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(54) **METHOD OF DISINTEGRATING ROCK BY MELTING AND BY SYNERGISM OF WATER STREAMS**

VERFAHREN ZUR GESTEINSZERSETZUNG DURCH SCHMELZEN UND SYNERGIE VON  
WASSERSTRÖMEN

PROCÉDÉ DE DÉSINTÉGRATION D'UNE ROCHE PAR FUSION ET PAR SYNERGIE DE JETS  
D'EAU

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## Description

### Technical Field

[0001] The invention relates to a method of disintegrating rock by synergism of melting and water streams and it is designed to be used especially in the drilling process, particularly of hard rocks.

### Background Art

[0002] The interaction of natural melt (magma or lava) in nature is known for thousands of years as one of the most monumental natural phenomenon - volcanic eruption accompanied by huge outpouring of hot ash.

[0003] This natural phenomenon, called hydro-magmatic explosion, has been a subject of scientific study, of explanation of its physical background, but also a subject of intensive creation of hypotheses, theories, models, mathematical descriptions and comprehensive theoretical systems, in the last half century.

[0004] But these works were aimed at obtaining more knowledge about physical process of interaction of water and melt, so that model of natural phenomenon could be specified. Several comprehensive works explaining and mathematically describing beginning and course of explosion or detonation, were created.

[0005] Experimental works of volcanologists, by which the rock melt is injected into larger volume of water or water stream is injected into melt, are described in literature.

[0006] All mechanisms of hydro-magmatic explosion, morphology of particles being formed, and conditions under which these processes occur, are described in detail in the mentioned literature. This professional literature also shows, that ongoing processes can be utilised for the benefit of drilling technique utilizing the interaction of plasma/rock/water.

[0007] In these publications, the authors describe the mechanisms of explosive interaction of water with melted rock.

[0008] Wohletz KH, 1986, Explosive magma-water interactions: Thermodynamics, explosion mechanisms, and field studies, Bulletin of Volcanology 48, 245-264.

[0009] Wohletz KH and Zimanowski B, Physics of phreatomagmatism, part I: explosion physics, Terra Nostra 2000/6, 515-523.

[0010] Zimanowski B and Wohletz K. H., Physics of phreatomagmatism, part II: eruption physics, Terra Nostra 2000/6, 535-544.

[0011] Wohletz, K.H., Zimanowski, B., and Buttner, R., 2008, Magma-Water Interactions, Los Alamos National Laboratory Report LA-UR-08-0921, 41 pp.

[0012] The mentioned publications contain also more detailed description of morphology of forming particles.

[0013] Sheridan, M.F.; Wohletz, K.H. Hydrovolcanism: Basic Considerations and Review, Jour. Volcanol. Geotherm. Res., vol. 17, 1983

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[0015] Research of basic physical aspects of phreatomagmatic explosions:: Bernd Zimanowski, Georg Fröhlich, Volker Lorenz, Quantitative experiments on phreatomagmatic explosions, Journal of Volcanology and Geothermal Research, Volume 48, Issues 3-4, December 1991, Pages 341-358

[0016] Research of explosions by interaction of water with silicate melts: Bernd Zimanowski, Georg Fröhlich, Volker Lorenz, Experiments on steam explosion by interaction of water with silicate melts, Nuclear Engineering and Design, Volume 155, Issues 1-2, 2 April 1995, Pages 335-343.

[0017] Phreatomagmatic explosions of rhyolitic magma: A. Austin-Erickson, R. Büttner, P. Dellino, M. H. Ort, B. Zimanowski, Phreatomagmatic explosions of rhyolitic magma: Experimental and field evidence, JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 113, B11201, 12 PP., 2008.

[0018] Research of the surface features of ash grains as an indicator of dynamic interaction of liquid water and magma: Ralf Büttner, Pierfrancesco Dellino & Bernd Zimanowski, Identifying magma-water interaction from the surface features of ash particles, Nature 401, 688-690 (14 October 1999) |doi:10.1038/44364; Received 6 May 1999; Accepted 23 August 1999. Phenomenological model of interaction of water with melt: Ralf Büttner and Bernd Zimanowski, Physics of thermohydraulic explosions, Phys. Rev. E 57, 5726-5729 (1998). The paper Modeling of Laser Spallation Drilling of Rocks for Gas and Oilwell Drilling by Z. Xu et al. describes and theoretically analyzes the spallation of the rock by laser delivered energy. There is no interaction with water and there is no plasma generation.

[0019] US Patent no. 2738162 by Robert B. Aitchison describes one of the first heat generation for spallation of the rock by chemical plasma. There is no interaction with water and there is no melted phase of the rock.

[0020] The utilisation of this phenomenon in technical application is known neither in professional nor patent literature. No application for disintegrating rock and for the purposes of drilling in technical or geological formations is known. Patents related to the given field: US 6319434, US 5667147, US 6660223, US 2533633, US 3594142, US 4286647, US 6349548, US 5987899 are related to interaction of melt and water for production of fine granules or powders.

**[0021]** The aim of the present invention is to increase the efficiency of drilling process considerably, particularly of hard rocks, as process of synergism of thermal processes and water action.

#### Nature of technical solution

**[0022]** The aim of the present invention is utilization of thermal processes with synergism of water and with utilization of conversion of thermal energy into kinetic energy of particles of disintegrated rock in the drilling process, particularly of hard rocks, in order to increase efficiency of drilling process.

**[0023]** Nature of method of disintegrating rock by melting and by synergism of water streams according to the present invention consists in that:

- the heat or energy flow source acts on the rock at least until its local phase transition into the melt occurs,
- at least one water stream is directed into the locally created melt,
- physical explosion occurs in the melt, on which the water stream acts.

**[0024]** It is preferable if the water stream is interrupted in dependence on heat balance of heating process and in the time of realization of rock heating process by the energy flow.

**[0025]** Physical explosion, fragmentation process and conversion of heat energy into kinetic energy of fragmented particles movement occurs in the rock melt. The fragmented particles, that have been formed, create the eccentric flow of the particles, which undergo the reverse phase transition into the solid phase.

**[0026]** The eccentric flow of particles empties the action area of the heat flow, and the disintegrated rock by melting and by synergism of the water streams and prepares it for new action of the heat flow.

**[0027]** The water streams are directed into one direction or they are directed parallelly with the direction of the heat flow action or they are directed tangentially around the area of the heat flow action or they are directed eccentrically from the area of the heat flow action, so that they disintegrate the rock by synergism of the water streams and local acting of heat flow, until phase transition of it into the melt occurs.

**[0028]** Heat flow and synergism of at least one water stream acts on the rock and the melt along the abscissa (linearly).

**[0029]** The action of the water streams, which act on the created melt along one side or from all sides of the created melt, is being interrupted in dependence on heat balance of heating process causing melting of the rock.

**[0030]** By repeating of process of disintegrating the rock by melting, the sphere of action extends into the depth of the rock.

**[0031]** By repeating of process of disintegrating the

rock by melting successive on different rock area, the sphere of action extends sideways next to the original area.

**[0032]** Main advantage of solution according to the present invention is increasing the efficiency of drilling processes, particularly of hard rocks.

#### Examples of embodiment

**[0033]** Fig. 1 shows the device consisting of the heat flow source 1, which produces the thermal plasma flow 2. The plasma flow acts on the rock 3 and on its surface melts the rock into the melt 4. After some time, the water stream 6 is injected into the melt 4 by nozzle 5.

**[0034]** Fig. 2 shows a state after injecting water stream 6 into the melt 4, where the explosive stream 7 of the fragmented particles of melt is formed, and the particles convert into the solid phase again and fly away from the area of interaction of the water stream 6 and the melt 4. The stream 7 of particles of melt has kinetic energy from the heat energy supplied to the melt 4.

#### Claims

1. Method of disintegrating rock in the drilling process by melting and by synergism of water streams, comprising action of the heat flow source on the rock (3), action of the water stream source (6) on the melted rock (3), **characterized in that:**
  - the heat flow source (1) or the energy flow source acts on the rock (3) at least until its local phase transition into the melt (4) occurs,
  - at least one water stream (6) is directed into the locally created melt (4), on which it acts,
  - by action of water stream (6) on the melt (4) by physical explosion, a rock melt (4) fragmentation process is realized,
  - simultaneously with the fragmentation process, a process of conversion of heat energy into kinetic energy of fragmented particles movement occurs,
  - fragmented particles undergo the reverse phase transition into the solid phase.
2. Method of disintegrating rock according to claim 1, **characterized in that** the water stream (6) is interrupted in dependence on heat balance of heating process and in the time of realization of rock heating process by the energy flow.
3. Method of disintegrating rock according to claims 1 and 2, **characterized in that** fragmented particles create the eccentric stream (7) of the particles.
4. Method of disintegrating rock according to claims 1 to 3, **characterized in that** the eccentric stream (7)

of particles empties the heat flow area and prepares it for new action of the heat flow.

5. Method of disintegrating rock according to claims 1 to 4, **characterized in that** the water streams (6) are directed into one direction. 5
6. Method of disintegrating rock according to claims 1 to 5, **characterized in that** the water streams (6) are directed parallelly with the direction of the heat flow action. 10
7. Method of disintegrating rock according to claims 1 to 6, **characterized in that** the water streams (6) are directed tangentially around the area of the heat flow action. 15
8. Method of disintegrating rock according to claims 1 to 7, **characterized in that** the water streams (6) are directed eccentrically from the area of the heat flow action. 20
9. Method of disintegrating rock according to claims 1 to 8, **characterized in that** the heat flow acts on the rock (3) along the abscissa (linearly). 25
10. Method of disintegrating rock according to claims 1 to 9, **characterized in that** the water streams (6) act on the melt (4) along one side or from all sides inwards the created melt. 30
11. Method of disintegrating rock according to claims 1 to 10, **characterized in that** by repeating of process, the sphere of action extends into the depth of the rock (3). 35
12. Method of disintegrating rock according to claims 1 to 11, **characterized in that** by repeating of process in successive steps on different rock area, the sphere of action extends sideways next to the original area. 40

#### Patentansprüche

1. Verfahren zur Gesteinszerstörung während des Bohrvorgangs durch Schmelzen und durch Synergie von Wasserströmen, umfassend Einwirkung einer Wärmestromquelle auf das Gestein (3), Einwirkung einer Wasserstromquelle (6) auf das geschmolzene Gestein (3), **dadurch gekennzeichnet, dass:**
  - a. die Wärmestromquelle (1) oder eine Energie-stromquelle auf das Gestein (3) zumindest so-lange wirkt, bis sein lokaler Phasenübergang zu einer Schmelze (4) auftritt,
  - b. mindestens ein Wasserstrom (6) in die lokal gebildete Schmelze (4) gerichtet ist, auf die er wirkt,
2. Verfahren zur Gesteinszerstörung nach Anspruch 1, **dadurch gekennzeichnet, dass** der Wasserstrom (6) in Abhängigkeit von der Wärmebilanz des Erwärmungsprozesses und während der Realisierungszeit des Gesteinszerstörungsprozesses durch Energiefluss unterbrochen wird.
3. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 und 2, **dadurch gekennzeichnet, dass** die fragmentierten Teilchen einen exzentrischen Strom (7) von Teilchen bilden.
4. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 3, **dadurch gekennzeichnet, dass** der exzentrische Strom (7) von Teilchen den Wärmestrombereich räumt und ihn für eine neue Einwirkung des Wärmestroms vorbereitet.
5. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 4, **dadurch gekennzeichnet, dass** die Wasserströme (6) in eine Richtung gerichtet sind.
6. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 5, **dadurch gekennzeichnet, dass** die Wasserströme (6) parallel zur Wirkungsrichtung des Wärmestroms gerichtet sind.
7. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 6, **dadurch gekennzeichnet, dass** die Wasserströme (6) tangential um den Wirkungsbe-reich des Wärmestroms gerichtet sind.
8. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 7, **dadurch gekennzeichnet, dass** die Wasserströme (6) exzentrisch von dem Wirkungs-bereich des Wärmestroms gerichtet sind.
9. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 8, **dadurch gekennzeichnet, dass** der Wärmestrom auf das Gestein (3) entlang einer Ab-szisse (linear) einwirkt.
10. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 9, **dadurch gekennzeichnet, dass** die Wasserströme (6) auf die Schmelze (4) entlang einer Seite oder von allen Seiten gerichtet in die gebildete

Schmelze einwirken.

11. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 10, **dadurch gekennzeichnet, dass** der Wirkungsbereich sich durch die Prozesswiederholung in die Tiefe des Gesteines (3) erweitert.
12. Verfahren zur Gesteinszerstörung nach den Ansprüchen 1 bis 11, **dadurch gekennzeichnet, dass** durch die schrittweise Prozesswiederholung auf einem anderen Gesteinsbereich sich der Wirkungsbereich neben dem ursprünglichen Bereich seitlich erweitert.

## Revendications

1. La méthode de la désintégration de roches pendant le processus de forage par la fonte et en synergie des cours d'eau comprenant l'action de la source du flux de chaleur vers la roche (3), l'action de la source (6) du cours d'eau vers la roche (3) fondue **caractérisée en ce que**:

- la source (1) du flux de chaleur ou la source du flux d'énergie agis sur la roche (3) au moins jusqu'à sa transition de phase locale à une coulée (4),
- un cours (6) d'eau au moins est dirigé à la coulée (4) crée localement à laquelle il agit,
- par l'action du cours (6) d'eau sur la coulée (4) et par explosion physique se déroule le processus de la fragmentation de la coulée (4) de la roche,
- simultanément, avec le processus de la fragmentation, l'énergie thermique se transforme à l'énergie cinétique du mouvement des particules fragmentées,
- les particules fragmentées interviennent dans la transition de phase inverse en phase solide.

2. La méthode de la désintégration de roches selon la revendication 1 **caractérisée en ce que** le cours (6) d'eau est interrompu en fonction du bilan thermique du processus de chauffage et au cours de la réalisation du processus de chauffage de la roche par le flux d'énergie.
3. La méthode de la désintégration de roches selon les revendications 1 et 2 **caractérisée en ce que** les particules fragmentées créent un cours (7) excentrique des particules.
4. La méthode de la désintégration de roches selon les revendications 1 à 3 **caractérisée en ce que** le cours (7) excentrique vide la zone du flux thermique et la prépare pour une nouvelle action du flux thermique.

5. La méthode de la désintégration de roches selon les revendications 1 à 4 **caractérisée en ce que** les cours (6) d'eau sont dirigés en une direction.

- 5 6. La méthode de la désintégration de roches selon les revendications 1 à 5 **caractérisée en ce que** les cours (6) d'eau sont dirigés en parallèle avec la direction d'action du flux thermique.

- 10 7. La méthode de la désintégration de roches selon les revendications 1 à 6 **caractérisée en ce que** les cours (6) d'eau sont dirigés tangentielllement autour du lieu de l'action du flux thermique.

- 15 8. La méthode de la désintégration de roches selon les revendications 1 à 7 **caractérisée en ce que** les cours (6) d'eau sont dirigés de façon excentrique du lieu de l'action du flux thermique.

- 20 9. La méthode de la désintégration de roches selon les revendications 1 à 8 **caractérisée en ce que** le cour d'eau agit sur la roche (3) le long de segment de droit (linéairement).

- 25 10. La méthode de la désintégration de roches selon les revendications 1 à 9 **caractérisée en ce que** les cours (6) d'eau agissent sur la coulée (4) le long d'un côté ou bien de tous côtés vers l'intérieur de la coulée (4) crée.

- 30 11. La méthode de la désintégration de roches selon les revendications 1 à 10 **caractérisée en ce qu'en** répétant le processus, l'espace de l'action s'étend en profondeur de la roche (3).

- 35 12. La méthode de la désintégration de roches selon les revendications 1 à 11 **caractérisée en ce qu'en** répétant le processus successivement sur différente zone de la roche, l'espace de l'action s'étend latéralement à côté de la zone d'originare.

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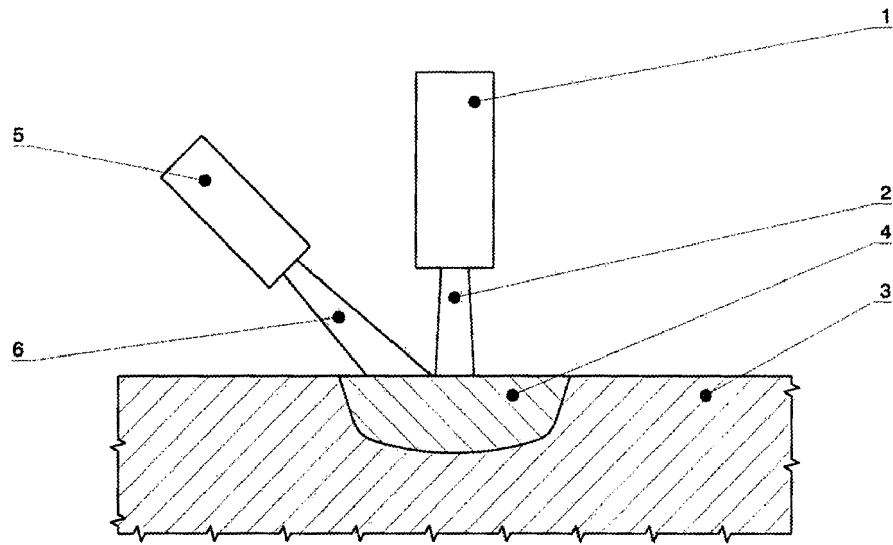


Fig. 1

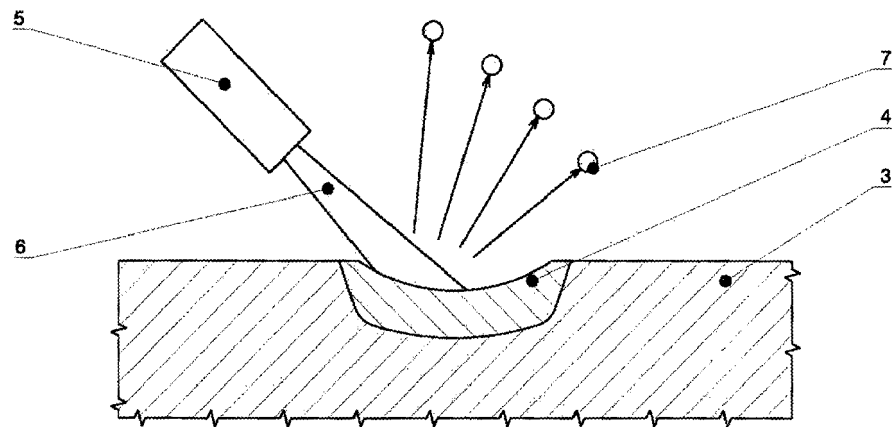


Fig. 2

## REFERENCES CITED IN THE DESCRIPTION

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