личении амплитуды геологического нарушения более 0,75 мощности угольного пласта процесс подземной газификации переходит в процесс подземного сжигания угля. Результаты исследований в полной мере позволят внести коррективы в расчет теплового баланса процесса газификации.

Научная новизна. Установлено, что с увеличением амплитуды дизъюнктивного геологического нарушения возникают дополнительные потери тепла за счет конвекционного теплообмена в месте разрыва пласта и уменьшение его выделения в связи с изменением зеркала огневого забоя по плоскости сместителя.

Практическая значимость. Полученные результаты стендовых экспериментальных исследований с достаточной для практического применения точностью могут использоваться для регулирования параметров теплового баланса и теплового режима подземного газогенератора, дают возможность расширить область применения технологии скважинной подземной газификации угля в зонах геологической нарушенности горного массива и, в перспективе, привлекать к отработке некондиционные запасы каменных углей для получению генераторного газа, химических продуктов и тепловой энергии.

Ключевые слова: *стендовые исследования, дизъюнктивные геологические нарушения, подземный газогенератор, температурный режим, сместитель*

Рекомендовано до публікації докт. техн. наук І.А.Ковалевською. Дата надходження рукопису 13.09.15.

UDC 622.236.03

A. Yu. Dreus, Cand. Sc. (Tech.), Assoc. Prof.,
K. Ye. Lysenko, Cand. Sc. (Tech.)

Oles Honchar Dnipropetrovsk National University, Dnipro, Ukraine, e-mail: dreus.a@dnu.dp.ua

COMPUTER SIMULATION OF FLUID MECHANICS AND HEAT TRANSFER PROCESSES AT THE WORKING FACE OF BOREHOLE ROCK

А. Ю. Дреус, канд. техн. наук, доц.,
К. Є. Лисенко, канд. техн. наук

Дніпропетровський національний університет ім. О. Гончара, м. Дніпро, Україна, e-mail: dreus.a@dnu.dp.ua

КОМП'ЮТЕРНЕ МОДЕЛЮВАННЯ ПРОЦЕСІВ ГІДРОДИНАМІКИ ТА ТЕПЛООБМІНУ НА ВИБОЇ СВЕРДЛОВИНИ, ЩО БУРИТЬСЯ

Purpose. The numerical study of the drill mud flow speeds field at the working face of a borehole. Substantiation of methodology to calculate the convection heat transfer rates on the surface of a diamond core bit during its cooling.

Methodology. Computational fluid dynamics methods (CFD modeling) were used in the course of the study.

Findings. The physical and mathematical models of fluid mechanics and heat transfer processes at the working face of a borehole during its boring with diamond core bits are suggested herein. The field of circulating drill mud flow speeds around the diamond core bit at the drilling of rock formation was obtained. Regarding the convective heat exchange, the computer simulation demonstrated that a notable change of flow speed field during the boring occurs throughout the height of the bit. In the course of the bit rotation the flow speed field can be considered uniform alongside the azimuthal direction. The ultimate non-uniformity of the speed field is revealed in the water hole passages of the drilling core bit, which results in its heavier wear. Based on the distribution speed calculation results, the convection heat transfer coefficients were defined throughout the height of the drilling core bit. The study revealed that, owing to significant acceleration of the flow, the most intense heat exchange processes took place in the waterhole passages.

Originality. The theory of fluid mechanics processes at the working face of a borehole during the boring was further developed. New data were obtained on the distribution of the flow speed field and pressure field in the circulating fluid at the bottom-hole area. The non-uniform nature of the fields was demonstrated herein. It is shown that, due to the locally uniform field of speeds distribution, it is possible to assume that the bit convection heat exchange ratios are constant in the certain areas.

Practical value. The outcomes of the fluid mechanics field modeling can be used for determination of the optimum sizes and shapes of the waterhole passages in the course of designing new boring tools and equipment. The obtained heat exchange ratios enable to carry out calculations of temperature fields in the crown bit body, which is necessary to establish the resource and power saving modes of drilling.

Keywords: *drilling core bit, drilling, fluid mechanics, computing modeling, heat exchange*

© Dreus A. Yu., Lysenko K. Ye., 2016

Introduction. The fluid mechanics processes at the working face in the course of the hole drilling significantly define the efficiency of the mine rock decomposition. The circulating mud flood is supplied to the hole during the drilling. It cleans the bottom-hole area from cuttings, at the same time the flood acts as a cooling agent for the drilling tools. The flow parameters (i.e. flow speed, pressure) in the course of flow-over of the bit may significantly vary alongside its surface because of the bit design particular qualities. Such particulars should be taken into account when defining the hydrodynamic forces applied to the bit in order to adjust the drilling mode parameters, as well as for enhancing the design of the bit in the course of new drilling tool designing. The speed field distribution is of special interest from the perspective of determining heat exchange conditions. This data is a precondition for the forecasting of the temperature mode of the bit operation in order to prevent its overheating and intensive wear. The relevance of the task to study fluid mechanics and heat transfer processes on the working face of borehole is conditioned, in particular, by development of new drilling techniques using pulse flushing [1].

The experimental research of the speed field distribution at the working face area is related to a number of unbiased difficulties: complexity and high cost of research in the real borehole; technical challenges while installing the measuring equipment and devices and ensuring their trouble-free operation; difficulty of ensuring the repetitiveness of experiment etc. Some bed tests and theoretical study of fluid dynamics and thermodynamics of the flow of flushing fluid are presented in work [2]. It allows obtaining only integral characteristics of the fluid mechanics processes; they fail to represent any possible local effects related to forming of dead water zones and changes of the flow speed or those of heat exchange ratios throughout the boring tool surface.

Mathematical modeling along with carrying out computational experiment seems to be the effective tool to ensure thorough research of such processes. Modern approach to modeling of fluid mechanics and heat exchange processes using the CFD (Computational Fluid Dynamics methods) modeling tools ensure the successful outcome of such research. These methods are a sound alternative to physical experiments. Thus, to reveal the physical picture at the bottom-hole area and to analyze fluid mechanics and heat exchange processes during the diamond bit drilling it is expedient to use the computing modeling methods.

Analysis of recent research and unsolved aspects of the problem. Methods of computing modeling of hydrodynamic, mechanical and temperature fields gained wide scope of application for research of fluid mechanics and heat transfer processes in the course of processing tool operations. The mathematical models describing similar tasks are based on the systems of differential equations of transfer of mass, energy, momentum, turbulence characteristics etc. As a rule, numeric implementation of mathematical models is realized using the finite element method – the most effective numeric method to calculate 3D complex geometry tasks. The detailed review of application of mathematical modeling methods to solve the tasks of metal-cutting and boring equipment heating is provided in reference article [3]. However, as it is shown in work [4], the results obtained for metal-cutting tools cannot be used for the study of mine rock boring because of a number of differences between the technological processes and physical features.

The methods of computation modeling have been effectively used as a research tool to optimize the design and drafting of PDC (Polycrystalline Diamond Compact) bits. Article [5] represents the outcomes of the modeling of fluid mechanics of drilling fluid flow in the course of flow-over of the cutting edges of the PDC bit, as well as the analysis of influence of the flow mode to the efficiency of jet flushing of the bottom-hole area. When boring with PDC bits, it is rational to apply the washing liquid to the mine rock decomposition area under pressure. Fluid mechanics processes at the bottom-hole area, various aspects of their modeling and prospects of its use for designing of full-hole non-core drilling were studied in works [6, 7]. Modeling of flow-over of a plug bit during the process of drilling with air flushing was presented in work [8]. The outcomes of the modeling allowed forecasting the influence of the tool geometry on the losses of the cleaning fluid flow.

Thus, the tasks to define the speed field at the working face of a borehole under full-hole non-core drilling were considered in the reference literature in detail. The methods of computation modeling do not only reveal their high efficiency, but also ensure the research of the instances when application of experimental methods is technically impossible. At the same time, however, very few scientific works are devoted to the tasks of fluid mechanics at the working face area under the probe boring with diamond drilling bits.

The CFD investigation of the cleaning fluid flow at the bottom-hole area in the course of boring with diamond drilling bits was represented in work [9]. The work dwells on the study of the speeds and pressure distribution fields during flow-over of the drilling tools, which enabled to assess the efficiency of various designs of the drilling bits. Both positive and negative hydrodynamic phenomena were demonstrated in the work. In particular, the possibility to increase the mine rock decomposition efficiency owing to the local manifestation of cavitation effects in the "tool–bottom-hole area" hydro-thermodynamic system during its movement along the drilling zone. On the other hand, the possibility of early wearing of the drilling bit lifetime was demonstrated in the article. However, the matter of influence of the speed field distribution on the heat exchange conditions between the drilling bit and washing fluid was not considered in the article.

Temperature, mechanical and mud speed fields in the course of boring with diamond drilling bits were subject of research in article [10]. However, a number of problems, in particular, defining the heat exchange value, remained without consideration. Moreover, the physical model proposed in the article calls for further thorough grounding.

A new set of problems related to development of pulse drilling technologies [11] requires additional research of physical processes existing at the bottom-hole area in the course of drilling. In particular, defining the distribution of the drilling fluid speed field is important for calculating the convection heat exchange process and further modeling of the temperature modes of drilling. This task can be successfully solved using the computation modeling methods.

The objective of the present study is to carry out the numerical study of the circulating flood speed field in the bottom-hole area and to substantiate the methodology for calculation of the convection heat transfer rates on the surface of a diamond crown bit during its cooling.

Presentation of the main research. Let us take a few assumptions in order to develop the mathematical model.

1. *A drilling bit* consists of the body and hard-alloyed matrix armored with diamonds or hard-alloy inserts. The matrix is divided into sectors by flushing jets, or water courses. Various bits have different numbers and sizes of water courses. Let us take a standard drilling bit 01A3 with diameter of 59 mm as a sample for modeling of fluid mechanics and heat exchange processes during the drilling. The general view of the bit is shown in Fig. 1. The 3-D model for calculating the drilling bit flow-over process at the bottom-hole area is shown in Fig. 2.

2. *Drilling process* is carried out through core drilling. The direction of circulating water flow depends on the borehole washing method. Let us assume the direct washing for our calculations. According to the scheme, the washing fluid (water) is pumped to the borehole through the column of drilling pipes. In the barrel core the water runs between its inner cavity and the core through the inner part of the drilling bit and goes into the borehole through the water courses. Let as make the following assumptions: washing liquid intake is $Q = 0.99 \cdot 10^{-3}$ m^3/sec; temperature of the liquid is 20 °C; axial weight on the drilling bit is 1.500 N; drilling tool rotation speed is 470 rpm.

3. *Physical assumptions*. It would be safe to assume that the following should be ignored: existence of sludge in the drilling mud return; loss of washing fluid due to its intake by porous structure of the mine rock; uneven nature of the borehole and core; roughness of the bottom-hole area surface. The following should be assumed: physical properties of the washing fluid and its temperature are constant values; with a course of time the flow will be stabilized; the drilling bit slightly penetrates into the mine rock; amount of fluid under the operating surface of the matrix is neglectful since the fluid moves along the water courses. The last assumption is fairly substantiated if one could take into account the relatively small clearance between the mine rock surface and matrix (ca. 0.3 mm), its significant hydraulic resistance, existence of sludge and high temperatures under the matrix bottom which provide for the fluid evaporation.

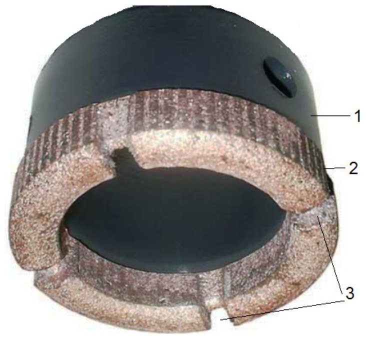


Fig. 1. General view of the diamond drilling bit:
1 – body; 2 – matrix; 3 – water course

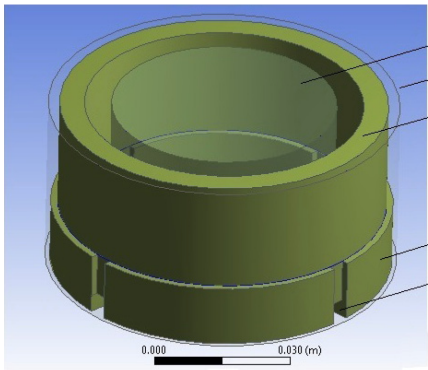


Fig. 2. 3-D model of the calculated area:
1 – core; 2 – wall of the hole; 3 – body; 4 – matrix; 5 – water course

Under the given intake of the fluid, we can assess the Reynolds number from the ratio

$$\mathrm{Re} = \frac{Q}{4 \cdot h \cdot \nu},$$

where ν is kinematic coefficient of viscosity; $h = 4$ mm is a water course height. Under the assumed water temperature we can obtain the following value Re = = 61 875 which is the evidence of the developed turbulent flow. Thus, to describe the hydrodynamic processes we shall use a standard two-parameter $k - \varepsilon$ turbulence model.

The mathematical model includes the system of differential equations of momentum transfer, continuity and transfer of the turbulence characteristics as follows

$$\frac{\partial u_j}{\partial x_j} = 0; \tag{1}$$

$$\frac{\partial u_i}{\partial \tau} + \frac{\partial}{\partial x_j}\left(u_j u_i\right) = -\frac{1}{\rho}\frac{\partial p}{\partial x_i} + \frac{\partial}{\partial x_j}\left(\left(\nu + \nu_t\right)\frac{\partial u_i}{\partial x_j}\right) + f_i; \tag{2}$$

$$\begin{gathered} \frac{\partial k}{\partial \tau} + \frac{\partial}{\partial x_j}\left(u_j k\right) = +\frac{\partial}{\partial x_j}\left(\left(\nu + \frac{\nu_t}{\sigma_k}\right)\frac{\partial u_i}{\partial x_j}\right) + \\ + \frac{\nu_t}{\rho}\left[\frac{\partial u_i}{\partial x_j} - \frac{\partial u_j}{\partial x_i}\right]\frac{\partial u_i}{\partial x_j} - \varepsilon; \end{gathered} \tag{3}$$

$$\frac{\partial \varepsilon}{\partial \tau}+\frac{\partial}{\partial x_j}\left(u_j\varepsilon\right)=+\frac{\partial}{\partial x_j}\left(\left(\nu+\frac{\nu_t}{\sigma_\varepsilon}\right)\frac{\partial \varepsilon}{\partial x_j}\right)+ +C_{1\varepsilon}\frac{\varepsilon}{k}\nu_t\left[\frac{\partial u_i}{\partial x_j}-\frac{\partial u_j}{\partial x_i}\right]\frac{\partial u_i}{\partial x_j}-C_{2\varepsilon}\frac{\varepsilon^2}{k}, \quad (4)$$

where $i = 1, 2, 3$ correspond to x, y, z — coordinates in Cartesian system; u stands for averaged components of the speed vector; f_i stands for components of mass forces (Coriolis and centrifugal); k is kinetic energy of turbulence; ε is dissipation of the turbulence energy; p is averaged pressure; ν_t is kinematic coefficient of viscosity; ρ is density; τ is time; $C_{1\varepsilon} = 1.44$, $C_{2\varepsilon} = 1.92$, $C_\mu = 0.99$, $\sigma_k = 1.0$, $\sigma_\varepsilon = 1.3$ — empirical constant of the model.

To ensure the model closure we use the expression for the turbulent viscosity

$$\nu_t = C_\mu \frac{k^2}{\varepsilon}.$$

The boundary conditions for (1–4) are as follows. In an inlet cross section we assume the consumption of the washing fluid. In an outlet cross section we assume "soft" boundary conditions. Along the entire surface of the drilling bit and contacting rock surface, we assume no-slip conditions. The wall function method is used for the turbulence characteristics.

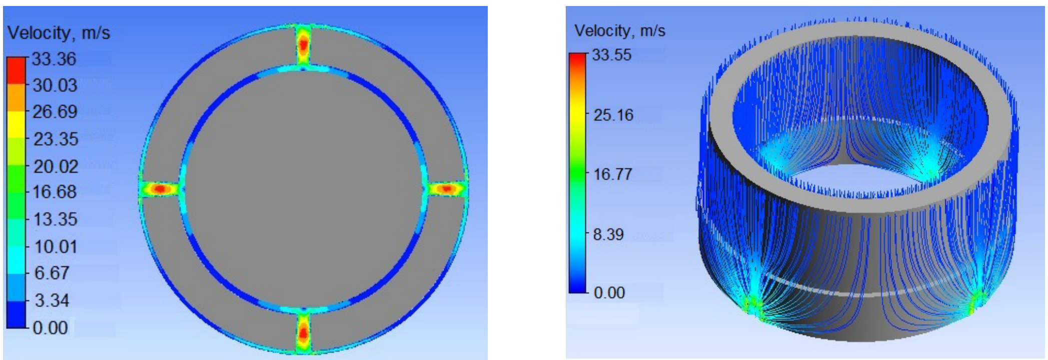
At the initial instant of time $\tau = 0^-$ the drilling bit does not move and it is washed by the flow having the initial temperature. The process of flow-over of the motionless bit at the initial moment before commencing of the drilling process is shown in Fig. 3. In Fig. 3, *a* the distribution of the speed field in the plain parallel to the bottom-hole area and within 2 mm from it, are shown.

One can see the symmetric picture of the washing fluid flow, with certain increase in the flow speed in the water courses where the speed can reach 33.3 m/sec. In Fig. 3, *b* the flow lines along the side surfaces of the drilling bit for the initial instant of time are shown. Here, the conditions of convective cooling of the drilling bit are changing both alongside the bit's height and on the azimuthal coordinate plane along the side surface of the bit.

Then at the moment $\tau = 0^+$ the drilling process is begun, and the bit rotation are started. During the drilling the bit is rotating. Thus, the flow lines have a more complex look. The findings of the calculation experiments revealed that in 3 sec after commencing of the drilling process the stationary mode of the fluid flow is established. These are confirmed by the experimental data provided in [2, 4]. As shown by the calculation outcomes defined in Fig. 4, the symmetry of flow through the water courses is violated because of the bit rotation. The maximum of the flow speed is repositioned in the water course in conformity with the rotation direction towards the receiving wall of the matrix, while on the opposite wall of the water course the dead water area with lower speed of the flow is emerging (Fig. 4, *a*). Intense mixing of the flow occurs along the side surfaces of the bit (Fig. 4, *b*). This results in leveling of the speeds field on the azimuthal coordinate along the surface. Such behavior of the flows allows assuming that only the changes of the flow speed along the bit height should be considered as significant.

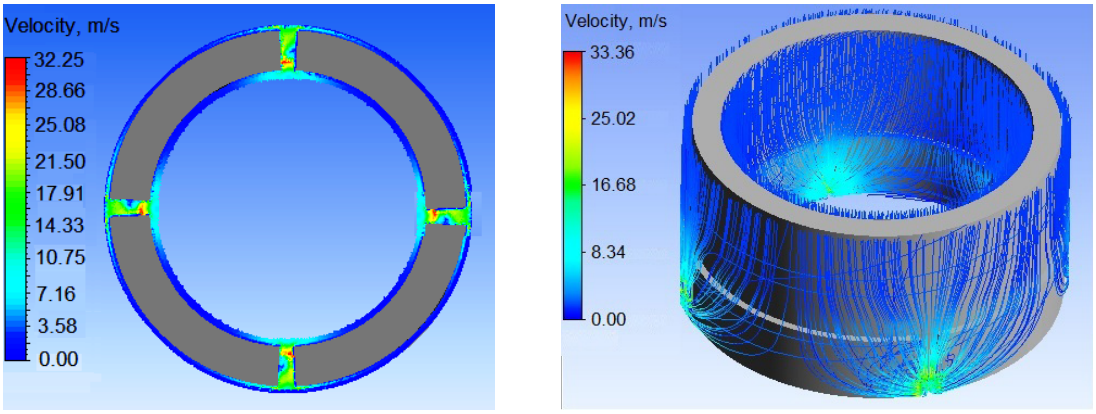
The behavior of the flow speed and excessive pressure along the flow-over in the water courses of the drilling bit is shown in Fig. 5. The flow speed during flow-over of the matrix of the drilling bit is increasing from 2 to 33 m/sec in the water courses (Fig. 5, *a*). Because of the distribution, the washing fluid flow speed fields and pressure fields are non-homogenous, thus the low pressure area is emerging, as shown in Fig. 5, *b*. Such pattern of the flow may result in local erosion of the bit due to possible emerging of cavitation in the low pressure area. Moreover, such non-homogenous nature of the flow should be considered when determining the forces of hydraulic backwater from the bit.

The obtained speed field makes it possible to determine the heat transfer coefficients along the side surface of the bit. Taking into account that the obtained behavior of the flow allows us to consider the heat exchange conditions as being significant only along the drilling bit height, we shall assume that the heat transfer coefficient will remain unchanged within the water courses, side surface of the matrix and body of the drilling bit. To establish the heat transfer coefficients we use the criterial equation for heat exchange calcula-



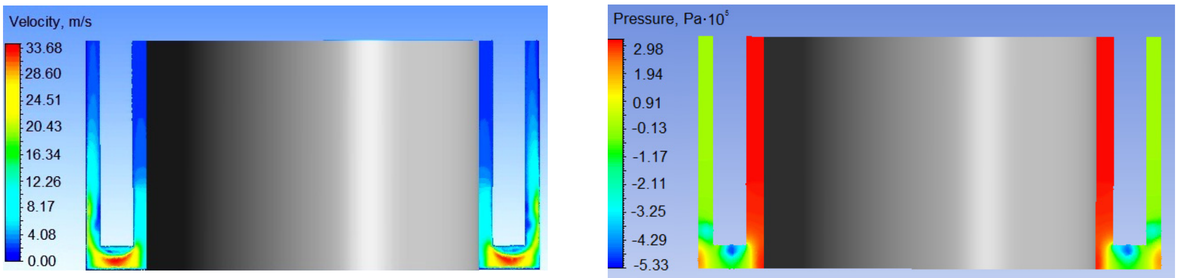
a *b*

Fig. 3. Distribution of the speed field at the moment of $\tau = 0$*:*
a — in the plane parallel to the bottom-hole area; b — during the flow-over of the bit



a *b*

Fig. 4. Distribution of the speed field at the moment of $\tau = 3$ *sec:*
a — in the plane parallel to the bottom-hole area; b — during the flow-over of the bit



a *b*

Fig. 5. Distribution of the washing fluid flow speeds (a) and pressures (b) along the drilling bit

tion during the drilling process [2].

$$\alpha = 0.021 \cdot \left(\frac{w \cdot D}{\nu}\right)^{0.8} \cdot \mathrm{Pr}^{43} \cdot \left(\frac{\mathrm{Pr}}{\mathrm{Pr}_c}\right)^{0.25} \cdot \frac{\lambda}{D},$$

where α is heat transfer coefficient; w – flow speed; D is the diameter of the drilling bit; Pr is Prandtl's number taken at the fluid temperature; Pr_c is Prandt's number taken at the drilling bit temperature; λ is washing fluid heat conduction coefficient.

Table shows the outcomes of the calculations of the averaged (regarding the bit height) heat transfer coefficients on the drilling bit surface.

Conclusions. The numeric study of fluid mechanics processes on the working face of the borehole during the process of drilling using diamond drilling bits is represented in the present work. The analysis of the modeling results revealed that in the azimuthal direction the flow speed field can be considered as homogenous owing to rotation of the drilling bit. For the first time ever the speed field of the washing fluid in the water courses was studied, and its non-homogenous nature was demonstrated herein. The ultimate non-uniformity of the speed distribution field is revealed in the water courses of the drilling bit, which may result in local effects in the form of heavier wearing of the drilling bit. The outcomes of the hydrodynamic field modeling can be used to determine the optimum dimensions of the water courses when designing new drilling bits.

The flow behavior obtained herein makes it possible to assume that, from the convection heat exchange perspective, the speed field changing is significant alongside the drilling bit height only. Therefore, when determining convective heat transfer coefficients, they can be assumed as being constant within the boundaries of the matrix, body and water courses of drilling bits. The obtained heat transfer ratios enable to carry out calculations of temperature fields of the drilling bit necessary to establish the resource and power saving modes of drilling.

Table

Estimated heat transfer coefficient

Drilling bit surface	α, Wt/($m^2 \times K$)
Body	3540
Matrix	3858
Water courses	11720

References / Список літератури

1. Kozhevnikov, A. A., Filimonenko, N. V., and Zhikaliak, N. V., 2010. *Impulsnaia promyvka skvazhin* [Pulse flushing of drilling holes]. Donetsk: "Knowledge" Publishing House.

Кожевников А. А. Импульсная промывка скважин / Кожевников А. А., Филлимоненко Н. В.,

Жикаляк Н. В. – Донецк: Изд-во „Ноулидж“ (Донецкое отд.), 2010. – 275 с.
2. Dreus, A., Kozhevnikov, A., Sudakov, A. and Lysenko, K., 2016. Investigation of heating of the drilling bits and definition of the energy efficient drilling modes. *Eastern-European Journal of Enterprise Technologies,* No. 3/7 (81), pp. 41–46.
3. Abukhshim, N.A., Mativenga, P.T. and Sheikh, M.A., 2006. Heat generation and temperature prediction in metal cutting: A review and implications for high speed machining. *International Journal of Machine Tools & Manufacture*, No. 46, pp. 782–800.
4. Kozhevnikov, A.A., Goshovskyi, S.V., Dreus, A.Yu. and Martynenko, I.I., 2008. *Teplovoi factor pri burenii skvazhin* [Heat factor in the course of well drilling]. Kiev: Ukrainian State Mining Exploration Publishing House.

Тепловой фактор при бурении скважин / Кожевников А.А., Гошовский С.В., Дреус А.Ю., Мартыненко И.И. – К.: Изд-во УкрГГРИ, 2008. – 166 с.
5. Zhao Jian, Xu Yiji, Ren Jianhua and Hou Deju, 2014. Numerical Simulation of the Bottom Hole Flow Field of Particle Impact Drilling. *Advances in Petroleum Exploration and Development*, Vol. 8 (02), pp. 18–23.
6. Yu-Ying Zhang, Yong-Wang Liu, Yi-Ji Xu and Jian-Hua Ren, 2011. Drilling characteristics of combinations of different high pressure jet nozzles. *Journal of Hydrodynamics. Ser. B.* , Vol. 23 (3), pp. 384–390.
7. Chang-Heon Song, Ki-Beom Kwon, Jin-Young Park, Joo-Young Oh, Shinok Lee, Dae-Young Shin and Jung-Woo Cho, 2014. Optimum Design of the Internal Flushing Channel of a Drill Bit using RSM and CFD Simulation. *International journal of precision engineering and manufacturing*, Vol. 15(6), pp. 1041–1050.
8. Khrutskyi, A.A., 2009. Mathematical modeling of flange bit flow-over with pressed air in the course of drilling in the environment COSMOSFloWorks. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universitetu*, No. 11, pp. 38–42.

Хруцкий А.А. Математическое моделирование процесса обтекания штыревой коронки сжатым воздухом при бурении в среде COSMOSFloWorks / А.А.Хруцкий // Науковий вісник Національного гірничого університету. – 2009. – № 11. – С. 38–42.
9. Chen Yan, Liu Zhiyi and Duan Longchen, 2012. Simulation on hydraulic performance of two kinds of coring diamond bits with different crown. *Advanced Materials Research*, Vol. 497, pp. 350–355.
10. Karakozov, A.A., Popova, M.S., Parfenyuk, S.N., Bogdanov, R.K. and Zakora, A.P., 2013. Creation of single-layered diamond drilling bits equipped with synthetic mono-crystals. *Scinetific articles of Donetsk National Technical University. Ser : Mining exploration*, No. 2, pp. 245–252.

Создание однослойных алмазных коронок, оснащённых синтетическими монокристаллами / А.А.Каракозов, М.С.Попова, С.Н.Парфенюк [и др.] // Наукові праці Донецького національного технічного університету. Серія: Гірничо-геологічна – 2013. – № 2. – С. 245–252.
11. Dreus, A.Yu., Kozhevnikov, A.A., Sudakov, A.K., Vakhalin, Yu.M., 2016. Study on thermal strength reduction of rock formation in the diamond core drilling process using pulse flushing mode. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universitetu*, No. 3, pp. 5–10.

Исследование термического разупрочнения горной породі при бурении с импульсной промывкой / А.Ю.Дреус, А.А.Кожевников, А.К.Судаков, Ю.Н.Вахалин // Науковий вісник Національного гірничого університету. – 2016. – № 3. – С. 5–10.

Мета. Чисельне дослідження поля швидкості бурового розчину у привибійній зоні свердловини та обґрунтування методики розрахунку коефіцієнтів конвективної тепловіддачі на поверхні алмазної коронки при її охолоджені.

Методика. Для дослідження використані методи комп’ютерного моделювання гідродинамічних процесів (CFD–моделювання).

Результати. Запропоновані фізична й математична моделі гідродинамічних процесів і тепловіддачі на вибої свердловини при бурінні алмазними коронками. Отримано розподіл поля швидкостей бурового розчину при обтіканні коронки під час її поглиблення. З точки зору конвективного теплообміну показано, що істотна зміна поля швидкості відбувається лише по висоті коронки. В азимутальному напрямку розподіл швидкостей потоку під час обертання коронки можна вважати однорідним. Найвища неоднорідність поля швидкостей спостерігається у промивальних каналах, що сприяє інтенсивному зносу коронки. Результати розрахунку поля швидкостей дозволили визначити коефіцієнти тепловіддачі за висотою коронки. Показано, що, за рахунок значного прискорення потоку, найінтенсивніша тепловіддача має місце у промивальних каналах.

Наукова новизна. Набула подальшого розвитку теорія гідротермодинамічних процесів у вибої при бурінні свердловин. Одержані нові дані з розподілу поля швидкостей та поля тиску в буровій рідині на вибої. Показано, що, за рахунок локально однорідного розподілу поля швидкостей, можна при розрахунку коефіцієнтів конвективної тепловіддачі коронки прийняти їх постійними в межах окремих ділянок.

Практична значимість. Результати моделювання гідродинамічних полів можуть бути використанні для визначення оптимальної геометрії промивальних каналів при проектуванні бурового інструмента. Отримані коефіцієнти тепловіддачі дозволяють проводити розрахунки температурних полів у тілі коронки, що необхідно для визначення ресурсо- та енергозберігаючих режимів буріння.

Ключові слова: *бурова коронка, буріння, гідродинаміка, комп’ютерне моделювання, тепловіддача*

Цель. Численное исследование поля скоростей бурового раствора в призабойной зоне скважины и обоснование методики расчета коэффициентов конвективной теплоотдачи на поверхности алмазной коронки при ее охлаждении.

Методика. Для исследования использованы методы компьютерного моделирования гидродинамических процессов (CFD – моделирование).

Результаты. Предложены физическая и математическая модели гидродинамических процессов и теплоотдачи на забое скважины при бурении алмазными коронками. Получено распределение поля скоростей бурового раствора при обтекании алмазной коронки в момент углубки скважины. С точки зрения конвективного теплообмена показано, что существенное изменение поля скоростей при бурении происходит по высоте коронки. В азимутальном направлении распределение скоростей потока при вращении коронки можно считать однородным. Наибольшая неоднородность поля скоростей наблюдается в промывочных каналах, что приводит к повышению износа материала коронки. Результаты расчета поля скоростей позволили определить коэффициенты конвективной теплоотдачи буровой коронки по высоте. Показано, что, за счет значительного ускорения потока, наиболее интенсивная теплоотдача имеет место в промывочных каналах.

Научная новизна. Получила дальнейшее развития теория гидротермодинамических процессов на забое в процессе бурения скважин. Получены новые данные по распределению поля скоростей и поля давлений в буровой жидкости в призабойной зоне. Показано, что, за счет локально однородного поля распределения скоростей, можно при расчете коэффициентов конвективной теплоотдачи коронки принять их постоянными по отдельным участкам.

Практическая значимость. Результаты моделирования гидродинамических полей могут быть использованы для определения оптимальной геометрии промывочных каналов при проектировании бурового инструмента. Полученные коэффициенты теплоотдачи позволяют проводить расчеты температурных полей в теле коронки, что необходимо для определения ресурсо- и энергосберегающих режимов бурения.

Ключевые слова: *буровая коронка, бурение, гидродинамика, компьютерное моделирование, теплоотдача*

Рекомендовано до публікації докт. техн. наук А. К. Судаковим. Дата надходження рукопису 11.09.15.