2

High-pressure Water Jet Technology Application for Abyssal Well Renovation

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1. Introduction

In order to ensure long lasting and efficient delivery of water characterized with good quality, it is necessary to own high efficiency technical equipment but first of all abyssal well enabling to draw the water up. However usual exploitation of such wells leads to constant growing old, what depends on many constructional parameters, technical equipment as well as on hydraulic and hydro-chemical properties of near orogenic belt and underground water [7].

Taking above purposes into consideration, in order to choose adequate renovation strategy and conservation, the fact of well ageing process is unavoidable. This process causes parallel well efficiency decrease that in consequence might effects in well devastation and irreversible changes to the water intake [11]. Therefore, the main reason of all renovation processes is to restore well efficiency and stop aging processes.

One of the most efficient renovation method of deep well is to introduce high-pressure water jet technique [2, 3]. Adequate water jets are selected each time for practical incrustation conditions of the filters and water-bearing layers silting-up. This paper presents own experiences in effective renovation of deep well filters utilizing high-pressure water jet.

2. Abyssal well exploitation

Typical exploitation of well cause constant construction ageing that depends on many parameters mentioned above as well as on the following ones influencing efficiency decrease:

- corrosion of construction and pumping equipment,
- water-bearing layers silting-up as well as filtering gravel caused by fine grains fractions,
- incrustations occurring as an effects of hydro-chemical and microbiological processes,
- pumping equipment failure,
- effectiveness decrease of water-bearing formations caused of excessive exploitation or changing of reproduction mechanisms.

In this way it occurs that after several years its efficiency is decreased (Fig. 1). This situation is often connected with worse water quality. Such situation after few dozen years results in creation of hard nodular sediments that are deposit inside. Efficient renovation of such accretions is an essential problem because these impurities are characterized with great adhesion and their main components are compounds of iron, manganese, calcium and silicon.

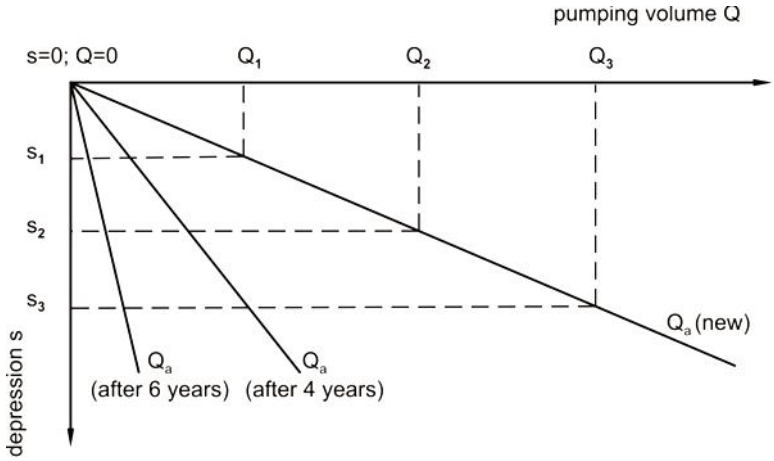

Fig. 1. Efficiency characteristics of typical working well (without renovation)
Rys. 1. Charakterystyka wydajnościowa pracy typowej studni (bez renowacji)

Well water pumping efficiency depends on filter inlet surface A_F as well as on its critical flow through the filter. It can be described by the following formula:

$$Q = \pi \cdot D_F \cdot H_F \cdot V_C \quad [\mathrm{m}^3/\mathrm{s}] \tag{1}$$

where:
D_F – outer diameter of the filter [m],

H_F – hydraulic height of the filter [m],
V_c – critical flow velocity close to outer wall of the filter [m/s].

Converting the above expression, it is possible to establish critical water flow:

$$V_c = \frac{Q}{\pi \cdot D_F \cdot H_F} \quad \text{[m/s]} \tag{2}$$

The value of above determined flow depends on maximum pumping efficiency which decreases together with exploitation time.

Generally, critical inlet water velocity for filter gaps should not exceed the value of 0.03 m/s. In turns, critical outlet ground water velocity flowing out to filter gravel ridge should achieve the values range 0.02 to 0.03 m/s [8].

3. Abyssal well renovation

After few decades of exploitation water-bearing and filtering gravel is naturally silting-up. It makes water flow difficulties by its inflow decrease into the well that causes in turns its efficiency problems.

Until recently, this kind sediment was removed by chemical or mechanical methods using different types of scrappers [7, 8]. However those standard renovation techniques don't assure enough high level of their renovation as it is presented in Fig. 2.

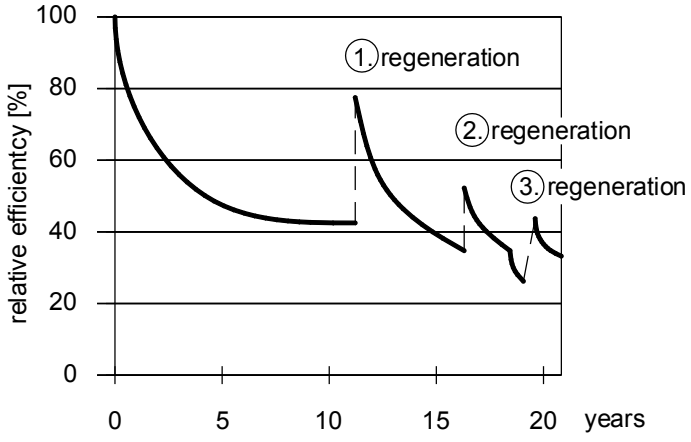

Fig. 2. Typical time course of well relative efficiency including regeneration
Rys. 2. Typowy przebieg czasowy wydajności względnej studni uwzględniający regenerację

Effects that are much more efficient can be assured by introducing water jet technology [1, 4]. Firs time it was used over 25 years ago in the USA to deep well filters cleaning [13, 17]. Thanks to achieved high efficiency of this method, it was adopted for different applications [6, 10, 12, 16] and therefore introduced in many countries [5, 8, 9, 10, 16]. Nowadays, similar hydro-jet techniques have also been used for the cleaning of well systems [1, 8, 9, 12].

Considering above, such method needs some more characteristic that is presented in this paper.

4. Problem diagnosis

In order to estimate the amount of well devastation and necessary renovation conditions special TV cameras are used for. One of the newest types of such systems is exemplified on Fig. 3. Specific character of well installation causes that camera used for inspection should ensure higher working pressure standards because well depth can reach even to 300 m.

a) b)

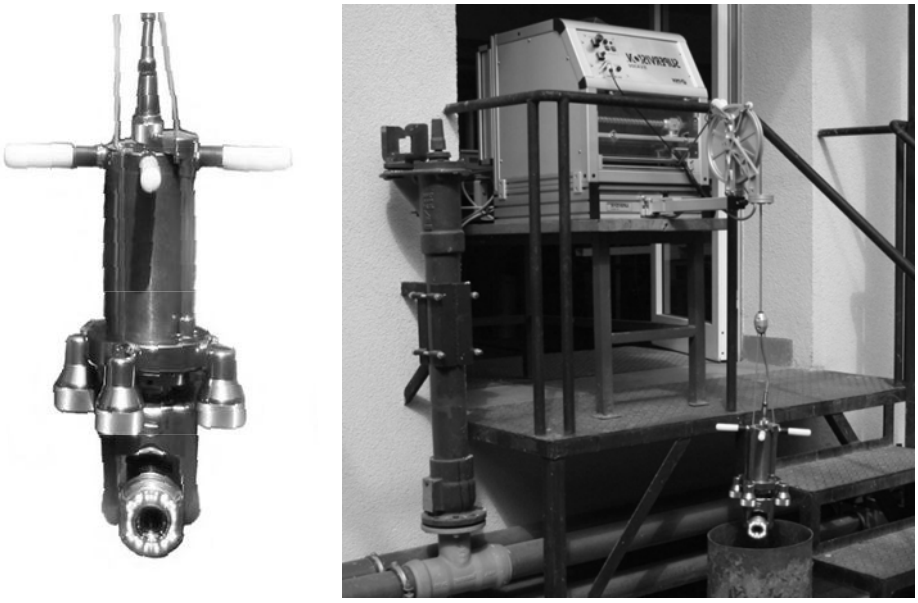

Fig. 3. TV Supervision iPEK TV-camera used for deep well monitoring (a) equipped with semi-automatic cable winder drum (b)

Rys. 3. Kamera telewizyjna firmy Supervision iPEK do monitorowania studni głębinowych (a) wyposażona w półautomatyczny bęben do nawijania przewodów sygnałowych (b)

Such a specialist TV monitoring should include following characteristic technical details:

- all well pipes including their corrosion stage,
- all pipes connections,
- individual elements of the filtering pipe especially filtering dilatations.

Proper monitoring let to prepare conscious regeneration in the next step. Thanks to that, sometimes it is possible to 'find' old lost parts of hydro technical installation. Special evident for that could be extraction of three-segmented slotted filter pipe [4] of 18 m length (Fig. 4), which was lost during improper regeneration.

Fig. 4. Slotted stainless steel filter extracted from well bottom after 75 years of its exploitation

Rys. 4. Szczelinowy filtr wykonany ze stali nierdzewnej wyciągnięty z dna studni po 75 latach jej eksploatacji

5. Conditions of wells' hydro-jetting cleaning

A special designed rotary heads are used for high-pressure water jet wells cleaning (Fig. 5) that are equipped in adequate type and number of water nozzles [15]. Technological water is pressured to necessary level [14] in the hydro-pump system.

High-pressure water of adequate parameters is directed next to the working head through special hoses. This process is connected with pressure lost that depends on nominal water pressure and its output as well as on working head type and used hose dimensions. Fig. 6 illustrates some exemplary relations of mentioned pressure loss.

Fig. 5. Different rotary working heads types used for high-pressure water jet wells cleaning

Rys. 5. Różne typy głowic obrotowych używanych do wysokociśnieniowego czyszczenia studni głębinowych

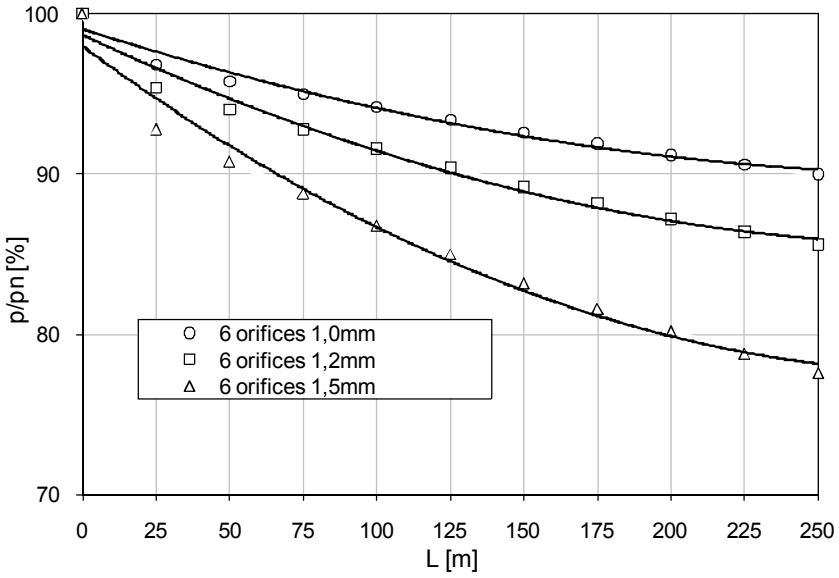

Fig. 6. Influence of hose length and water orifice diameter of six-orifice cleaning head on the working pressure for hose diameter of 12.5 mm, (p_n=25 MPa)

Rys. 6. Wpływ długości węża wysokociśnieniowego i średnicy otworu sześciootworowej głowicy czyszczącej na ciśnienie robocze strugi dla średnicy węża 12,5 mm, (p_n=25 MPa)

Such a renovation conditions are mainly connected with the filter type and its technical condition [4], water-bearing layers type and material parameters of the well e.g. pipe material type resistance on corrosion intensity as well as on abyssal wells diameter and depth [1].

6. Regeneration technology outline

The matter of hydrodynamic regeneration of deep wells consists in proper formulated high-pressure water jet [1, 2, 3] that is introduced inside the well pipe especially in the filtering zone. Such high-pressure cavitating water jet created inside special multi-outlet working heads reacts directly on sediments. Heterogeneity of such water jet also its adequate geometrical displacement in rotating head causes that the influence area is in practice a few dozen times larger than for standard high-pressure jet. In consequence such process of sediments erosion causes much efficient washing out of silting-up layers.

In practice, rotating working heads characterized with spatial nozzles orientation are used for such regeneration processes (Fig. 7). Adequate synchronization of rotary movements of such self-driven head with its reciprocating vertical movements (along the filter pipe) ensures efficient cleaning of the filter as well as nearby gravel zone. The same way, but not such intensively, the upper- and under-filter pipe is cleaned.

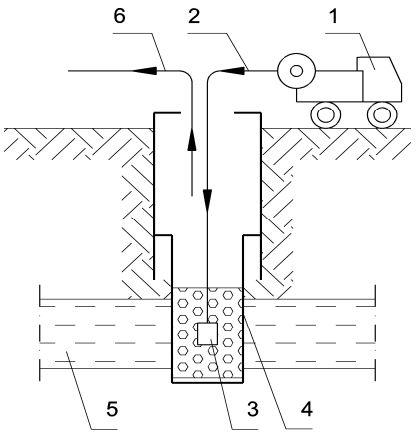

Fig. 7. Schematic view of well renovation process using HydroBor system:
1 – hydromonitor, 2 – hose, 3 – working nozzle, 4 – well filter, 5 – water-bearing layer, 6 – pollution draining

Rys. 7. Schemat procesu renowacji studni przy użyciu systemu HydroBor:
1 – hydromonitor, 2 – wąż, 3 – głowica robocza, 4 – filtr, 5 – złoże wodonośne, 6 – odsysanie zanieczyszczeń

Thanks to mentioned cavitations effect and pulsing water pumping after regeneration, impurities separated from the filter surface are then sucked out of the well.

7. Process efficiency

Above described regeneration process efficiency is very high. Such method ensures values of water critical flow through the filter exceeding 0,0025 m/s and the same way suitable level of effectiveness enlargement. If regeneration process doesn't need additional cleaning of external water-bearing layers, total operational time of the well renovation usually includes between 12 to 18 hours.

Thanks to TV inspection that enables proper recognition of technical conditions of pipe and filter, it is possible to establish adequate method and requirements for its renovation as well as technology effectiveness after processing. Exemplary photographs in Fig. 8 present situation before and right after (Fig. 9) proper renovation was introduced. Such technology, taking into account a marginal financial cost of its realization ensures good efficiency of the well operation that is close to its after built state.

a) b)

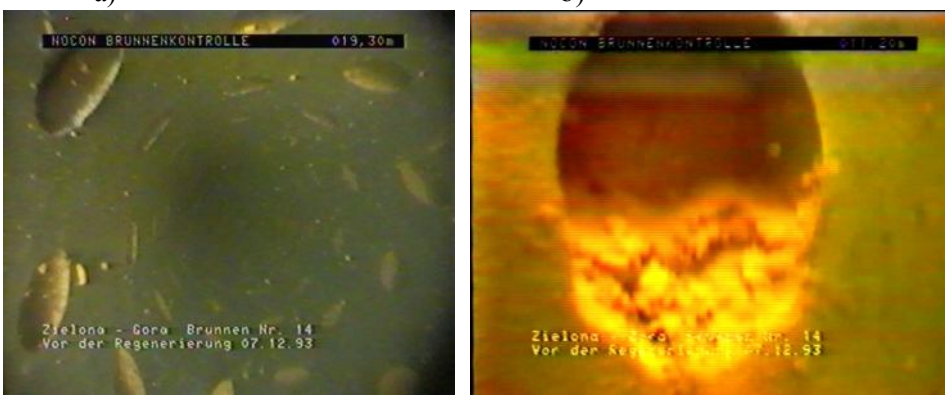

Fig. 8. Exemplary view of well inside showing out filter zone before renovation: a – general view, b – technological water inlet hole incrustation

Rys. 8. Przykładowy widok wnętrza studni ukazujący strefę filtra przed renowacją: a – widok ogólny, b – inkrustacja napływowego otworu technologicznego

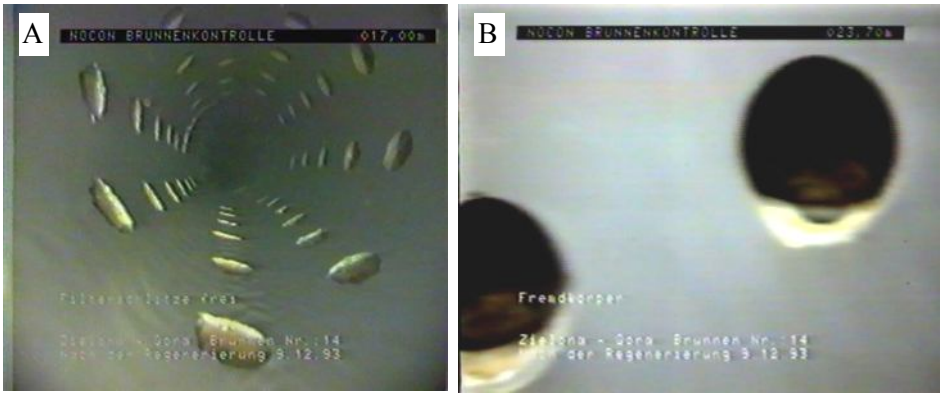

Fig. 9. Exemplary view of well inside showing out filter zone after regeneration: A – general view, B – cleaned technological water inlet holes
Rys. 9. Przykładowy widok wnętrza studni ukazujący strefę filtra po renowacji: A – widok ogólny, B – wyczyszczone otwory technologiczne

8. Conclusion

It should be stated in the conclusion that presented above technology introduces new quality in hydro-technical equipment regeneration, especially for deep wells. These are economically advantageous methods, well-founded considering civilization and urban situations. But they need rational acting basing on natural and environmentally friendly methods introduction like hydrojetting technologies assisted with monitoring inspection.

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Zastosowanie wysokociśnieniowej strugi wody do czyszczenia studni głębinowych

Streszczenie

W artykule zaprezentowano efektywną metodę hydrostrumieniowego czyszczenia zakolmatowanych rur i filtrów studni głębinowych po kilkudziesięciu latach ich eksploatacji. Metoda ta polega na wprowadzeniu do wnętrza regenerowanej studni specjalnie skonstruowanej wysokociśnieniowej głowicy roboczej, z której wypływa wysokociśnieniowa struga wody charakteryzująca się turbulentną wielofazową strukturą. Struga ta zapewnia wystarczająco wysoką energię, aby skutecznie rozbić zalegające wewnątrz osady a jednocześnie nie spowodować zniszczenia delikatnej konstrukcji filtrującej. Wytrącone w ten sposób osady, odsysane są następnie wraz z poprocesową wodą na zewnątrz rurociągu a całość operacji regeneracyjnej kończy etap płukania. Metoda ta zapewnia wysoką, przeszło 90% skuteczność odtwarzania pierwotnej wydajności studni i jest zarazem ekologicznie przyjazną gdyż czynnikiem roboczym jest strumień czystej wody.