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SIMULATION HEATING PROCESS FOR WEAKLY REACTIVE COAL IN THE HORIZONTAL REACTOR.

In this study results of the active medium parameters influence formed by hot air on the thermal heating process of weakly reactive coal from the formation «Maikubensk 3B» for the extraction of additional heat are represented. In the course of the research the regularities of the hygroscopic moisture and volatile combustible substances release for the obtaining additional heat have been determined. Optimal temperature ranges of the stage heating taking into account thermal destruction of coal in the temperature range from 20 ℃ to 600 ℃, the main steps of the insulated heating process, the moisture content gradient propagation lines and dependence of the heat transfer and mass transfer coefficients on the temperature and the humidity during the thermal heating process in the horizontal coal heating reactor. The results show that it is possible to release volatile combustible gases with a gradual increase of temperatures in the obtained mode. The heating mode comprises a pre-

heating stage with hydroscopic moisture release, in the temperature range from 20 °C to 105 °C, the stage of isothermal heating in the temperature range from 105 °C to 400 °C and the phase of flame-free combustion in the temperature range from 400 °C to °600 C with the temperature rise above the set value. Process simulation was carried out in the Comsol Multiphisics software environment for the weakly reactive coal real-world heating conditions.

Keywords: coal heating, weakly reactive coal, isothermal heating, step-by-step heating, Lagrange method, non-liner equation, non-stationary process.

Introduction

The necessity to improve fuel combustion efficiency has been identified, first of all, by developing clean coal technologies with the possibility of obtaining additional heat while increasing fuel combustion and reducing toxic emissions. [1, p. 22]. Such conditions are set by the global trend towards zero carbon emissions and the Strategy for the development of the Republic of Kazakhstan until 2060 [2, p. 43 – 44]. The world Clean Coal Development Direction has three main pathways, such as the design and adjustment of the coal-using plants geometry, the use of coal-additives, modifiers, activators, etc., and the introduction of flexible fuel combustion technologies, including preheating. Preheating is well established in such devices as low-power long-term combustion boilers, synthesis gas generation installations, coke installations and volatile fuel gas emission devices for the replacement of high-calorific fuel oil [3, p. 3 – 5]. However, such installations mainly use prepared high calorific coking or long-flame coals and have required for the implementation of the above technologies significant thermal voltage of flue volume, according to which high temperature ranges [4, p. 48], [5, p. 12]. In conditions of the weakly reactive fuels preheating it is possible to provide the carbon recharge zones with hot CO_2 while increasing the thermal voltage of the flue volume due to the flame-free burning of the released combustible gases [6, p. 4 – 5]. In addition, preheating process do not required the preparing of the fuels, therefore it is economic process. However, the development of such technologies requires flexibility in the using of weakly reactive coals in the heating mode, active medium type, stages, taking into account the temperature impact and the emitted components from the thermal destruction during the thermal heating process [7, p. 226 – 228], [8. – p. 5 – 6].

Materials and methods

The method of reproduction and analysis of finite elements for the process of heating weakly reactive coal in the Comsol Multipfisics application software. Lagrangian variation method for non-stationary heat exchanging, where the main unknown is the displacement point of the discrete system, defined by the volume of coal contained in a rectangular container with dimensions represented in the Tabl. 1.

Table 1 – Container parameters

№	Name	Designation	Unit	Amount
1	Height of the container	L_1	[m]	1.2
2	Width of the container	L_2	[m]	0.9
3	Depth of the container	L_3	[m]	1.0
4	Container wall thickness	δ	[m]	0.05
5	Maximum filling height of coal	H_1	[m]	0.8
6	Actual filling coal height	H_2	[m]	0.7

Time dependent coefficient from partial differential equation of the Lagrange shape function in the heat transfer through the steel wall of the container and inside of coal:

$$e_a \frac{\partial^2 T}{\partial t^2} + \partial_a \frac{\partial T}{\partial t} + \nabla \cdot \left(-c\nabla T - aT + \gamma\right) + \beta \cdot \nabla T + aT = f \quad (1)$$

where:

$$\nabla = \left[\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right]$$

c – diffusion coefficient $\left[W / m \cdot C\right]$;

e_a – mass coefficient $\left[W / m^3 \cdot C\right]$;

a – absorption coefficient $\left[kg / m \cdot s \cdot C\right]$;

f – source term $(\rho \cdot g)_{coal}\left[W/m^3\right]$;

d_a – damping coefficient $(\rho \cdot c)_{coal}\left[J/m^3 \cdot C\right]$;

β – convection coefficient $\left[W/m^2 \cdot C\right]$;

γ – conservative flux source $\left[W/m^2\right]$.

Data base properties for the process represented in the Tabl. 2

Table 2 – Data base properties

№	Name	Amount
1	Coal temperature of the beginning of the process	20 [C]
2	Reactor temperature at the beginning of the process	380 [C]
3	Indoor air temperature at the beginning of the process	400 [C]
4	Density of coal	800 [kg/m^3]
5	Coal thermal capacity	1300 [J/kg C]
6	Coal thermal conductivity	0.33 [W/m C]
7	High carbon steel density	7900 [kg/m^3]
8	Steel thermal capacity	460 [J/kg C]
9	Steel thermal conductivity	0.76 [W/m C]

Zero flux in the time dependent process was defined:

$$-n \cdot \left(-c\nabla T - aT + \gamma\right) = 0 \tag{2}$$

where:

$$\nabla = \left[\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right]$$

Accordingly, flux source was defined:

$$-n \cdot \left(-c\nabla T - aT + \gamma\right) = g - qT \tag{3}$$

where: $\nabla = \left[\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z}\right]$;

g – $T - T_{air}$ – boundary flux, $\left[W/m^2\right]$;

q – boundary absorption, 0 $\left[W/m^2 \cdot C\right]$.

Results and discussions

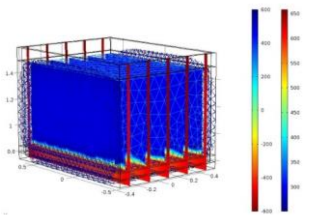
The simulation of the weakly reactive coal heating process has achieved the following objectives:

1) identification of the most optimal temperature ranges of the moisture and combustion components;

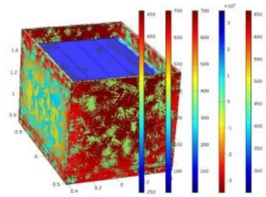
2) heat pressure and hygroscopic coal moisture relationship;

3) requirements for the thermal heating temperature ranges of the weakly reactive coal in a horizontal type reactor.

Simulation of coal heating process in air volume had performed using Comsol Multiphisics software with detection of the optimal temperature ranges of heating and provision of hydroscopic moisture release in the temperature range from 105 °C to 200 °C. Heating was carried out within 10 min at the rate of heating samples 6 °C/min. The results of the experiment which represented in Fig.1 demonstrate the heating temperature zones of weakly reactive coal in the temperature range from 100 °C to 600 °C, taking into account the vacuum layer available in the reactor near the wall [9, p. 9 –11].



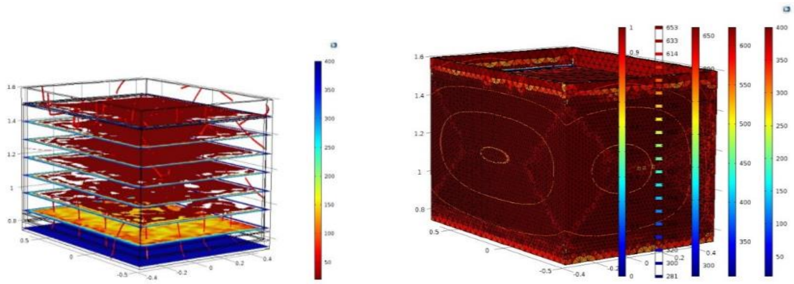
a – slice time dependent process of heating



b – arrow volume

Fig.1 – The process of non-isothermal coal heating in the horizontal reactor

Despite the presence of the vacuum layer in the volume of the bedding, the highest increase in temperature is observed with the formation of temperature ranges from 500 °C to point values of 700 °C at a predetermined heating up to 600 °C. This indicates the presence of additional heat within the coal volume. Nonthermal heating of coal in a hot air medium is the result of molecular and kinetic component of coal and hot air during heat transfer through the steel wall of the reactor, according to the resulting temperature and moisture content gradients. The results of the experiments which have represented in Fig. 2 (a, b) show that for thermal destruction, which is necessary as an initial condition for the decomposition of intramolecular bonds, the initial stage of the heat transfer agent supply to the coal heating reactor is the most effective, since the partial pressure inside the reactor is determined only by the function of the temperature of the medium: $T_m = T_{air} - T_{coal}$.



a – humidity gradient direction *b – poincare map*

Fig. 2 – Non-isothermal coal heating in the horizontal reactor

Further rise of temperature leads to the release of hygroscopic moisture and the formation of a water film on the coal surface, which reduces the heating efficiency until the end of the condensation and evaporation period. At the same time, the convection coefficient in the horizontal reactor will always be connected by thermal head $T_{air} - T_{coal}$ according to the formule of A. A. Kucharenko [9, p. 23]:

$$\beta = \frac{5170 - 20.5\left(T_{air} - T_{coal}\right)}{\sqrt[4]{H_2\left(T_{air} - T_{coal}\right)}} \quad (4)$$

Thus, the qualitative heating conditions of the weakly reactive coals in the horizontal reactors are directly dependent on the flexible step-by-step temperature mode, taking into account coal moisture content evaporation, the process of the condensation and the further destruction of the internal bonds due to thermal heating, determined by the kinetic nature, molecular bonds and thermal head between the temperature of air and coal.

The coefficients of heat transfer and mass transfer are determined by the local gradient of temperature and moisture content, in accordance with which:

$$e_a = \frac{\rho_2 \cdot \nabla W_1 - \rho_1 \nabla W_2}{\rho_1 \nabla T_2 - \rho_2 \nabla T_1} \quad (5)$$

$$c = \frac{\rho_2 \cdot \nabla T_1 - \rho_1 \nabla T_2}{(\nabla W_1 \nabla T_2 - \nabla W_2 \nabla T_1)\gamma_0} \quad (6)$$

where: $\nabla W_1; \nabla W$ – humidity gradient in the set section at a set point in time;

$\nabla T_1; \nabla T_2$ – temperature gradient at a set point in time;

γ_0 – specific gravity of moisture content.

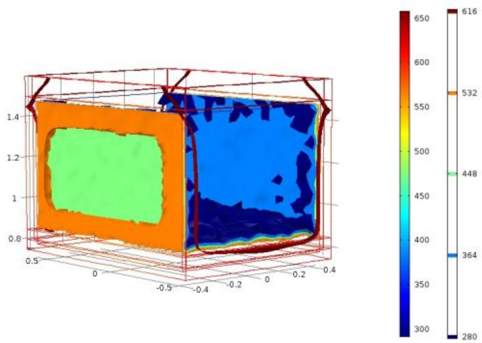


Fig. 3 – The intensive condensation process in the non-isothermal coal heating in the horizontal reactor.

Heat and mass transfer coefficients reach the peak in the initial heating period during the10 minutes as shown in the Fig. 3. Significant temperature and moisture changes in coal volume due to the development of chemical processes to release CO_2 and CH_4 intensify the destruction processes in coal, determined by the non-consensual thermal expansion of coal components [9, p. 7 – 10].

Consequently, the thermal heating process of coal in the medium formed by hot air, under conditions of the hygroscopic moisture vapours condensation contributes to:

the emergence of thermal destruction processes in the outer layers of coal due to the release of moisture expansion;

ensuring temperature drops along the cross section of the coal to be heated;

the emergence of the pressure gradient.

All the above mentioned have a significant impact on the destruction processes in the coal to be heated, which are necessary for the release of volatile combustible substances, and indicate the possibility of conducting short thermal heating modes of the weakly reactive coals.

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Conclusions

The time-dependent coal heating process in a horizontal reactor in the medium formed by hot air has determined by the air supply mode, taking into account the properties of coal and the size of the reactor, exactly height of the coal filling, which directly affect the heat and mass transfer process under conditions of mass losses at the stages release of the hygroscopic moisture , the destruction of the fragmentary composition, the weak molecular bonds with the release of volatile gases components and the decomposition of the carbon residue with the release of low molecular combustible gases. The results of the study have showed that for the brown coal from the formation «Maykubensk 3B» , warm-up in a horizontal reactor is directly determined by the level of actual coal filling in the reactor, its humidity and temperature pressure between hot air and coal. The optimum mode proposed for the heating process of sabotage coals with additional heat is determined by three general stages:

coal drying with temperature rising range from 20°C to 105°C;

time-dependent heating in the temperature range from105°C до 400°C;

Temperature rising to 600°C followed by insulated isothermal heating process.

REFERENCES

1 Ob utverzhdenii Strategii dostizheniya uglerodnoj nejtral`nosti Respubliki Kazaxstan do 2060 goda. Ukaz Prezidenta Respubliki Kazaxstan ot 2go fevralya 2023 goda № 121. [On approval of the Strategy for achieving carbon neutrality of the Republic of Kazakhstan until 2060. Presidential Decree of 2nd February 2023 Number 121]. [Electronic resource]. URL: – https://adilet.zan.kz/rus/docs/U2300000121

2 E`kologicheskij Kodeks Respubliki Kazaxstan ot 2go yanvarya 2021g. № 400–VI–ZRK. [Environmental Code of the Republic of Kazakhstan, dated January 2nd, 2021]. [Electronic resource]. URL: – https://adilet.zan.kz/rus/docs/K2100000400

3 **Mergalimova**, **A., Ongar**, **B., Georgiev**, **A., Калieva**, **К., Abitaeva**, **R., Bissenbayev, P**. Parameters of heat treatment of coal to obtain combustible volatile substances. [Text] // Energy. – 2021. – № 224 – 120088.

4 **Zhang, L, Wang, Q., Xue, Q., Zuo, H., She, X, Wang, J.** (2021). Effect of preheating on coking coal and metallurgical coke properties: A review. [Text] // Fuel Processing Technology. – 2021. – № 221 –106942.

5 **Zhang, J., Zhu, J,. Liu, J.** Experimental Studies on Preheating Combustion Characteristics of Low-Rank Coal with Different Particle Sizes and Kinetic Simulation of Nitrogen Oxide *Energies*. [Text] // Energy. – 2023. – № 16 (20) – 7078.

6 **Atyaksheva, Al., Atyaksheva, An., Ryvkina, N., Yermekov, M., Rozhkova, O., Smagulov, A.** Effectiveness analysis of Maikuben brown coal combustion in the heating boiler «Kamkor-300». [Text] // Journal of Physics: Conference Series . – 2022. – № 2211 – 012003.

7 **Ybray** , **A. Dikhanbaev** , **B. Dikhanbaev**, **A. Mergalimova** Development of a technology for the production of hydrogen-enriched synthesis gas with

waste-free processing of Ekibastuz coal. [Text] // Energy. – 2023. – № 278 (Part A) –127817

8 **Hao, L., Kaiyi, Z.** Mechanism Exploration and application on Improving Coal Permeability by Heat Treating. [Text] // IOP Conference Series: Earth and Environmental Science. – 2021. – 2021. – 062076.

9 **Mergalimova, A., Atyaksheva, A., Sultan, Y., Nursultan, S.** Identification of the low-rank coals thermal heating behavior. [Text] // Eastern-European Journal of Enterprise Technologies. – 2023. – № *2* (6 (128). – P.39–48.

10 **Novoselov, A., Seliverstova, E., Sorokin, S.** Diffusion of gases in liquids. The molecular diffusion coefficients of oxygen in water. [Text] // Scientific journal SRU ITMO. Series «Processes and devices of food productions». – 2020. – № 3. – P.21–26.

СПИСОК ИСПОЛЬЗОВАННЫХ ИСТОЧНИКОВ

1 Об утверждении Стратегии достижения углеродной нейтральности Республики Казахстан до 2060 года. Указ Президента Республики Казахстан от 2 февраля 2023 года № 121. [Электронный ресурс]. URL: – https://adilet.zan.kz/rus/docs/U2300000121

2 Экологический Кодекс Республики Казахстан, от 2 января 2021г. № 400–VI–ЗРК [Электронный ресурс]. URL: – https://adilet.zan.kz/rus/docs/K2100000400.

3 Mergalimova, **A., Ongar**, **B., Georgiev**, **A., Кalieva**, **К., Abitaeva**, **R., Bissenbayev, P**. Parameters of heat treatment of coal to obtain combustible volatile substances. [Text] // Energy. – 2021. – № 224 – ID number:120088.

4 Zhang, L, Wang, Q., Xue, Q., Zuo, H., She, X, Wang, J. Effect of preheating on coking coal and metallurgical coke properties: A review. [Text] // Fuel Processing Technology. – 2021. – № 221 – ID number: 106942.

5 **Zhang, J., Zhu, J, Liu, J.** Experimental Studies on Preheating Combustion Characteristics of Low-Rank Coal with Different Particle Sizes and Kinetic Simulation of Nitrogen Oxide *Energies.* [Text] // Energy. – 2023. – № 16 (20) – ID number: 7078.

6 **Atyaksheva, Al., Atyaksheva, An., Ryvkina, N., Yermekov, M., Rozhkova, O., Smagulov, A.** Effectiveness analysis of Maikuben brown coal

combustion in the heating boiler “Kamkor-300”. [Text] // Journal of Physics: Conference Series . – 2022. – № 2211 – ID number: 012003.

7 Ybray, **A. Dikhanbaev**, **B. Dikhanbaev**, **A. Mergalimova** Development of a technology for the production of hydrogen-enriched synthesis gas with waste-free processing of Ekibastuz coal. [Text] // Energy. – 2023. – № 278 (Part A) – ID number: 127817

8 **Hao, L., Kaiyi, Z.** Mechanism Exploration and application on Improving Coal Permeability by Heat Treating. [Text] // IOP Conference Series: Earth and Environmental Science. – 2021. – ID number: 062076.

9 **Mergalimova, A., Atyaksheva, A., Sultan, Y., Nursultan, S.** Identification of the low-rank coals thermal heating behavior. [Text] // Eastern-European Journal of Enterprise Technologies. – 2023. – № *2*(6 (128). – P. 39–48.

10 **Novoselov, A., Seliverstova, E., Sorokin, S.** Diffusion of gases in liquids. The molecular diffusion coefficients of oxygen in water. [Text] // Scientific journal SRU ITMO. Series «Processes and devices of food productions». – 2020. – № 3. – P.21–26.

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КӨЛДЕНЕН РЕАКТОРДА ӘЛСІЗ РЕАКТИВТІ КӨМІРДІ ЖЫЛЫТУ ПРОЦЕСІН МОДЕЛЬДЕУ

Бұл зерттеуде қосымша жылу алу үшін Майкөбенск ЗВ кен орнының әлсіз реактивті көмірін қыздыруға ыстық ауаның әсерінен түзілетін белсенді ортаның параметрлерінің әсер ету нәтижелері берілген. Зерттеу барысында қосымша жылу алу үшін гигроскопиялық ылгалдың және ұшатын жангыш заттардың бөліну заңдылықтары анықталды. 20°С-тан 600°С-қа дейінгі температура диапазонында көмірдің термиялық деструкциясын ескере отырып, кезең-кезеңмен қыздыру үшін оңтайлы температура диапазондары анықталды. Сондай-ақ изотермиялық қыздыру процесінің негізгі аймақтары, ылгалдылық градиентінің таралу сызықтары және көлденең реактордағы қыздыру процесінде жылу беру және масса алмасу коэффициенттерінің температура мен ылгалдылыққа тәуелділігі анықталды. Алынган нәтижелер температураның берілген бірте-бірте көтерілуімен ұщқыш жангыш газдардың шыгу мүмкіндігін көрсетеді. Қыздыру режимі гигроскопиялық ылгалдың бөлінуімен, 20 °С-тан 105 °С-қа дейінгі температура диапазонында алдын ала қыздыру кезеңін, 105 °С-тан 400 °С-қа дейінгі температура диапазонында изотермиялық қыздыру кезеңін және жалынсыз жану фазасын қамтиды. Температураның белгіленген мәннен жогары көтерілуімен 400 °С-тан 600 °С -қа дейінгі температура

диапазонында байқалды. Әлсіз реактивті көмірді нақты қыздыру жағдайлары үшін процесті модельдеу Comsol Multiphysics бағдарламасында жүзеге асырылды.

Кілтті сөздер: көмірді қыздыру, әлсіз реакциялы көмір, ұшқыш жанғыш газдар, изотермиялық сатылы қыздыру, Лагранж көбейткіш әдісі, тұрақсыз процесс, Ньютон әдісі.

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МОДЕЛИРОВАНИЕ ПРОЦЕССА НАГРЕВА СЛАБОРЕАКЦИОННОГО УГЛЯ В ГОРИЗОНТАЛЬНОМ РЕАКТОРЕ

В настоящем исследовании представлены результаты влияния параметров активной среды, образованной горячим воздухом на нагрев слабо реакционного угля месторождения «Майкубенск ЗВ» для извлечения дополнительного тепла. В ходе исследований определены закономерности выделения гигроскопической влаги и летучих горючих веществ для получение дополнительной теплоты. Выявлены оптимальные температурные диапазоны поэтапного нагрева с учетом термического разрушения угля в температурном диапазоне от 20℃ до 600℃, основные зоны процесса изотермического прогрева, линии распространения градиента влагосодержания и зависимость коэффициентов теплопереноса и массопереноса от температуры и влажности в течение процесса *нагрева в горизонтальном реакторе. Полученные результаты свидетельствуют о возможности высвобождения летучих горючих газов при заданном поэтапном повышении температур. Режим нагрева включает этап предварительного нагрева с выделением гидроскопической влаги, в диапазоне температур от 20 ℃ до 105 ℃, стадию изотермического прогрева в диапазоне температур от 105℃ до 400℃ и фазу беспламенного горения в диапазоне температур от 400 ℃ до 600 ℃ с повышением температуры выше заданного значения. Моделирование процесса проводилось в среде программного обеспечения Comsol Multiphisics для реальных условий нагрева слабореакционного угля.*

Ключевые слова: нагрев угля, слабо реакционный уголь, летучие горючие газы, изотермический поэтапный прогрев, метод множителей Лагранжа, нестационарный процесс, метод Ньютона.

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