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MODELLING TEST OF AUTOTHERMAL GASIFICATION PROCESS USING CFD

BADANIE MODELOWE AUTOTERMICZNEGO PROCESU ZGAZOWANIA Z WYKORZYSTANIEM CFD

There are many complex physical and chemical processes, which take place among the most notable are the chemical reactions, mass and energy transport, and phase transitions. The process itself takes place in a block of coal, which properties are variable and not always easy to determine in the whole volume. The complexity of the phenomena results in the need for a construction of a complex model in order to study the process on the basis of simulation.

In the present study attempts to develop a numerical model of the fixed bed coal gasification process in homogeneous solid block with a given geometry were mode. On the basis of analysis and description of the underground coal gasification simulated in the ex-situ experiment, a numerical model of the coal gasification process was developed. The model was implemented with the use of computational fluid dynamic CFD methods. Simulations were conducted using commercial numerical CFD code and the results were verified with the experimental data.

Keywords: Computational fluid dynamics (CFD), coal gasification process, numerical modelling

W trakcie zgazowania węgla zachodzi wiele złożonych procesów fizykochemicznych, spośród których do najważniejszych można zaliczyć reakcje chemiczne, transport masy i energii oraz przemiany fazowe. Sam proces przebiega w bloku węgla, której właściwości są zmienne i nie zawsze łatwe do określenia w całej objętości. Złożoność zjawisk powoduje, że badanie procesu na podstawie symulacji wymaga skonstruowania złożonego modelu.

W pracy podjęto próbę opracowania modelu numerycznego zgazowania węgla zachodzącego złożu jednorodnym o zadanej geometrii. Na podstawie dokonanych analiz oraz opisu eksperymentu zgazowania węgla przeprowadzanego w reaktorze doświadczalnym *ex-situ*, w której symulowano warunki PZW, został opracowany model zachodzących procesów. Model został zaimplementowany z wykorzystaniem

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metod numerycznej mechaniki płynów CFD (z ang. *Computational Fluid Dynamics*). Przeprowadzone zostały symulacje, a ich rezultaty zostały odniesione do rezultatów uzyskiwanych podczas eksperymentów.

Słowa kluczowe: numeryczna mechanika płynów (CFD), proces zgazowania węgla, modelowanie numeryczne

Nomenclature

a – absorption coefficient,
A – reactor working cycle coefficient,
C_μ – empirical constant, $C\mu = 0.09$,
$C_{\varepsilon 1}$ – empirical constant, $C_{\varepsilon 1} = 1.44$,
$C_{\varepsilon 2}$ – empirical constant, $C_{\varepsilon 2} = 1.92$,
$C_{\varepsilon 3}$ – empirical constant,
D – diffusion coefficient, [$m^2\ s^{-1}$],
G_k – turbulence kinetic energy due to fluid velocity gradient, [$m^2\ s^{-2}$],
G_b – turbulence kinetic energy due to fluid buoyancy force, [$m^2\ s^{-2}$],
h – enthalpy, [$J\ kg^{-1}$],
H_r – heat of reaction, [$J\ mol^{-1}$],
E – energy, [J],
k – kinetic energy fluctuations (turbulence), [$m^2\ s^{-2}$],
k_{eff} – effective thermal conductivity, [$W\ m^{-1}\ K^{-1}$],
$\dot{m}_0$ – gasification agent mass flux for $t = 0$, [$kg\ m^{-3}$],
$\dot{m}$ – local gasification agent mass flux, [$kg\ m^{-3}$],
mp – particle mass,
n – refractive index,
p – pressure, [Pa],
R_i – chemical reaction rate, [$kg\ m^{-3}\ s^{-1}$],
R – correlation coefficient,
S_h – source of the energy exchange, [$J\ m^{-3}$],
S_i – rate of creation by addition from the dispersed phase, [$kg\ m^{-3}\ s^{-1}$],
t – time, [s],
T – local temperature, [K],
$\vec{u}$ – velocity vector, [$m\ s^{-1}$],
Y_i – mass fraction of the i^{th} component of fluid, [-],

ρ – fluid density, [$kg\ m^{-3}$],
ε – kinetic energy dissipation rate of turbulence, [$m^2\ s^{-3}$],
μ_t – turbulent viscosity, [Pa s],
μ – dynamic viscosity, [Pa s],
σ – Stefan-Boltzmann constant ($\sigma = 5.669 \cdot 10\text{-}8$), [$W\ m^{-2}\ K^{-4}$],
σ_t – turbulent Prandtl number, $\sigma_t = 0.85 \div 1.3$,
σ_s – scattering coefficient,
λ – thermal conductivity, [$W\ m^{-1}\ K^{-1}$],
ω – reactor work cycle index, [s^{-1}],
$\tilde{\tau}_{eff}$ – stress tensor, [$kg\ m^{-3}\ s^{-1}$],
φ – porous change due to temperature, [-].

1. Introduction

Underground coal gasification creates many technical problems such as designing a coal gasification system in the in-situ conditions proves to be extremely difficult because only a few parameters can be controlled, unlike in the ex-situ conditions. Therefore, the process to be fully effective, should be designed in a way ensuring intended functionality and insensitivity to any changes in geological and mining conditions, which constitute a natural barrier of a reactor. One should also take into account the economic aspects of the technology in comparison to the conventional extraction methods of coal mining, including mitigation of a risk associated with human health hazards and ensuring safety and environmental protection (Tomeczek, 1991; Yang et al., 2003).

Coal gasification, as a prospective method of coal utilization becomes the subject of numerous research, both experimental and modelling. Commercialization of the technology will enable utilization of coal resources, which extraction with conventional methods are not feasible or economically justified (Białecka, 2008; Stańczyk et al., 2012; Wayne et al., 2010; Wachowicz et al., 2010).

Development of a numerical model of a reactor required realization of the following partial tasks:

- experimental tests,
- development of geometry and numerical grid of an ex-situ reactor,
- interpretation of the equations describing the process of coal gasification in an analyzed ex-situ reactor,
- verification of the results obtained from the numerical solution with experimental data.

2. Modelling the geometry of an analyzed reactor

2.1. Geometry

The experiment was conducted in a coal gasification reactor, designed and built to simulate the conditions of the underground coal gasification process. The conditions were simulated in terms of coal block and its influence on the surrounding rock mass. The reactor, designed as a cuboid of external dimensions 3.0 m × 1.4 m × 1.5 m, was filled with a layer of rocks imitating natural barrier of the reactor and the block of coal simulating the coal seam in the shape of a cuboid of dimensions of 2.5 m × 0.7 m × 0.7 m (Fig. 1) (Stańczyk et al., 2012).

A three-dimensional model of the reactor was developed taking into account the following information:

- geometry of the gasification agents supply system,
- geometry of the gasification channel,
- geometry of the block of coal.

The assumed geometry of the reactor was determined based on the following solid models (Fig. 2):

- solid model of block of the coal seam – 0.7 m × 0.7 m × 2.5 m
- solid model of the gasification channel – 0.07 m × 0.07 m × 2.5 m.

The developed numerical model of the reactor should enable to simulate the phenomena taking place in the coal seam and the technological parameters affecting the quality of the obtained reaction gas.

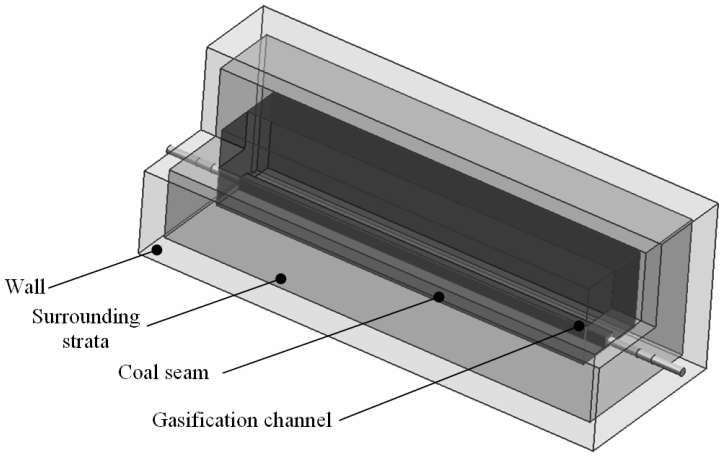

Fig. 1. Model of ex-situ reactor developed for simulation of the gasification process (Stańczyk et al., 2012)

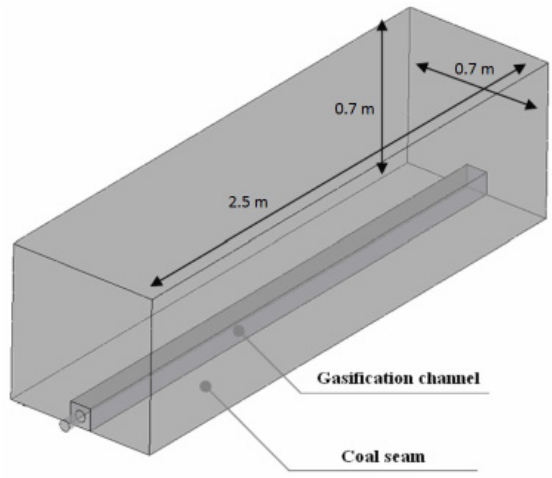

Fig. 2. Geometry of the coal seam (Stańczyk et al., 2012)

2.2. Discretization

After preparing a solid model of a reactor, the next stage was discretization of solution area. Figure 3 shows the results in the numerical grid of the area of flow in the gasification channel and results in the numerical grid of the seam coal. Two types of unstructured numerical grid were generated of:

- the gasification channel created from 9448 nodes and 17740 wireframe elements, reflecting the solid model occupied by the fluid (volume 0.012 m^3),
- coal seam created by 4234 nodes and 7680 wireframe elements, reflecting the solid model occupied by the solid body (coal block – volume 1.213 m^3).

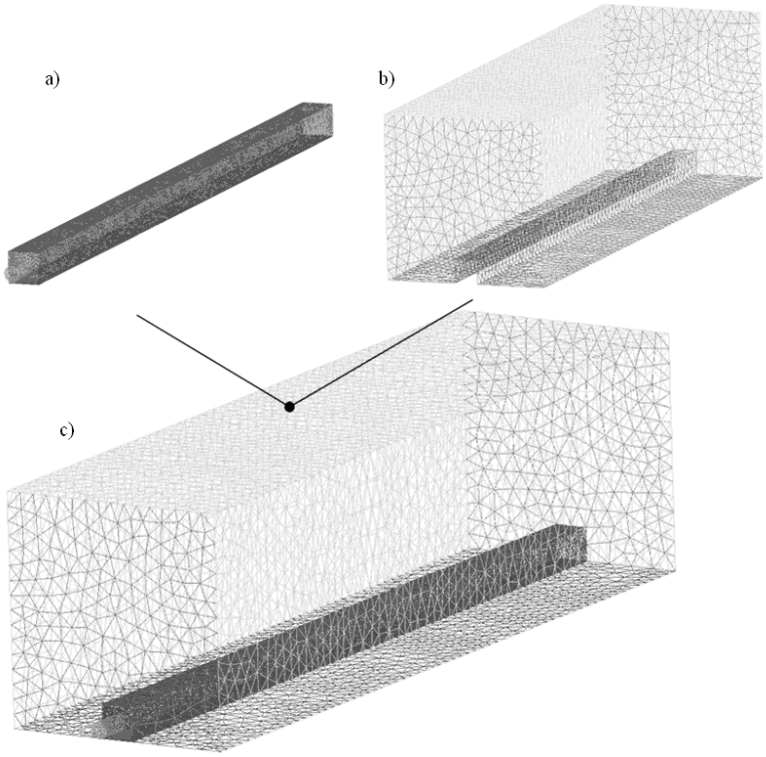

Fig. 3. Numerical model of the reactor – a) the discretization area of the fluid, b) – the discretization area of the solid body (coal seam) and c) – numerical model of the reactor

3. Numerical model of the coal gasification process

3.1. Assumptions of the CFD numerical method

Modelling of coal gasification process using the numerical fluid mechanics requires defining a flow of gasification agents as a decomposition of changes in parameters, such as the temperature, pressure and chemical composition. These parameters are determined in the reaction space of a defined geometry within a specified interval of time. Process modelling using CFD involves the solution of differential equations describing the principle of mass, momentum and energy conservation law, transport equations of fluid components with chemical reactions and equation of state (Choi et al., 2001; Janoszek et al., 2013).

Basic equations describing the behavior of the fluid flow along the gasification channel in CFD method describe the following relationships (Ajilkumar et al., 2008; Fluent, 2009; Jaworski, 2005; Silan et al., 2009):

– mass conservation equation:

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho \vec{v}) = 0 \tag{1}$$

– momentum conservation equation:

$$\frac{\partial}{\partial t}(\rho\vec{v}) + \nabla\cdot(\rho\vec{v}\vec{v}) = -\nabla p + \nabla\cdot(\tilde{\tau}) + p\vec{g} + \vec{F} \tag{2}$$

– energy conservation equation:

$$\frac{\partial}{\partial t}(\rho E) + \nabla\cdot(\vec{v}(\rho E + p)) = \nabla\cdot\left(k_{eff}\nabla T - \sum h_j\vec{J}_j + (\tilde{\tau}_{eff}\cdot\vec{v})\right) + S_h \tag{3}$$

– equation of species transport:

$$\frac{\partial}{\partial t}(\rho Y_i) + \nabla\cdot(\rho\vec{v}Y_i) = -\nabla\cdot\vec{J}_i + S_i + R_i \tag{4}$$

3.2. Turbulence modelling

For the purposes of coal gasification process modelling in the CFD system (Ansys-Fluent) associated with transport of gasification agents the most common form of the turbulence model was applied, enabling determination of viscosity by using of turbulence kinetic energy rate and rate of dissipation known as *k*-*ε* turbulence model (Fluent, 2009; Jaworski, 2005).

Viscosity turbulence model for fluid flow is expressed by the relation (Ajilkumar et al., 2008; Fluent, 2009; Jaworski, 2005; Silaen et al., 2009; Watanabe et al., 2006):

$$\mu_t = C_\mu\frac{k^2}{\varepsilon} = \frac{\mu_t}{\rho} \tag{5}$$

The most commonly used forms of transport equations for turbulence kinetic energy *k* and dissipation *ε* are expressions (Ajilkumar et al., 2008; Fluent, 2009; Jaworski, 2005; Silaen et al., 2009; Watanabe et al., 2006):

– for the turbulence kinetic energy (Fluent, 2009):

$$\frac{\partial}{\partial t}(\rho k) + \nabla(\rho k\vec{u}) = \nabla\left(\left(\mu + \frac{\mu_t}{\sigma_k}\right)\mathrm{grad}(k)\right) + G_k + G_b - \rho\varepsilon - Y_M + S_k \tag{6}$$

– for energy dissipation (Fluent, 2009):

$$\frac{\partial}{\partial t}(\rho\varepsilon) + \nabla(\rho\varepsilon\vec{u}) = \nabla\left(\left(\mu + \frac{\mu_t}{\sigma_k}\right)\mathrm{grad}(\varepsilon)\right) + C_{\varepsilon 1}\frac{\varepsilon}{k}(G_k + C_{\varepsilon 3}G_b) - C_{\varepsilon 2}\rho\frac{\varepsilon}{k} + S_\varepsilon \tag{7}$$

3.3. Modelling the gasification reaction

The reactions of gasification process (Table 1) were expressed in the form of four equations of the primary stoichiometric reactions between carbon and the gasification agent and two equations of stoichiometric reactions between the primary reaction products and the gasification agent. The chemical reactions are the result of transformation, in which the main role is played by such parameters as temperature and pressure prevalent in the fixed bed as well as mass fraction of gasification agents components (Daggupati et al., 2011; Janoszek et al., 2013).

TABLE 1

Summary of the coal gasification reactions (Białecka, 2008; Stańczyk, 2012)

Reaction type	Chemical equation	Heat of reaction ΔH_r
Primary reactions	$C_{(s)}+H_2O_{(g)} \rightarrow CO_{(g)}+H_{2(g)}$	$\Delta H_{r(T=298K)} = 131.2$ kJ mol^{-1}
	$C_{(s)}+CO_{2(g)} \rightarrow 2CO_{(g)}$	$\Delta H_{r(T=298K)} = 172.35$ kJ mol^{-1}
	$2C_{(s)}+O_{2(g)} \rightarrow 2CO_{(g)}$	$\Delta H_{r(T=298K)} = -221.15$ kJ mol^{-1}
	$C_{(s)}+2H_{2(g)} \rightarrow CH_{4(g)}$	$\Delta H_{r(T=298K)} = -74.71$ kJ mol^{-1}
Secondary reactions	$CO_{(g)}+H_2O_{(g)} \leftrightarrow H_{2(g)}+CO_{2(g)}$	$\Delta H_{r(T=298K)} = -41.15$ kJ mol^{-1}
	$CH_{4(g)}+H_2O_{(g)} \leftrightarrow 3H_{2(g)}+CO_{(g)}$	$\Delta H_{r(T=298K)} = -205.92$ kJ mol^{-1}

The volatiles and the products of char combustion (two mixture fractions) are released from solid porous zone, through the walls of gasification channel, into the stream of gasification agents (oxygen and steam) within the computational domain at a rate determined by the devolatilization. The chemical as well as devolatilization reactions were modeled based on the non-premixed combustion model (Fluent, 2009). The model of porous zone was implemented in numerical model based on the equation proposed in work (Seewald *et al.,* 1985) cited by (Białecka, 2008) in following form:

$$\varphi = 0{,}2286 + 0{,}01041T + 0{,}00001786T^2 \tag{8}$$

3.4. Modelling cycle of the reactor

The reactor was fed with the gasification agents (oxygen and steam) alternately. At the stage of gasification with oxygen, the oxygen supply was gradually increased from 1 [kg h^{-1}] to 7 [kg h^{-1}], usually in half-hourly intervals. The average cycle of the oxygen gasification was determined as the intervals of 2 hours. The steam gasification phase was determined in the cycles of 1 and 1.5 hours. The steam mass flow to the reaction zone was about 5 [kg h^{-1}]. Figure 5 presented the characteristics of the reactor in the conditions of the ongoing process of coal gasification process during 170 hours (Stańczyk et al., 2012).

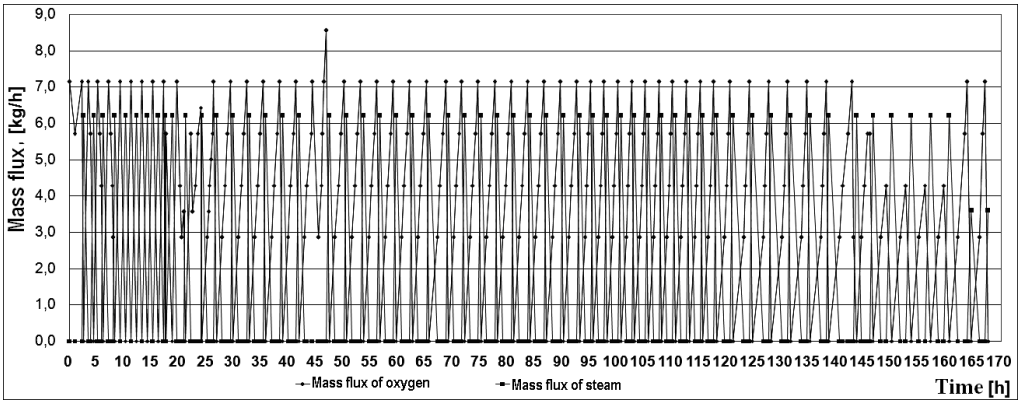

Fig. 5. The characteristics of the experimental reactor in the conditions of the ongoing process of the coal gasification process in 170 hours

Since the value of mass flux of the given gasification agent is transient, it was necessary to develop an appropriate mathematical model, reflecting the characteristics of reactor operation. An equivalent mathematical form, which approximates the conditions at the inlet to the reactor is the relationship:

$$\frac{\partial m}{\partial t} = m_0 + A\sin(\omega t) \tag{9}$$

Figure 6 shows the results of the mathematical model (9) for the following values:
- value of the mass transfer in $t = 0$ $\dot{m}_0 = 5$ [kg h^{-1}],
- work cycle amplitude of the reactor A = 5.0,
- work cycle of the reactor $\omega = 4.0$ [s^{-1}].

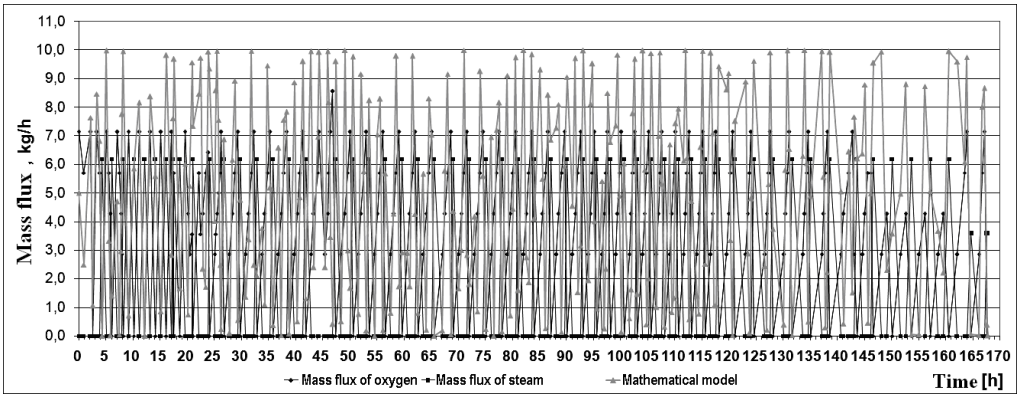

Fig. 6. Cycle characteristics of the reactor obtained from the experimental data and from the model

Equation (10) was implemented to the CFD system in the form of an external source code in C programming language in the CFD system (UDF-Fluent).

3.5. Defining the boundary conditions of the numerical model of the reactor

The numerical model of the reactor included models of fluid flow (gasification channel) and porous medium (coal seam) (Fig. 3), for which calculation were performed. The measurement system of process gas composition was located at the reactor outlet, as schematically shown in Fig. 7.

The following boundary conditions of the analyzed solution were examined, namely:

1. numerical model of fluid flow (gasification channel):
   - temperature and mass flux O_2 (Stańczyk et al., 2012) – 25 [°C] and from the expression (9) ,
   - specific heat of oxygen O_2 c_{pO_2} (Fluent, 2009) – $c_{pO_2} = 834.826 + 0.292 \cdot T - 0.0001495 \cdot T^2 + 3.41\text{e}^{-07} \cdot T^3 - 2.27\text{e}^{-10} \cdot T^4$ [J kg^{-1} K^{-1}],
   - temperature and mass flux H_2O – 100 [°C] and from the expression (9),
   - specific heat of steam H_2O c_{pH_2O} (Fluent, 2009) – $c_{pH_2O} = 1563.08 + 1.60 \cdot T - 0.002932794 \cdot T^2 + 3.21\text{e}^{-06} \cdot T^3 - 1.15\text{e}^{-09} \cdot T^4$ [J kg^{-1} K^{-1}],

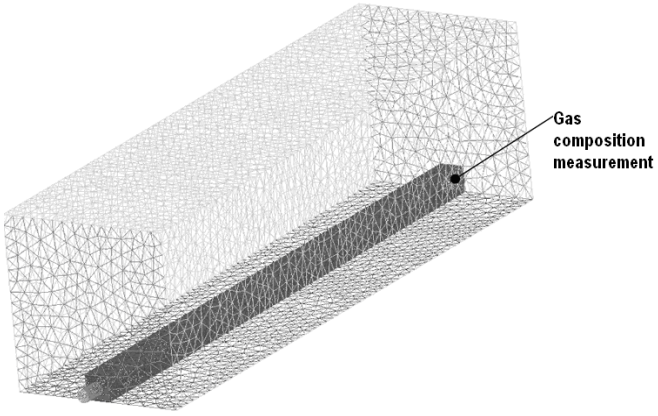

Fig. 7. The measurement system of process gas composition in the CFD system

- thermal conductivity of the mixture $O_2 - H_2O$ – 0.0454 [$Wm^{-1}K^{-1}$] (Fluent, 2009),
- coefficient of dynamic viscosity of the mixture $O_2 - H_2O$ (Fluent, 2009) – 1.72e^{-05} [kg m^{-1} s^{-1}].

2. numerical model of porous medium (coal seam):
   - gasification rate – 4 [kg h^{-1}],
   - density – 2700 [kg m^{-3}] (Białecka, 2008),
   - porosity – 5 [%] (Białecka, 2008),
   - permeability β – 1e^{-15} [m^2] (Białecka, 2008),
   - specific heat c_{pC} (Fluent, 2009) – $c_{pC} = -464.18 + 4.97 \cdot T - 0.003899261 \cdot T^2 + 1.482e^{-06} \cdot T^3 - 2.885e^{-10} \cdot T^4$ [J kg^{-1} K^{-1}],
   - temperature T – 298.15 [K],
   - thermal conductivity coefficient (Fluent, 2009) – 1.75 [W m^{-1} K^{-1}],
   - ultimate/proximate analysis of coal sample is presented in Table 2.

TABLE 2

Ultimate/proximate analysis of coal sample (Stańczyk et al., 2012)

Proximate Analysis	Fixed carbon	63.91%
	Volatile matter	32.41%
	Ash	2.21%
	Moisture	1.47%
Ultimate Analysis	Carbon (C)	83.84%
	Hydrogen (H)	4.94%
	Oxygen (O)	9.79%
	Nitrogen (N)	1.15%
	Sulfur (S)	0.28%
Heat of combustion	34.572 [kJ kg^{-1}]	

The following system settings in the CFD program were examined:
- unsteady state,
- gasification pressure – 101325 [Pa],

– turbulence model – k-ε,
– discrete-ordinates (DO) radiation model (MacPhee et al., 2009),
– ratio of oxygen to steam O_2/H_2O – 1:1.1.
– gasification run time – 612000s (170 hours) ,
– roughness of walls of the gasification channel – 0.1 [m],
– convergence of numerical calculations – $1 \cdot 10^{-4}$.

4. Analysis of test results

4.1. Development of the tests results

The changes of values in volume fraction of CH_4, CO_2, CO and H_2 obtained based on the experimental data and from the numerical model are presented in Figure 8-15.

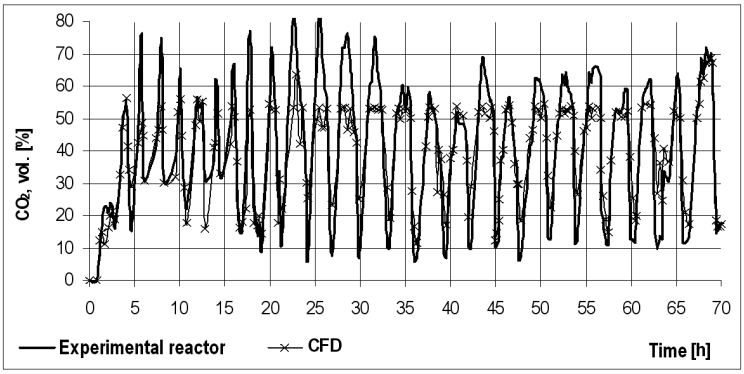

Fig. 8. Volume fraction changes of carbon dioxide CO_2 in the synthesis gas in the interval from 0 to 70 hours, based on the values measured in the reactor and from the model

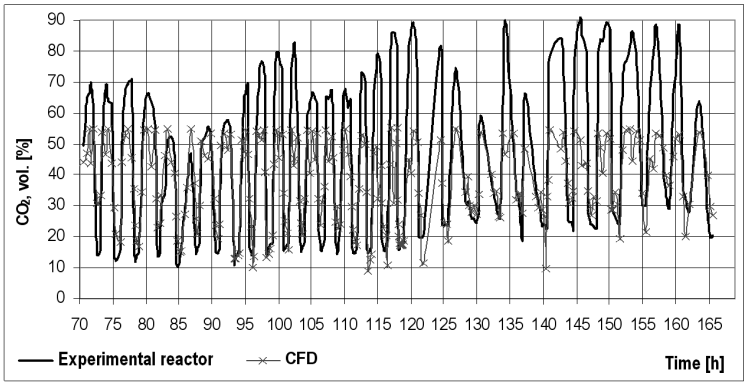

Fig. 9. Volume fraction changes of carbon dioxide CO_2 in the synthesis gas in the interval from 70 to 170 hours, based on the values measured in the reactor and from the model

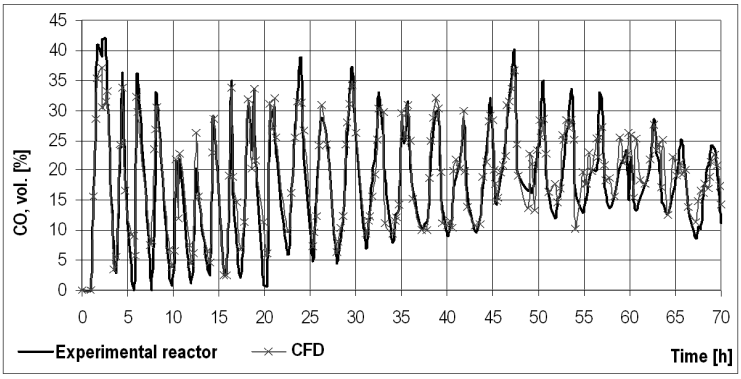

Fig. 10. Volume fraction changes of carbon monoxide CO in the synthesis gas in the interval from 0 to 70 hours, based on the values measured in the reactor and from the model

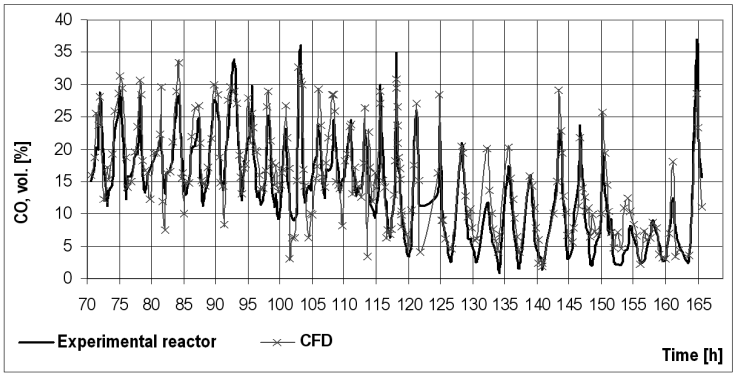

Fig. 11. Volume fraction changes of carbon monoxide CO in the synthesis gas in the interval from 70 to 170 hours, based on the values measured in the reactor and from the model

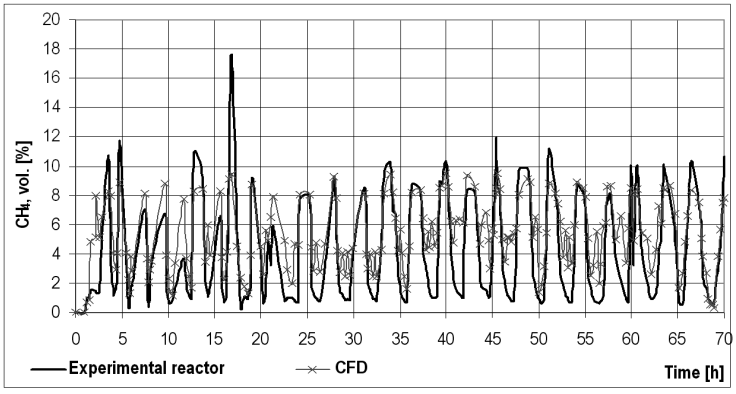

Fig. 12. Volume fraction changes of methane CH_4 in the synthesis gas in the interval from 0 to 70 hours, based on the values measured in the reactor and from the model

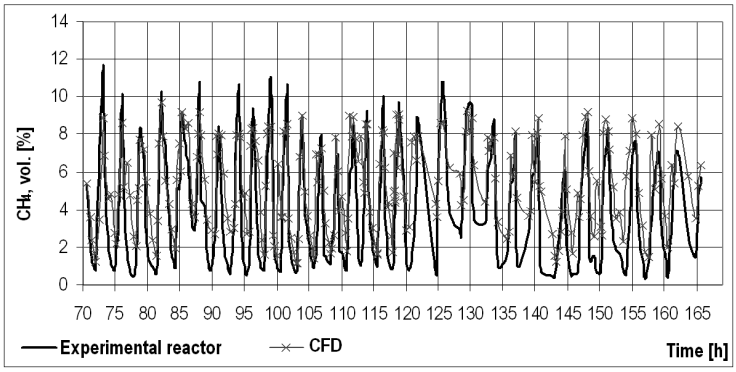

Fig. 13. Volume fraction changes of methane CH_4 in the synthesis gas in the interval from 70 to 170 hours, based on the values measured in the reactor and from the model

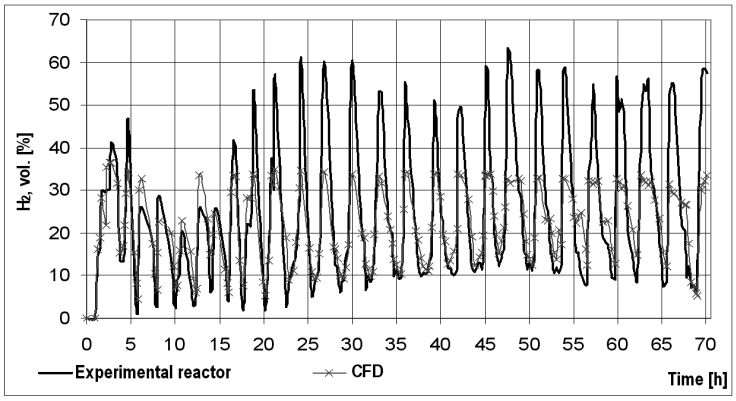

Fig. 14. Volume fraction changes of hydrogen H_2 in the synthesis gas in the interval from 0 to 70 hours, based on the values measured in the reactor and from the model

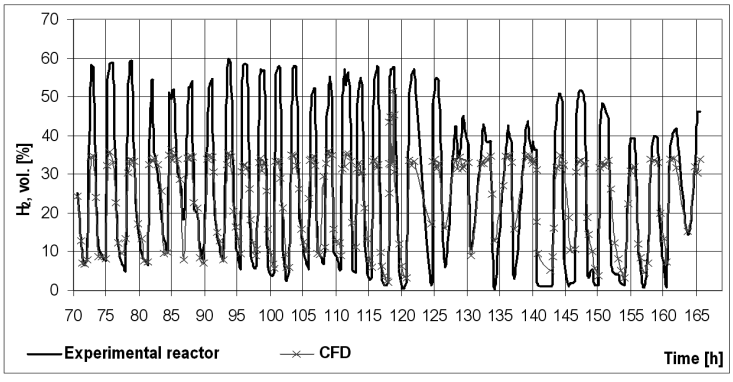

Fig. 15. Volume fraction changes of hydrogen H_2 in the synthesis gas in the interval from 70 to 170 hours, based on the values measured in the reactor and from the model

The components of the process gas obtained from measuring at the outlet of the reactor in the real conditions of the coal gasification process were shown in form of bold line colored in black. The average concentration of syngas components obtained from measuring were following:

- concentration of CO_2 in an amount of 42.01% in the time interval 70 hours and 42.67% in the time interval from 70 to 165 hours.
- concentration of CO in an amount of 19.06% in the time interval 70 hours and 14.47% in the time interval from 70 to 165 hours.
- concentration of CH_4 in an amount of 3.81% in the time interval 70 hours and 4.13% in the time interval from 70 to 165 hours.
- concentration of H_2 in an amount of 23.69 % in the time interval 70 hours and 30.71% in the time interval from 70 to 165 hours.

As a result of numerical analysis, using CFD method, were achieved the following average concentration of searched syngas components:

- concentration of CO_2 in an amount of 40.43% in the time period to 70 hours and 36.56% in the time interval from 70 to 165 hours.
- concentration of CO in an amount of 19.81%in the time interval 70 hours and 15.69% in the time interval from 70 to 165 hours.
- concentration of CH_4 in an amount of 5.22% in the time interval 70 hours and 5.33% in the time interval from 70 to 165 hours.
- concentration of H_2 in an amount of 21.38% in the time interval 70 hours and 24.41% in the time interval from 70 to 165 hours.

The comparison of results obtained from the solution of numerical model CFD and from the measurement in the real conditions of gasification process were shown in Table 3.

TABLE 3

Summary of results obtained from numerical model CFD with the results of measurements on the real object

Syngas component	**Experiment, [%]**	**CFD, [%]**
CO_2	42,34	38,49
CO	16,77	17,75
H_2	27,20	22,89
CH_4	3,97	5,28

Qualitative analysis of changes of process gas components along the gasification channel were shown in Fig. 16. Based on the qualitative analysis we can observed that the components of the syngas, such as CO_2, CO and H_2, are formed in the initial length of the gasification channel determined by the combustion reactions, and the component such as CH_4 is formed near to the outlet of the reactor, which are the result of the reactions between products of the primary reactions and the gasification agent components.

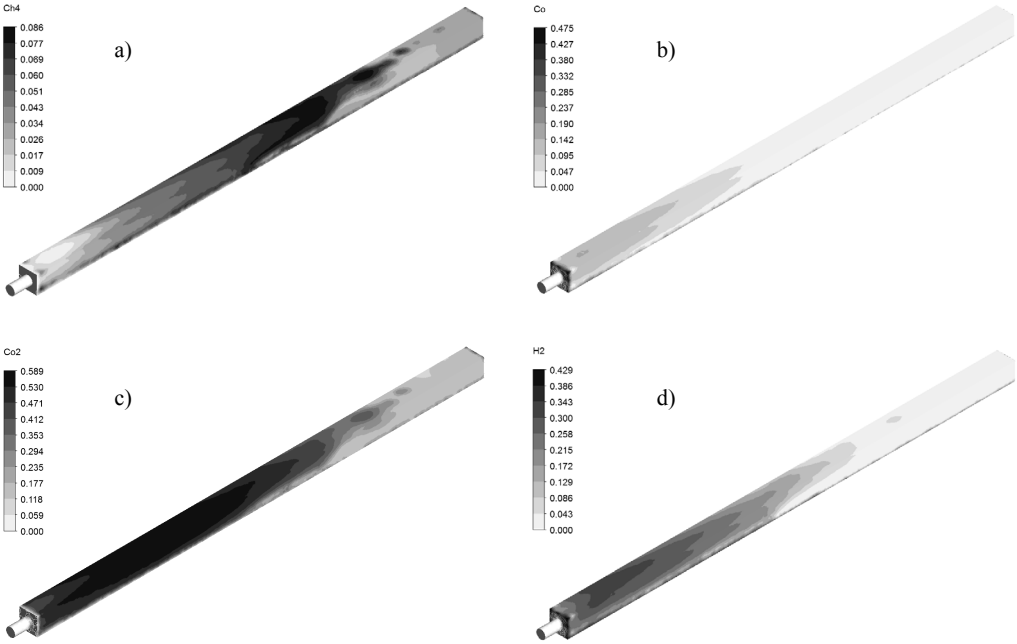

Fig. 16. Qualitative analysis of mass fraction changes of process gas components: a – CH_4, b – CO, c – CO_2, d – H_2

4.2. The adequacy of CFD numerical model of coal gasification process

The existence of a correlation between the values measured in the ex-situ reactor and the parameters of the numerical model was adopted as a criterion of adequacy of a numerical model used for prediction of the coal gasification process. Table 4 shows the results of the linear correlation between the examined parameters in the 170 hours period.

TABLE 4

The estimation of value of linear correlation R between the data obtained from the CFD model and from the measurements in the time interval of 170 hours

Values of linear correlation R			
CO_2	H_2	CH_4	CO
0.84	0.89	0.82	0.91

Figure 17 shows the effects of correlation values obtained based on the empirical data and the numerical data.

The results indicate to existence of significant correlation between the examined variables, which proves the correctness of the assumptions used to construct a numerical model of coal gasification process in CFD program. The investigated variables were examined in a computer program STATISTICA.

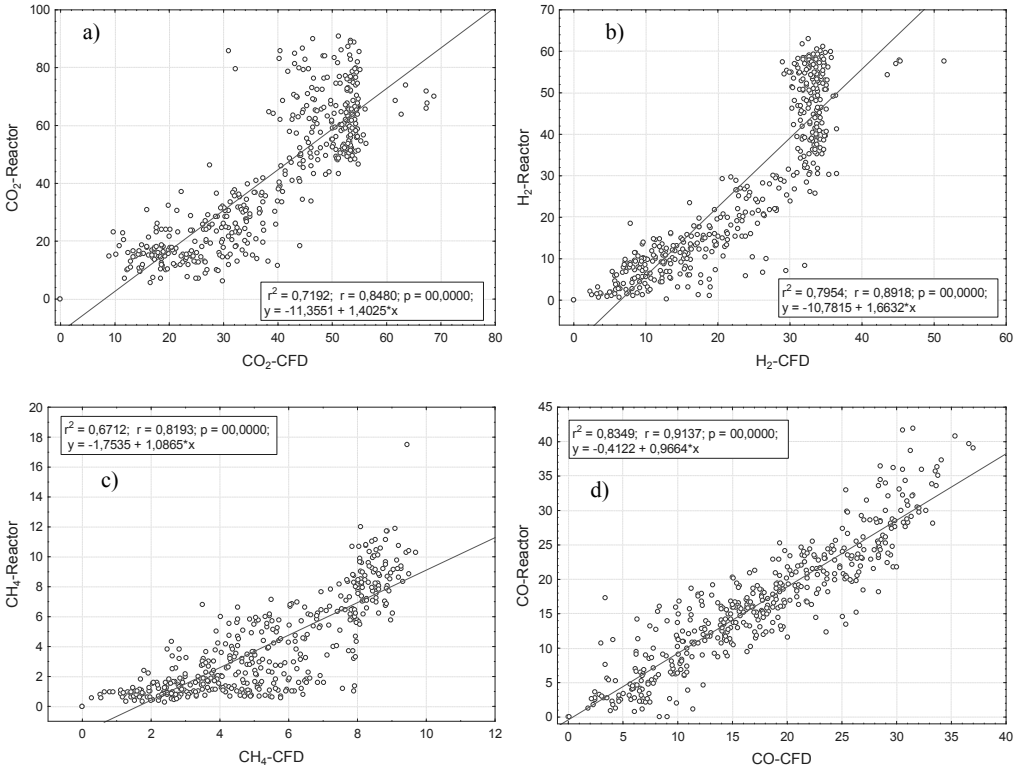

Fig. 17. Charts of linear correlation obtained based on the empirical data and the numerical model

5. Summary and conclusions

A numerical model based on the theory of computational fluid dynamics CFD, was implemented in the study to calculate the composition of the mixture formed in the process of coal gasification with oxygen and steam. The numerical method of fluid mechanics CFD-Ansys-Fluent was selected to analyze the technology parameters of coal gasification process. The use of numerical methods for fluid dynamics CFD made it possible to present the process of coal gasification in qualitative and quantitative forms. The distribution of the changes of the process gas components is comparable to the results observed in the real object. On the basis of the obtained correlation coefficients, the correctness of the developed numerical model in respect to experimental data can be determined.

The presented results and developed model of coal gasification process based on computational fluid dynamics CFD, allow to formulate the following conclusions:

- Method based on numerical fluid dynamics has proven to be a useful tool for creating models of coal gasification process occurring in a homogeneous block of coal of given geometry,
- Demonstration of a significant correlation between the variables obtained from the CFD analysis of the 3D model system, and the experimental results obtained in a reactor sys-

tem, confirm the appropriateness of the assumptions made in the numerical model of the reactor, based on the CFD method.
- Determination of the numerical model output variables allow for a simple and easy interpretation of the phenomenological phenomena during the gasification process,
- Knowledge of the coal gasification process and the parameters of the numerical model, influencing the phenomena, provide the possibility of modelling of the underground coal gasification.

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