Electro-hydraulic pulse technology of drilling wells for installation of heat exchange elements of heat pumps

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Abstract. The aim of the study is to develop scientific and practical principles of implementation of energy saving heat pump technology for heat and cold supply to residential, public and industrial premises on the basis of alternative and renewable sources of energy. One of the effective methods to generate heat from groundwater by means of heat pump technology is the use of wells for consolidation of heat exchange elements produced by drilling. Fundamentally new innovative method of making wells is electro-hydraulic drilling, when electrical energy directly in the bottomhole transforms into mechanical energy of shock waves that can break up rocks. This paper describes the results of studies of the impact of electro-hydraulic pulse on hard and super hard rock minerals.
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Introduction

One of the energy efficient methods is to obtain thermal energy is a heat pump technology which makes it possible to save energy using heat of the ground, underground water, water bodies, natural water flows, etc. [1]. The environmental benefit from the use of this technology is that it enables to completely avoid local greenhouse gas emissions from fuel combustion. Therefore, a priority and urgent task is to replace old boilers that use gas or liquid fuel by the systems based on a heat pump. This replacement would not only reduce the consumption of fossil fuels, but also substantially reduce emissions of carbon dioxide.

Heat pumps are compact, economical and environmentally friendly heating facilities for hot water supply and heating houses that use low-grade heat source by transferring it to a heating agent with a higher temperature.

The benefit of heat pumps is their efficient performance: to transfer 1 kWh of thermal energy to heating system a plant needs to spend only 0.2-0.35 kWh of electric power. Since the efficiency factor of conversion of thermal energy into electric power at large power stations is up to 50%, fuel efficiency when applying heat pumps rises. Another benefit of heat pump is the convenience of changeover from heating supply in winter to air-conditioning duty in summer, for that instead of radiator units fan coils or "cool ceiling" facilities are connected to an external collector.

The main heat exchanger element in the collecting system of low potential heat of the ground are coaxial vertical ground heat exchangers located outside the perimeter of the building. These heat exchangers are installed in wells with depth ranging from 32 to 35 m each, arranged around the building [2-4].

Nowadays there are many types of drilling rigs widely used in Kazakhstan. [5].

Widely used nowadays mechanical auger drilling methods are more efficient in case of soft ground without solid rock and stone slabs. Drilling to the depth of 25 meters at well diameters up to half a meter with the above mentioned inconveniences can be difficult.

Electro-hydraulic drilling is a fundamentally new method that has not yet been applied in industry; the task of research and the practical use of this technology remains relevant to this day.

The unique benefits of this new technology are the following:

- opportunity to perform work in confined working space conditions (inside of constructed buildings, premises, basements, etc.) where it is almost impossible to use conventional drilling methods due to bulky equipment;
- long term reliable operation due to the absence of rubbing and wearing parts of the equipment;
- ease of operation and maintenance, that is achieved by the use as an active part a widely available cable electrode that is a consumable product.
- low power consumption and environmental friendliness of performed work.

This technology, as compared to conventional ones, makes it possible to demolish such obstacles as solid rocks more efficiently and in a short time when drilling wells for heat exchangers by impact of shock waves at high-voltage discharges in aqueous media.

Experiment

Electro-hydraulic effect is a high voltage electrical discharge in a liquid medium. During the formation of an electric discharge in a liquid energy release occurs within a relatively short period of time. A powerful high-voltage electric pulse with a steep leading front causes a variety of physical phenomena. Such as the emergence of ultra-high hydraulic pulse pressure, electromagnetic radiation in a wide range of frequencies up, under certain conditions, to x-rays, cavitations phenomena [6-8].

Universal experimental board was constructed in laboratory of electric dynamics of Engineering thermal physics chair of Akylbayev Zh.S. of Karagandy State University name of academician E.A. Buketov for conducting laboratory research [9].

To form the pulse with a short leading front voltage applied to the discharge gap in the liquid we used the discharge gap in a gas – a gas discharger, and in order to generate certain pulse energy an accumulating electrical capacitor was used. We developed and implemented into practice electro-hydraulic setup and working cell for drilling (Fig. 1).

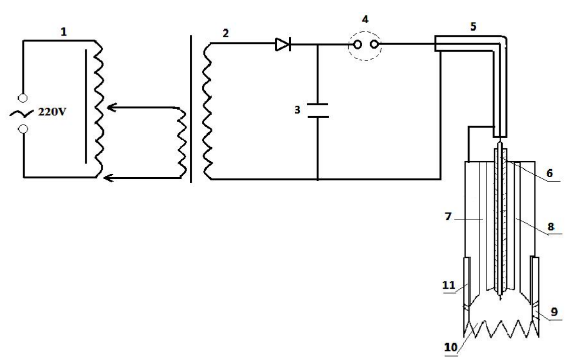


Fig.1. Scheme of electro-hydraulic apparatus and electro-hydraulic drill

1 – power supply, 2 – high-voltage generator, 3 – pulse capacitor, 4 – discharger, 5 – coaxial cable-electrode, 6 – centre electrode, 7 and 8 – water passages for injection the face, 9 – vent in the bit for gas outlet, 10 – teeth of the drilling bit, 11 – head of the drilling bit.

The setup consists of a power supply (1), high voltage generator (2), pulse capacitor (3) discharger (4), coaxial cable-electrode (5) and electro-hydraulic drill consisting of the centre electrode (6), (7) and (8) are water passages for injection the face, (9) – vent in the bit for gas outlet (10) – teeth of the drilling bit (11) – head of the drilling bit.

The appearance of the electro-hydraulic drill is shown on the picture (Fig. 2)

Fig. 2. The appearance of the electro-hydraulic drill

The setup works as follows. Pulse capacitor (3) is charged by a high voltage generator (2), that powered by controlled power supply (1). When reaching the specified voltage a breakdown takes place in the discharger (4) and the energy stored in the capacitor through an electrode cable is transferred to the working part of the electro-hydraulic drill. A pulse electric discharge occurs in the fluid, the latter being a source of powerful mechanical shock waves that are reflected from the head of the drill and focused on a processed rock thus destroying it into small pieces.

As a result of the pilot study, the optimal values of time and the number of spark discharges at electro-hydraulic drilling stones are determined, the time for destruction of stones and solid rocks while drilling is defined.

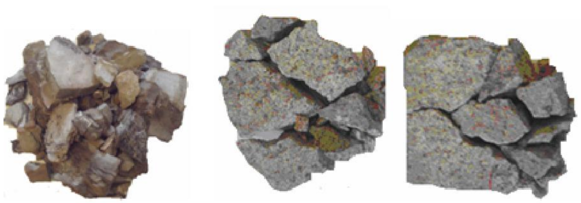
The objects of electro-hydraulic processing were such solid rocks as natural stones. A natural stone is a material of quite diverse structure, often composed of various minerals that are often exposed to significant tensions in the formation process and the subsequent occurrence in the Earth's crust [10]. For the experiment natural stones of 5-6 hardness units by the Mohs scale were used.

Photos of processed natural stones samples are in the picture (Fig. 3).

1 2 3

Fig. 3. Photos of natural stone samples

As a result of intensive electric hydro-pulse processing of natural stones the mentioned samples were crushed into small pieces (see photo in Fig. 4).



1 2 3

Fig. 4. Photos of natural stones samples after electric hydro-pulse processing

In the experiments, the electro-physical parameters of the setup were changed within the following limits (Tab.1):

Table 1: Values of the electro-physical parameters

$U_{high\ voltage}$, 10^3 V	$C_{capacitor}$, 10^{-6} F	δ, m	n	$l_{razryad}$, m	E, 10^3J
20	1	0,04	90 - 150	0,007	0,288
28	1	0,06	200 -250	0,010	0,420
35	1	0,08	300 - 400	0,012	0,612

The energy of the discharge is determined by the formula:

$$E = \frac{CU^2_{\mathbf{high\,voltage}}}{2}$$

In experiments natural stones having an average thickness of 42 mm to 80 mm were processed.

Experiments were conducted as follows. On the surface of the stone located in a tank of water, an to electro-hydraulic drill was mounted. After feeding electric power to the set-up, the number of discharges for the destruction process was determined.

The resulting diagram of number of discharges dependency on the thickness of the stone at different values of energy is presented in Figure 5.

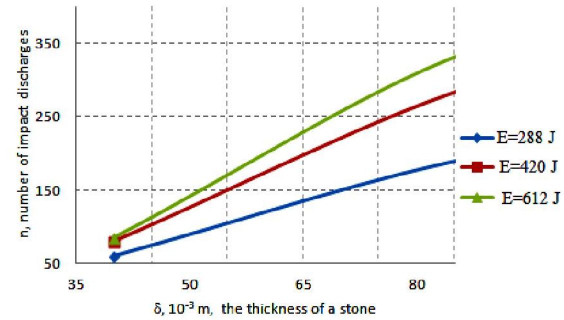


Fig. 5. Dependence of the number of impact discharges on the thickness of a stone prior to crushing

You can see that at the discharge energy level around 288 Joules destruction of a stone to the thickness of 55-60 mm is possible. The number of pulses is 230. When discharge energy rises, the thickness of destructed stones increases while the number of pulses required for destruction decreases [11]. For example, at the discharge energy level around 612 J it is possible to destruct stones of 80 mm thickness. This requires less number of pulses of about 170.

Conclusion

On the basis of experimental research the limits of electro-physical parameters of method, when the intensive destruction of solid rocks – natural stones begins were determined.

The quantitative dependency, characterizing the beginning of the process of destruction of rocks of various thickness depending on the number and energy of discharges was defined.

The experimental work proved the possibility of achieving higher drilling speeds compared to those at conventionally used plants. The electric pulse destruction is implemented without using a drilling bit, it does not require special tightness of electrodes to bottomhole surface with considerable force; therefore, the wear of the electrodes at electrohydraulic pulse drilling is relatively minor.

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