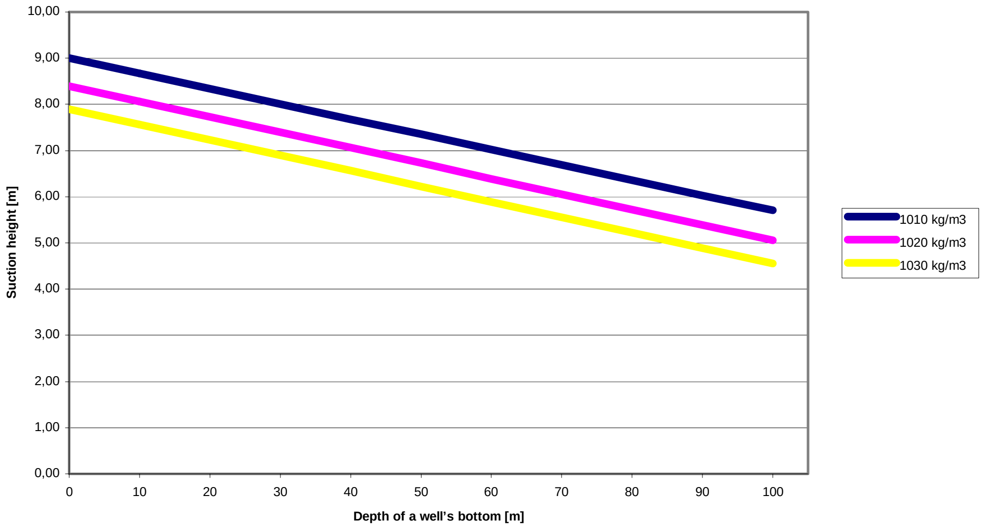
$$H_{z\max} = \frac{2d_w\left[p_o - p_p - H_{ot}(\rho_w - \rho_p)g\right] - k(H_{ot} + H_o)v_p^2 \cdot \rho_w - d_w \cdot \rho_w \cdot v_p^2 - w \cdot \rho_w \cdot v_p^2 \cdot d_w}{2 \cdot g \cdot \rho_w d_w} \tag{6}$$

Influence of selected parameters on the suction height of a stream pump

One of the most important parameters having an influence on the efficiency of a stream pump operation is the increase of density of mud discharged from the well. To illustrate this, respective calculations were made and the obtained results were plotted in Figs. 2a and 2b. The plots were made on the basis of the following data:

- Inner diameter of mud pumps – 0.10 (Fig. 2a) and 0,20 (Fig 2b) m,
- Mud flow velocity in the string – 2.0 m/s,
- Density of mud discharged from the well – 1010, 1020 and 1030 kg/m^3,
- Height of rise of mud over its level in the well – 8.0 m,
- Coefficient of losses caused by friction – 0.01441,
- Coefficient of losses caused by the friction dependent on the mud wellhead design – 0.21,
- Atmospheric pressure – 98065 Pa,
- Water evaporation pressure – 1783 Pa.

a,



b,

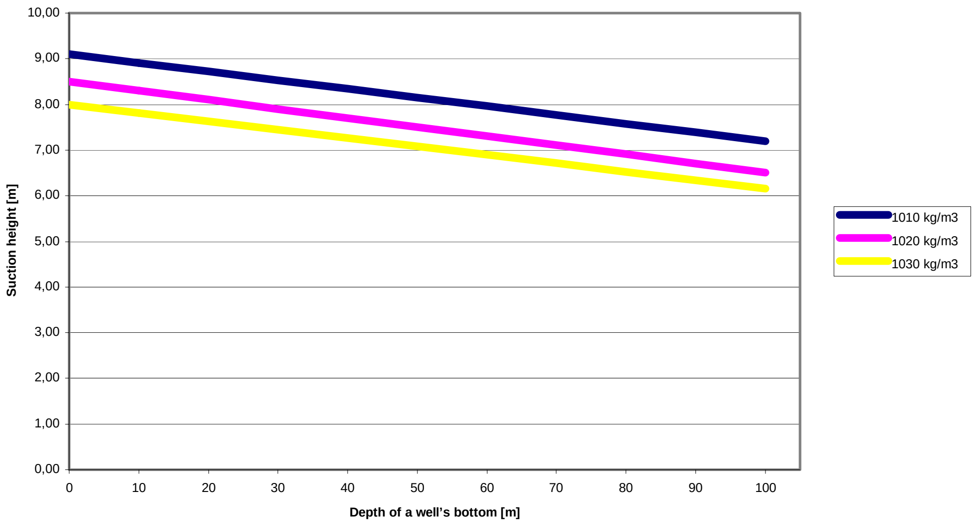


Fig. 2. Dependence of suction height of a stream pump on the depth of a well's bottom; a) for a string of a nominal of 0.1 m; b) of diameter 0.2 m

The difference of density of mud discharged from and injected to the well significantly influences the suction height of the stream pump. It is also evident that with the increase of a well's depth, the suction height of the stream pump decreases, thus decreasing the efficiency of its operation. When drilling deeper wells, the stream pump should be substituted with airlift.

In Poland, hydrogeological wells with the reverse mud circulation are usually equipped with a few strings, most frequently 0.1; 0.15 and 0.2 m of nominal diameter. A dependence of the suction height in a function of well's depth for two string's diameters D_w = 0.1 m (Fig. 2a) and D_w = 0.20 m (Fig. 2b) are presented in Fig. 2 to illustrate the influence of the string's diameter on the parameters of a stream pump operation. It follows from the analysis of the plots that the bigger is the inner diameter of the string, the bigger is the suction height of the stream pump. The increase of density of mud discharged from the well lowers the height of suction. A similar influence can be observed for an increase of the mud flow velocity in the string, as shown in Fig. 3 [2, 5].

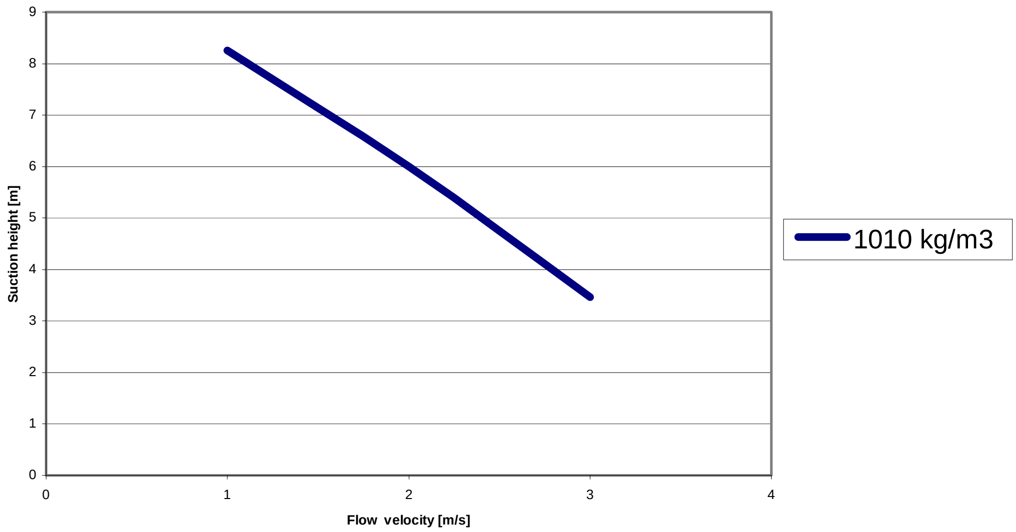


Fig. 3. Dependence of the suction height of a stream pump on the mud flow velocity in a string of a nominal diameter equal to 0.1 m.

Conclusions

1. One of the most efficient methods of drilling large diameter hydrogeological wells is the reverse mud circulation induced by a stream pump. This especially refers to the section drilled from the surface to some tens of meters of depth.
2. The efficiency of cuttings removal from the well's bottom to the surface significantly depends on:
   - Difference of density of mud discharged from and injected to the well,
   - Size and shape of the cuttings,
   - Geometrical parameters of the well and the string,
   - Elastic viscosity and the initial flow boundary of the mud.
3. The efficiency of the work of a stream pump decreases with: growing depth of the well, decreasing the string's diameter and increasing the height at which the mud wellhead has been disposed over the mud level in the well.

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