USE LIGNITE IN GASIFICATION – REVIEW OF POLISH-JAPAN PROJECT „UCESP”

INSTITUTE FOR CHEMICAL PROCESSING OF COAL

Since 1955

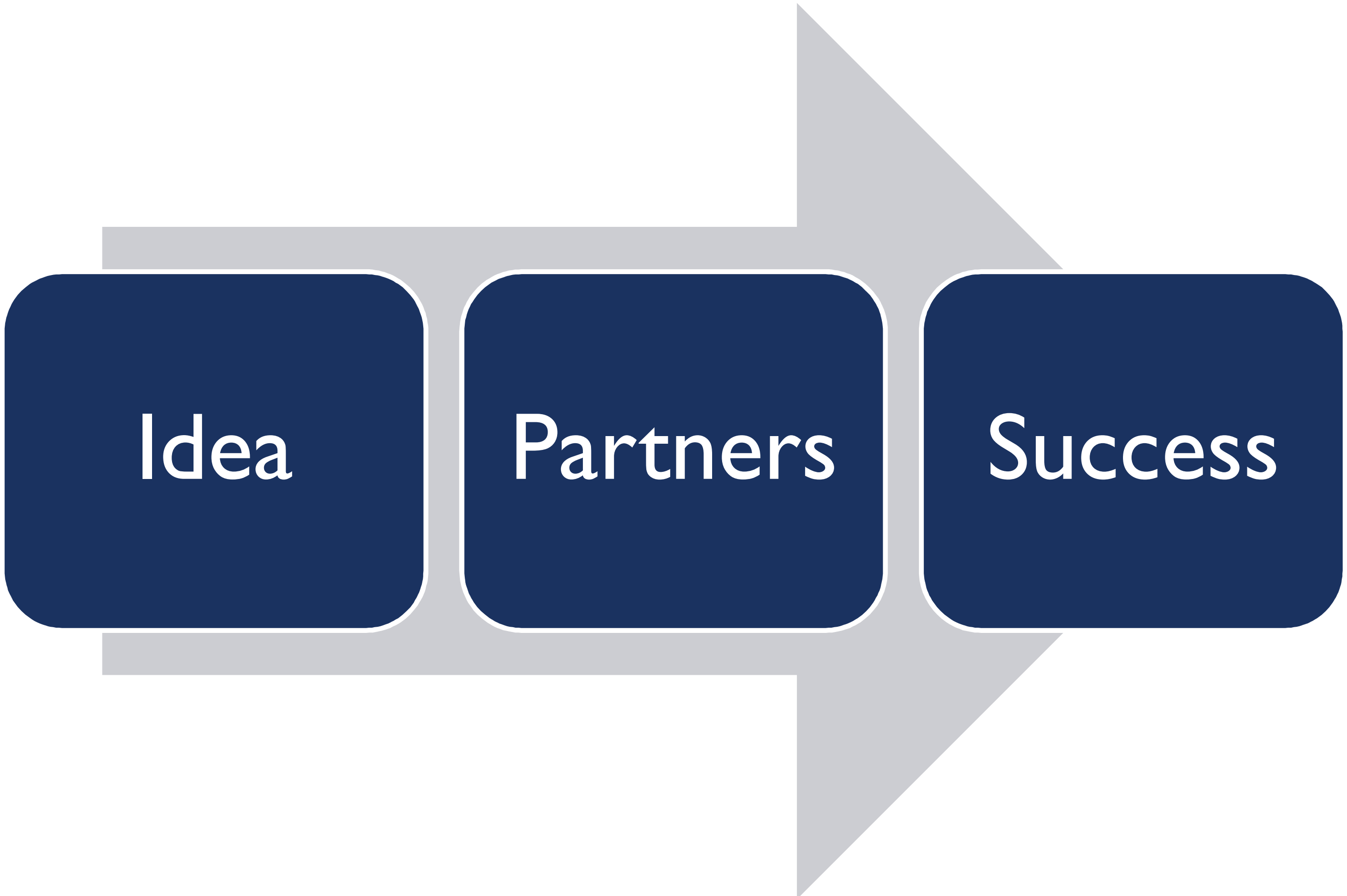
Workshop

DRYLIG project Final Workshop: Competitive pre-drying technologies and firing concepts for flexible and efficient lignite utilization

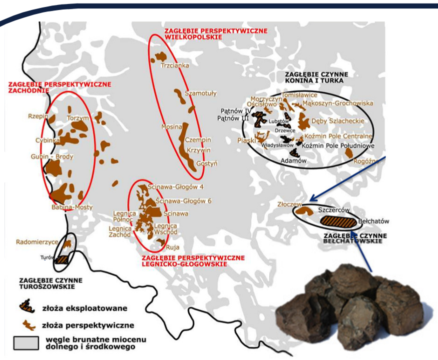
Thursday, 8th June 2017

Wrocław University of Technology

PROJECT



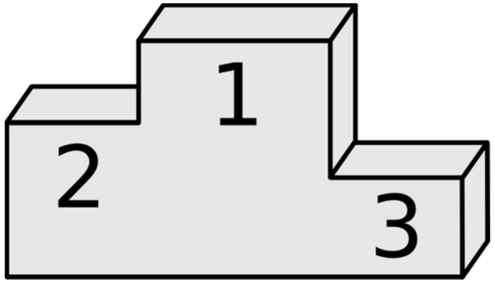
HOW WE GOT THERE



PGE Górnictwo i Energetyka Konwencjonalna S.A.

IChPW

IHI
Realize your dreams



Polish – Japanese bilateral cooperation – call No. 1 (2014)

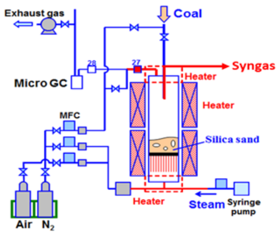
Narodowe Centrum Badań i Rozwoju

JCOAL Japan Coal Energy Center

SO-FAR PROJECT SCOPE

PGE GiEK SA

IChPW



IHI

Coal properties (detailed)

Kinetic data

Matrix of coal properties

Lab scale gasification

Prospective resources

Coal properties (selected parameters)

Kinetic data

Matrix of coal properties

„Gasification behavior”

LIGNITES` PROPERTIES

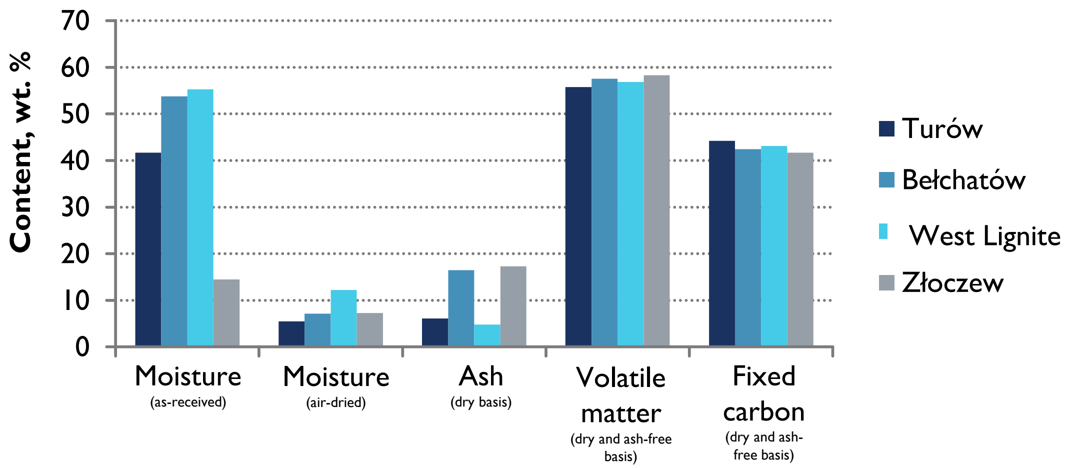
Lignite samples from currently exploited deposits:

- Bełchatów,
- Turów.

Lignite samples from perspective deposits:

- Złoczew,
- West Lignite.

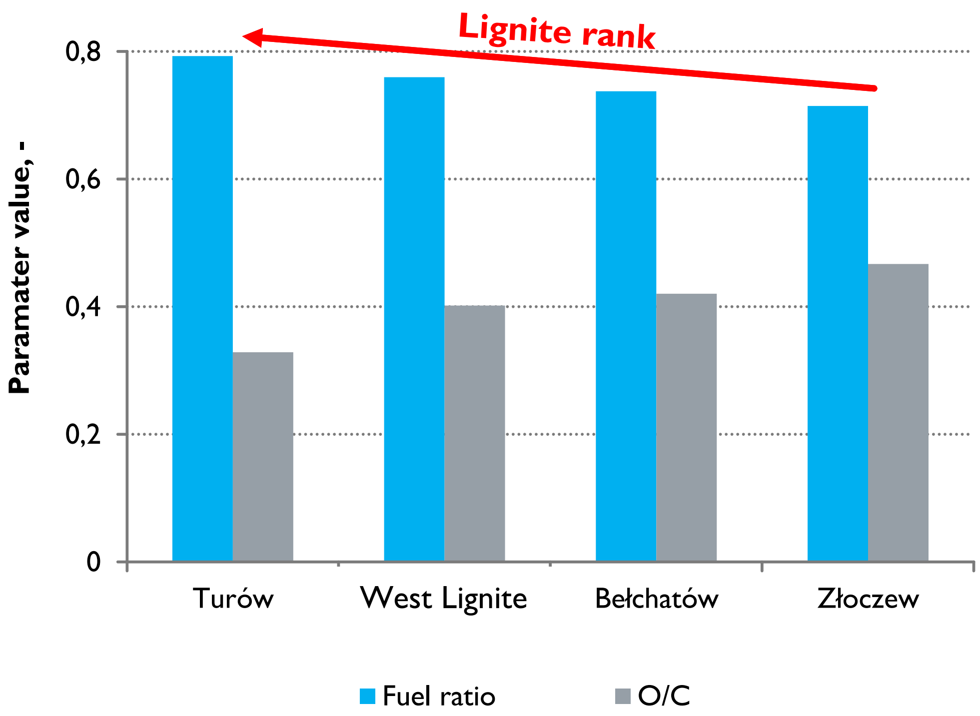
Proximate analysis



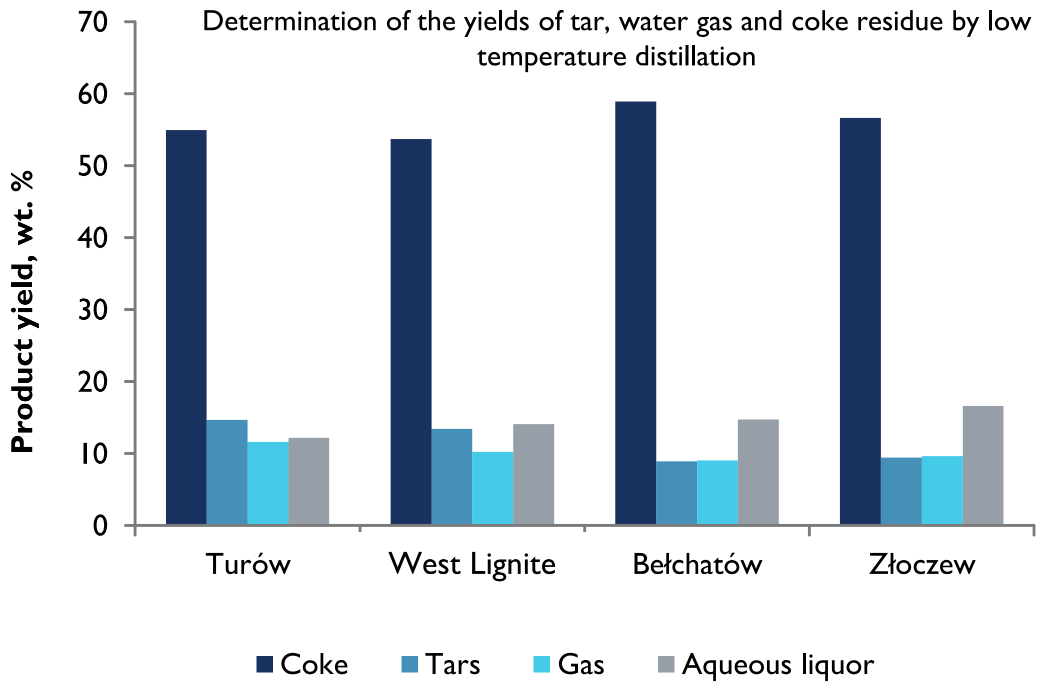
Ultimate analysis

Sample	Carbon	Hydrogen	Nitrogen	Total sulfur	Organic sulfur	Ash sulfur	Pyrite sulfur	Oxygen (by difference)
Turów	**62.6**	4.85	0.61	0.30	0.07	0.12	0.02	20.57
Bełchatów	51.4	4.06	0.53	**2.83**	0.01	1.40	0.43	21.60
West Lignite	56.7	3.35	0.69	0.37	0.07	0.30	0.02	22.79
Złoczew	**49.0**	3.76	0.71	**1.14**	0.36	0.78	0.11	22.87

LIGNITES` PROPERTIES



Low-temperature carbonization (Fischer assay at 500°C)



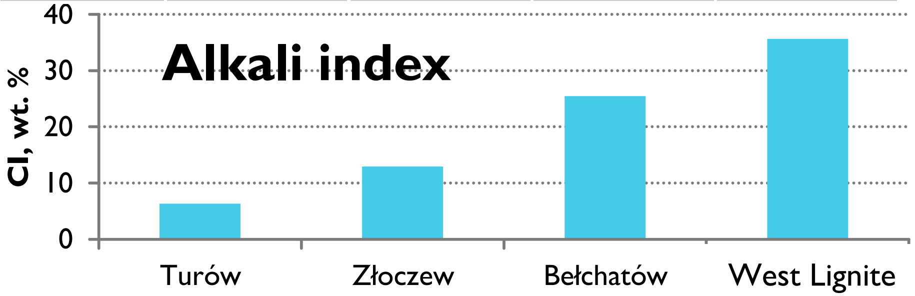
The samples demonstate noticeable differences in their rank expressed by the Fuel ratio and O/C atomic ratio.

LIGNITES` PROPERTIES

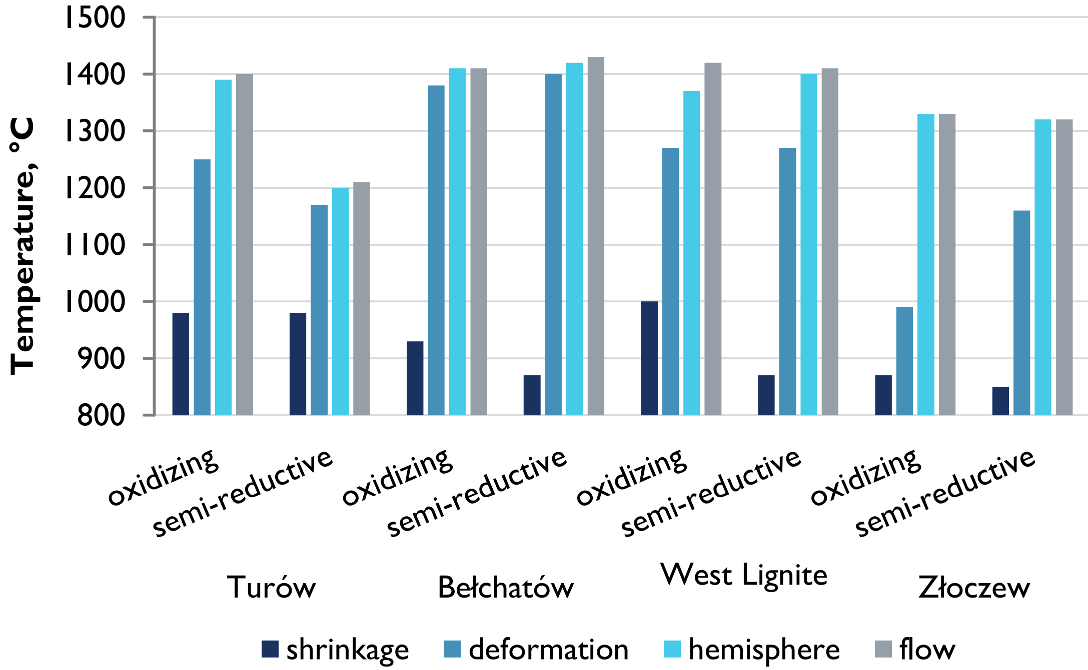
Chemical composition of ash (by ICP-OES)

Comp.	Turów	Bełchatów	West Lignite	Złoczew
SiO_2	27.12	17.96	**10.45**	**28.47**
Al_2O_3	26.19	18.92	**3.57**	**29.84**
Fe_2O_3	5.19	8.24	**13.64**	**4.44**
CaO	**7.93**	24.29	**38.31**	20.44
MgO	7.10	1.20	**9.96**	**0.83**
P_2O_5	1.06	0.21	0.05	0.4
SO_3	5.85	22.34	18.37	11.83
Mn_3O_4	0.02	0.05	0.26	0.03
TiO_2	2.88	0.65	0.3	0.6
BaO	0.22	0.04	0.03	0.03
SrO	0.08	0.04	0.72	0.05
Na_2O	**8.14**	**0.09**	0.37	0.17
K_2O	**0.96**	**0.14**	0.16	0.19

Alkali index



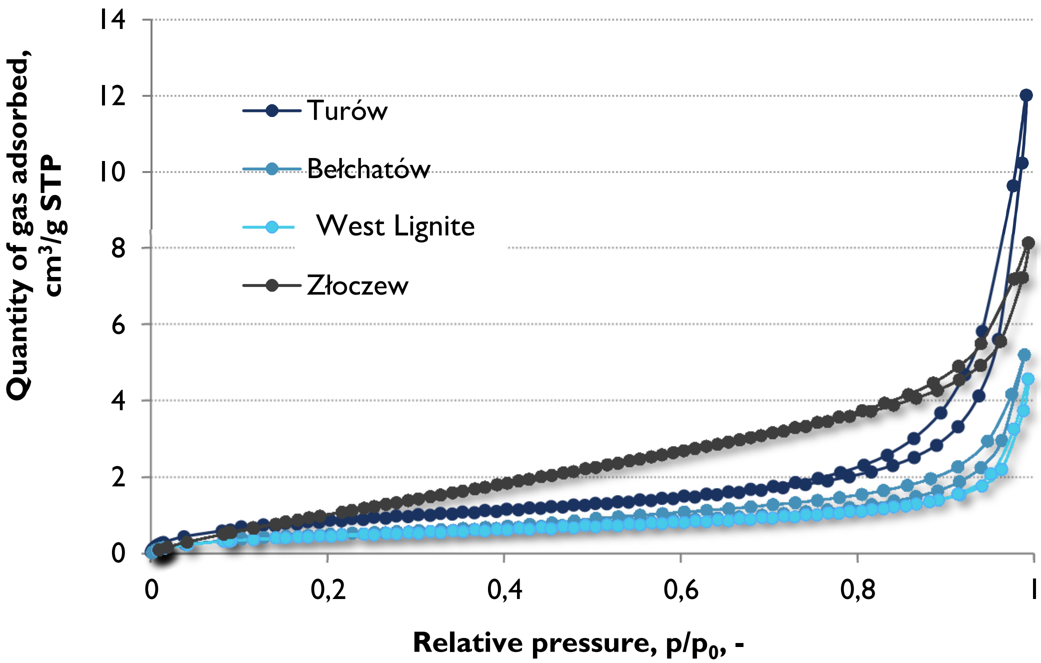
Ash fusion behavior

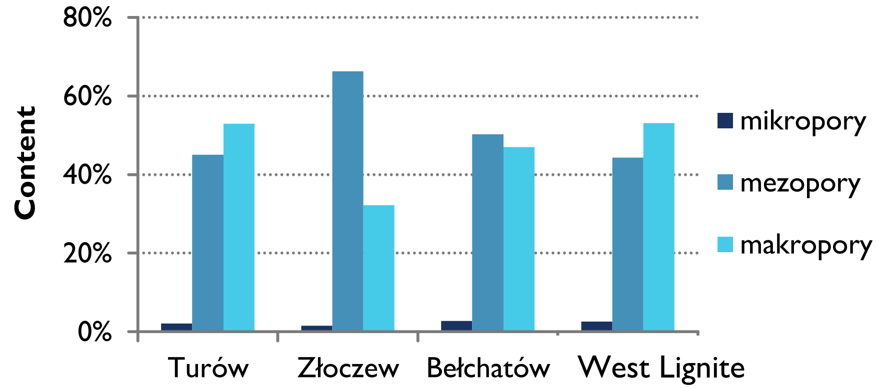


A distinctively alkaline character were found for the West lignite ash resulting in the highest alkali index as compared to other samples

POROUS STRUCTURE OF RAW LIGNITES

Adsorption of N_2 at 77 K



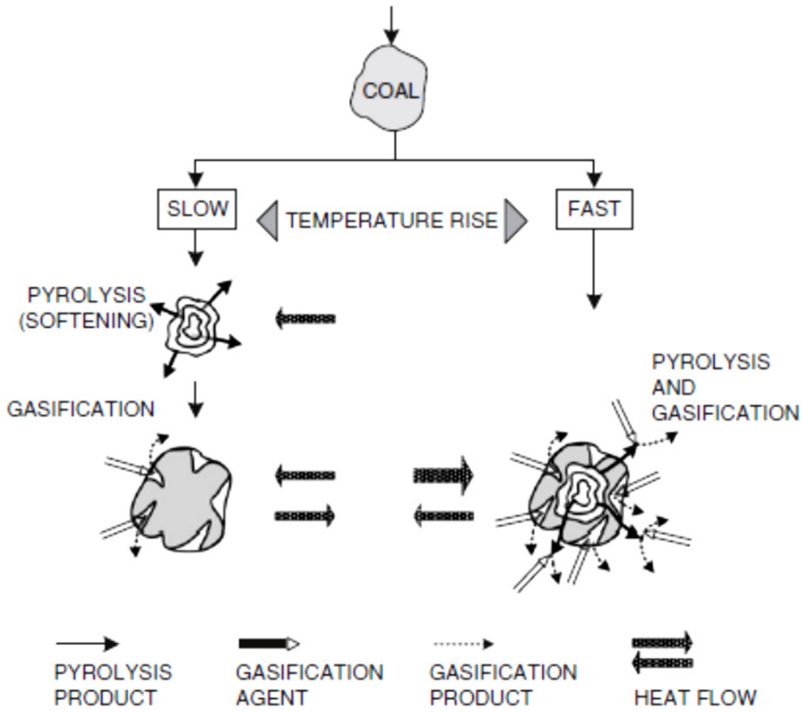


The samples demonstrate poorly evolved porous structure due to negligible presence of micropores.

Lignite	Turów	Bełchatów	West Lignite	Złoczew
V_{micro}, cm^3/g	0.0004	0.0002	0.0002	0.0002
V_{meso}, cm^3/g	0.0084	0.0041	0.0031	0.0084
$V_{macro < 300\,nm}$, cm^3/g	0.0098	0.0038	0.0038	0.0041
V_{total}, cm^3/g	0.0186	0.0081	0.0071	0.0126
S_{BET}, m^2/g	**3.22**	**1.94**	**1.91**	**6.32**

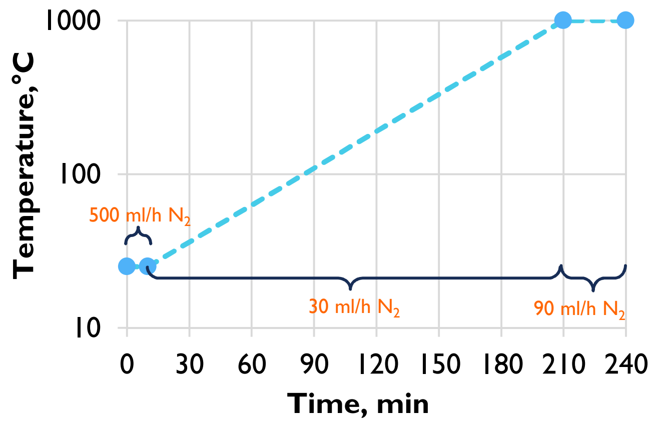
FORMATION OF LIGNITE CHARS

Two major steps can be distinguished during the gasification process: the initial rapid pyrolysis of coal to produce char, gases and tars and the subsequent gasification of the nascent char. **The rate of the second step is relatively low due to the poor reactivity of char.**



Credits: Ch. Higman, M. van der Burgt. Gasification Second Edition, 2007

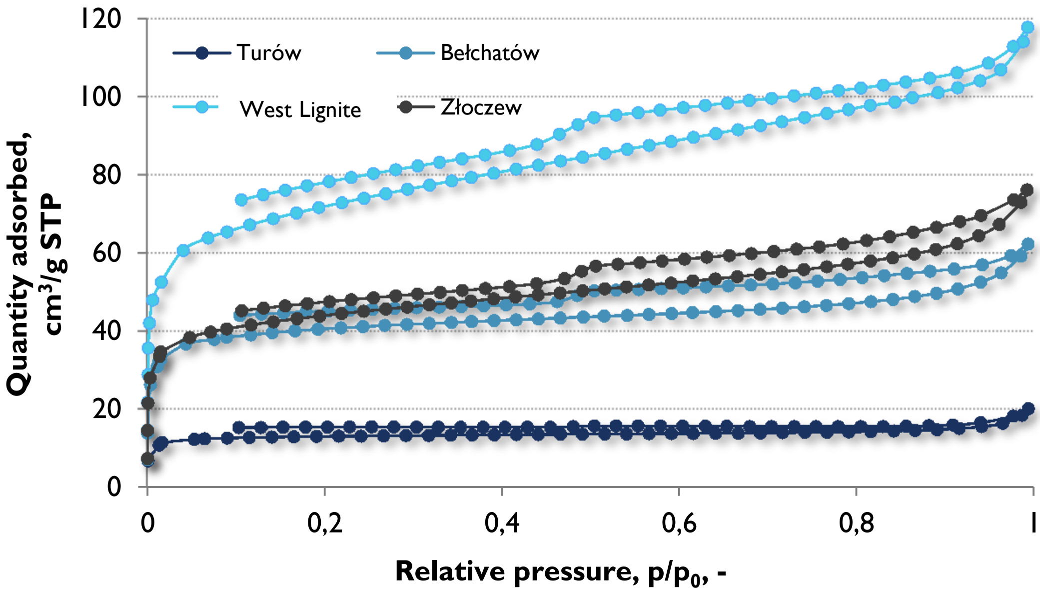
Pyrolysis conditions

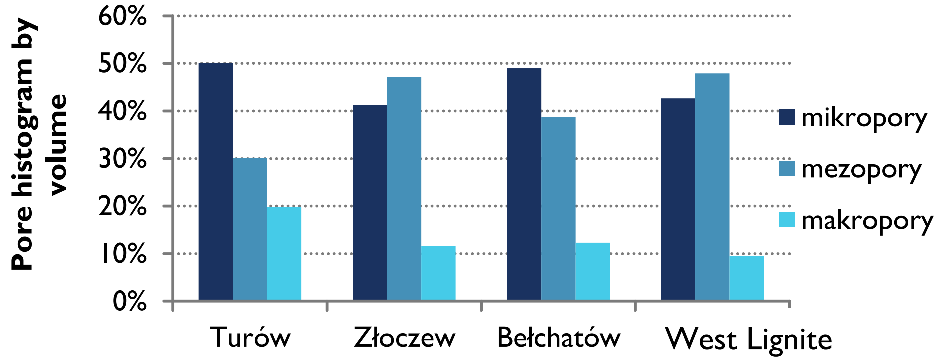


Conducting the devolatilization under the same temperature-time conditions permits for avoiding the effects of pyrolysis conditions on char structure and properties.

PROPERTIES OF LIGNITE CHARS

Char porous structure – Adsorption of N_2 at 77 K





In result of conducted pyrolysis, significant increase in micropore volume has been observed. Therefore, significant evolution in pore structure has been found reflecting in increase of surface area.

	Turów	Bełchatów	West Lignite	Złoczew
V_{mikro}, cm^3/g	0.0156	0.0472	0.0777	0.0487
V_{mezo}, cm^3/g	0.0094	0.0374	0.0873	0.0556
$V_{makro < 300 nm}$, cm^3/g	0.0062	0.0118	0.0173	0.0137
V_{total}, cm^3/g	0.0313	0.0964	0.1823	0.1179
S_{BET}, m^2/g	**51.70**	**158.41**	**262.05**	**161.91**

CHAR REACTIVITY TOWARDS CO_2 – TEST PROTOCOL DEVELOPED AT INSTITUTE

Laboratory set-up for studies on reactivity of solid fuels under elevated pressure and is equipped with an on-line gas analyzer

$t_{max.}$ = 975°C
$P_{max.}$ = 50 bar
Max. sample mass = 5 g

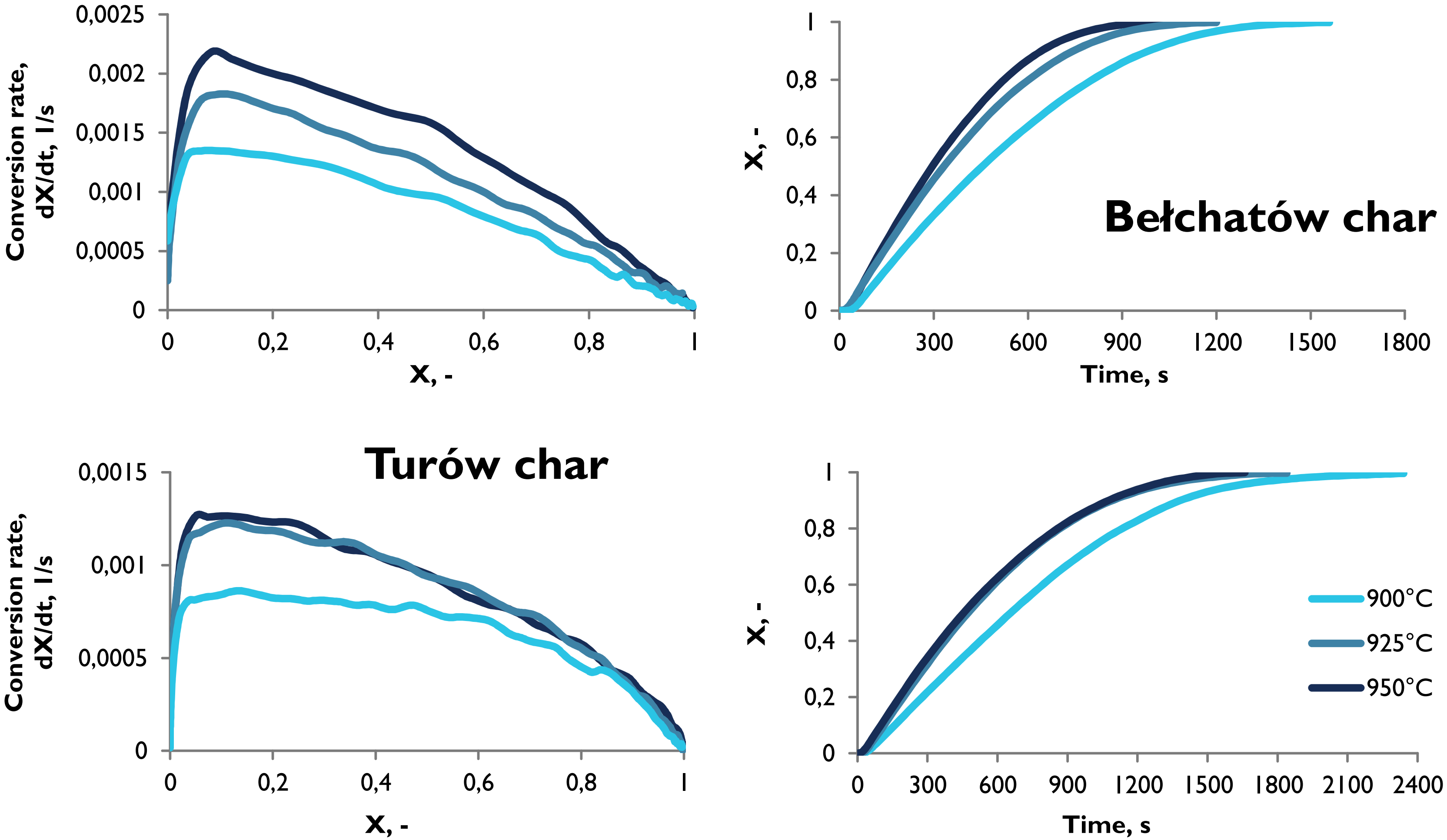
Conditions applied in this study:

Sample mass: 1 g (on air-dried basis)

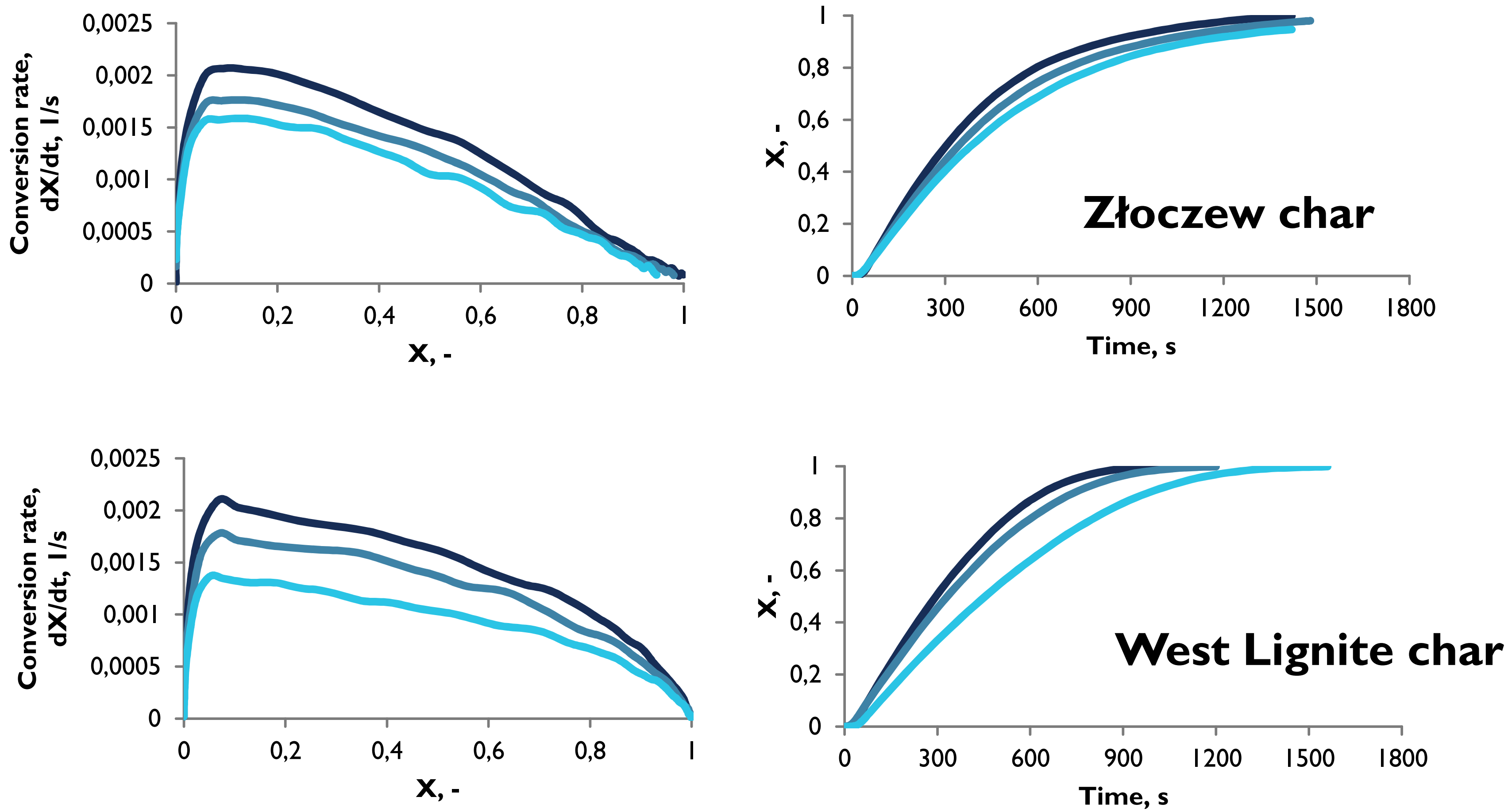
Temperature: 900, 925 and 950°C
CO_2 pressures: 1, 6 and 11 bar_a
CO_2 flowrate: 100 g/h

The procedure includes estimation of fractional conversion on carbon as reaction proceeds from change of composition and flowrate of the product gas.

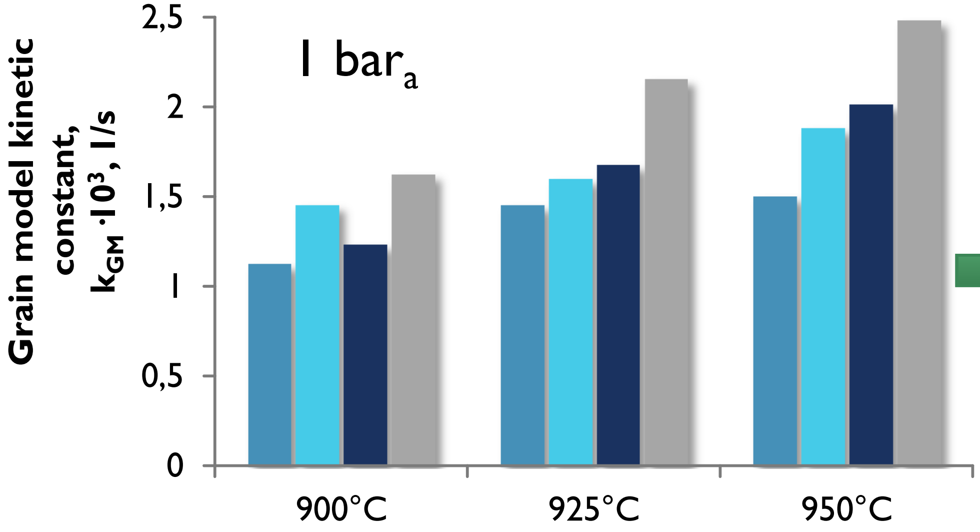
GASIFICATION KINETICS AT AMBIENT PRESSURE



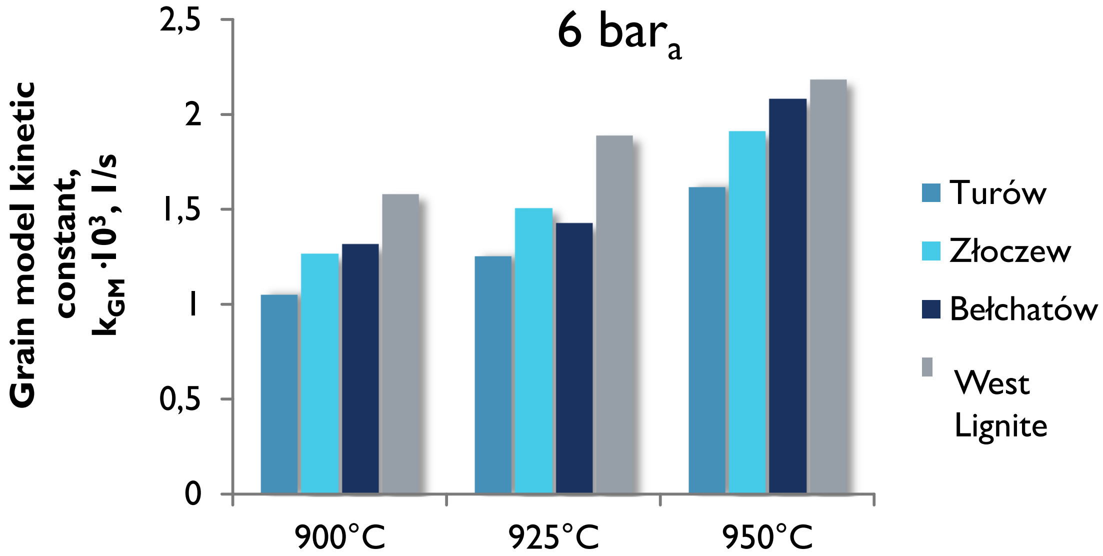
GASIFICATION KINETICS AT AMBIENT PRESSURE

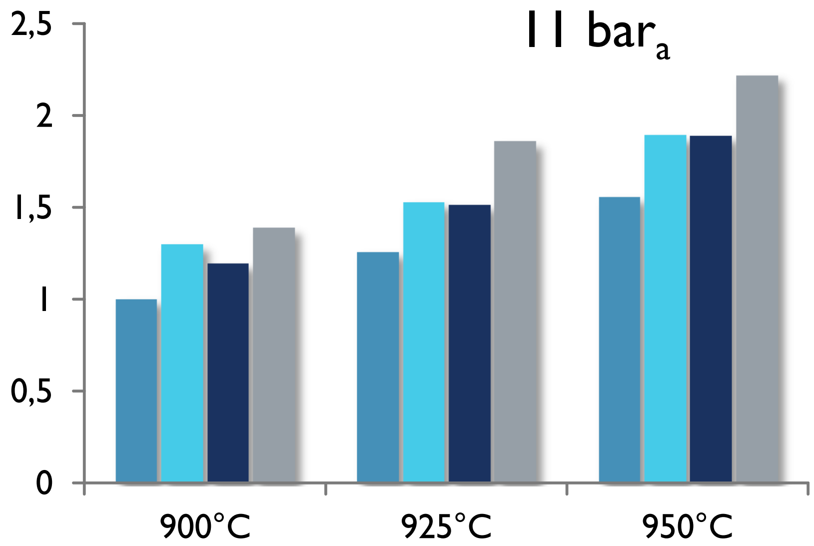


KINETIC CONSTANTS – REACTIVITY REPRESENTATIVES



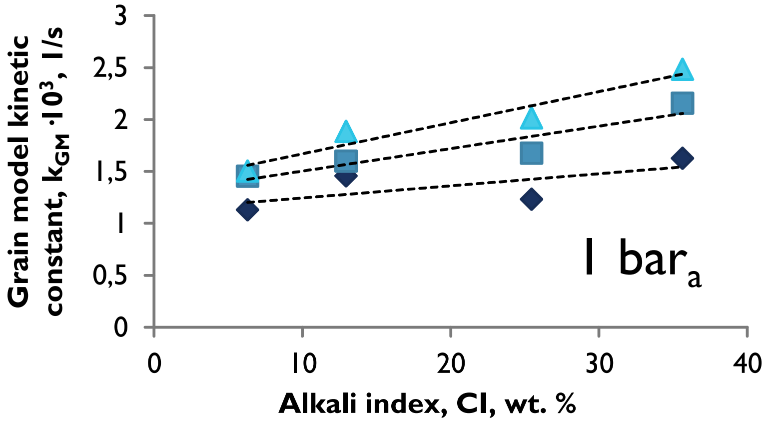
Char sample	Pre-exponential factor, 1/s	Activation energy, kJ/mol
Bełchatów	203.94	233.8
Turów	1.63	141.4
Złoczew	0.98	127.2
West Lignite	50.52	201.2

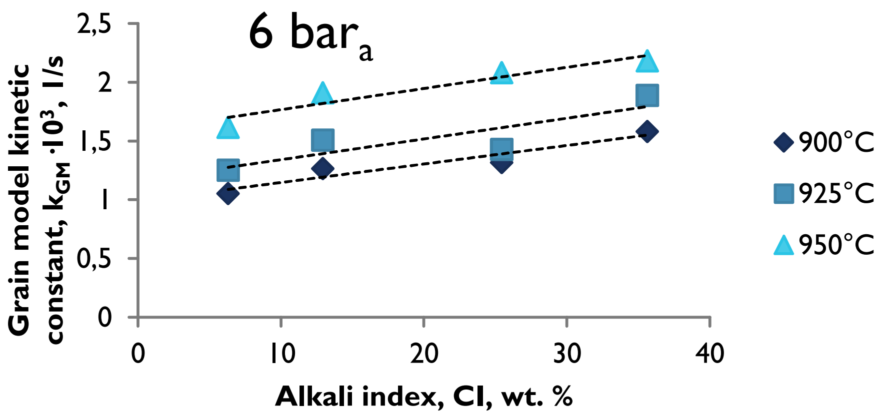


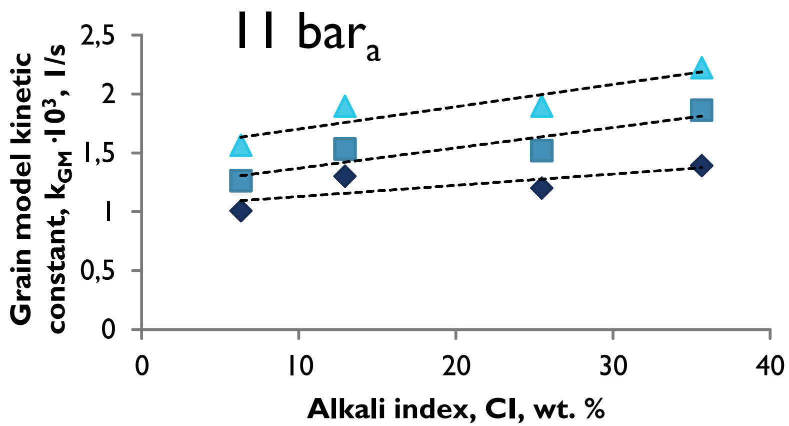


FACTORS DETERMINING THE REACTIVITY

Alkali index

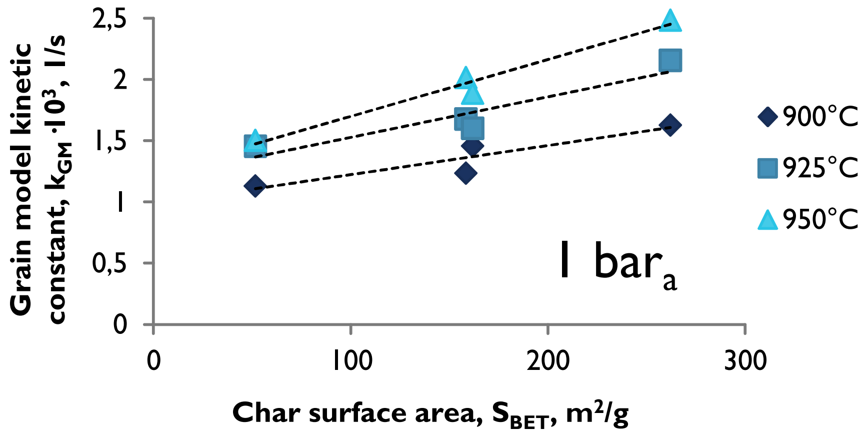


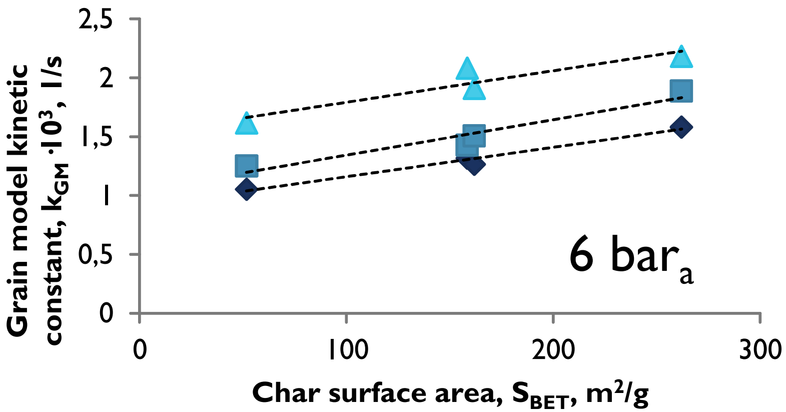


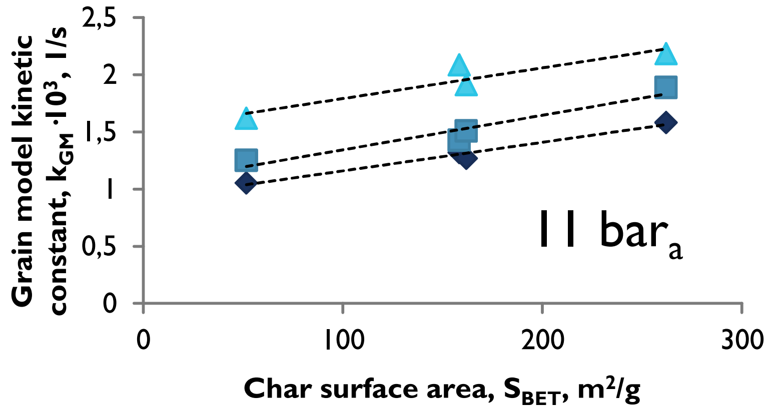


FUEL-BASED FACTORS DETERMINING THE REACTIVITY

Surface area







FINAL REMARKS

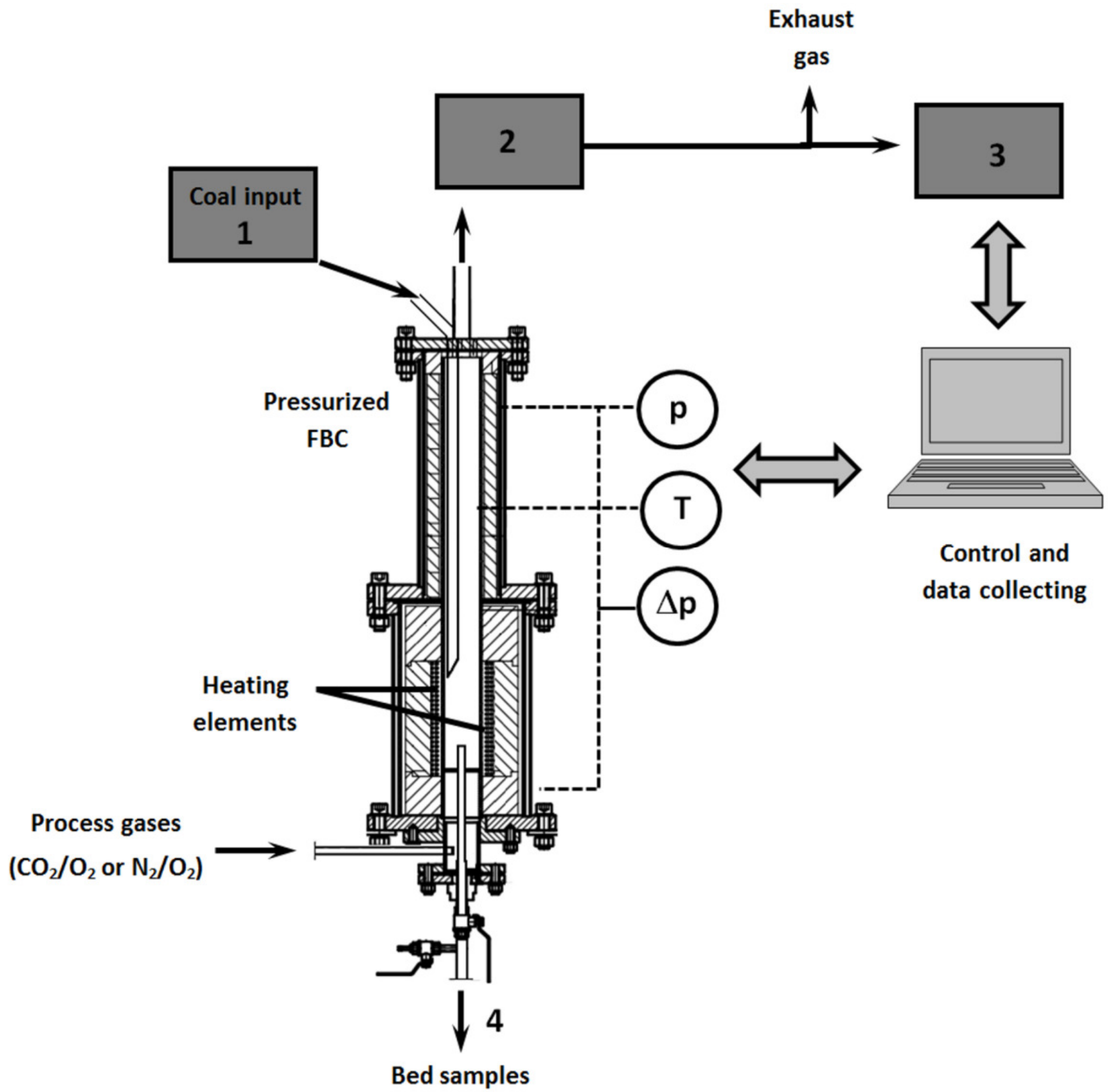
- Detailed characterization of 4 lignite samples from currently exploited and perspective deposits have been conducted. Despite relatively similar rank, the samples varied noticeably with their content and chemical composition of ash.
- The smallest content of ash was reported for West lignite. However, this ash was found to be of highest alkalinity due to significant content of calcium, magnesium and ferrous oxides and low concentration of acidic oxides of aluminum and silica.
- The gasification tests conducted at laboratory scale under ambient and elevated pressure revealed noticeable differences in samples reactivity. **The most reactive char was the West lignite** while the lower reaction rate was found for Turów lignite. Złoczew and Bełchatów lignite presented moderate susceptibility for gasification under applied conditions. **This reactivity ranking was unchanged irrespective of pressure employed during gasification.**
- For the kinetic characterization, the grain model was successfully adopted allowing for determination of kinetic constants and parameters of Arrhenius equation.
- The reactivity of coal chars has been found as a linear relationship of lignite ash alkali index and char surface area.

RECOMMENDATIONS

Taking into account issues related with ash content and fusion characteristics as well as the reactivity behavior, **the most appropriate lignite for gasification is placed in the West Lignite perspective deposit.**

EXPERIMENTAL COMBUSTION & GASIFICATION

Reactor:
diameter 0.075m,
height 1m,
bed height 0.25m
fuel tank capacity 0.004 m^3
Exhaust gas analysis:
FTIR analyzer (GASMET DX4000)
O_2 analyzers:
paramagnetic (Oxymat 61) and
zirconium sensor (AMS Analysen)



EXPERIMENTAL SETUP- REAL VIEW

LAB SCALE GASIFICATION TESTS

Gas composition comparison

Gas composition, $\%_{vol.}$	Bełchatów	Turów	West Lignite
CO	28.9	24.6	33.8
CO_2	15.5	24.1	15.5
CH_4	2.3	2.7	2.7
H_2	21.3	23.7	23.5

OUR PROJECT TEAM

Thank you for your kind attention !

ご清聴ありがとうございました

Narodowe Centrum Badań i Rozwoju

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