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The relation between the size of bituminous coal particles and the sorption of carbon monoxide

Introduction

Hard coal has been regarded in recent years as a complex colloidal system, with a distinct aromatic part that comprises structures made of condensed aromatic hydrocarbons. In this system different kind of free spaces can be distinguished, namely macropores, mesopores, micro and sub-micropores. The outer surfaces of the aromatic structures is formed by complexes of aliphatic-acyclic hydrocarbons. In this structure thermosets chains joining together aromatic domains can be distinguished, as well as not thermosets chains such as aliphatic chains being acyclic compounds not joining aromatic domains. The segments not aromatic, acyclic and aliphatic constitute a-polar centers that interact with sorbates by means of dispersion forces. On the other side, the centers on surface of coal rendering this surface polar are responsible for polar interactions of coal matter with sorbates (Kreiner, Żyła 2006). Among polar segments of coal surface our attention should be directed towards oxygenated groups occurring in the form of the following reactive groups: methoxyl (-OCH₃), hydroxyl (-OH), carboxyl and carbonyl (Lasoń, Czuhajowski 1960). The concentration of oxygenated groups can be determined by means of chemical analysis, spectral photometry in infrared as well as from the shape of isotherms of water vapor sorption at room temperature (Żyła 1963). The shape of sorption isotherms is affected by the concentration of polar centers within coal matter. The quantity of adsorbed molecules of water is proportional to the surface concentration of these reactive groups (Żyła, Kreiner 1993; Stachurski, Żyła 1995). The

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second factor influencing the quantity of adsorbed vapours or gases, especially a-polar ones (such as argon, nitrogen, krypton, or several low-carbon hydrocarbons) is porosity of the coal matter. The results of several sorption and porosymetry tests revealed that in this aspect special importance do have micro and sub-micro pores, that form the primary sorption system (Chaback et al. 1996; Bustin, Clarkson 1998; Saghafi et al. 2007). Micro-pores become accessible for adsorbate due to presence of mesopores that can be treated as transportation arteries (Czapliński 1994). The molecules of chemical compounds having small radius (helium, nitrogen, argon or carbon dioxide) because of its shape are the most suitable for determination of general porosity and the volume shares in it of micro- and sub-micro-pores. Numerous laboratory studies on sorption on coal were carried out and it emerged that carbon dioxide is one of the best adsorbates in this regard, because its molecules easily penetrate into the sub-micro and micro-pores (Mastalerz et al. 2004; Clarkson, Bustin 1999; Chalmers, Bustin 2007; Marecka 2007; Zarębska, Dudzińska 2008). The similar can be said in the case of water vapor that also easily penetrates into the micro-pores system of coal matter and can be treated as indicator of different chemical properties of coal surface related to carbon content within coal matter (Stachurski, Żyła 1995; Prinz, Littke 2005). The authors in this paper discuss a new topic concerning sorption of carbon monoxide on hard coal. Because of toxic properties of carbon monoxide the sorption studies with CO has not been undertaken as yet. Carbon monoxide is the gas present in air ventilating coal mines in wide range of concentrations – from trace amounts of 0.0001% up to 1% even. High concentrations of CO can be found in mine air during underground fires and as a result of spontaneous combustion processes, it can also be found in air samples taken from boreholes without relation to underground fire processes.

1. Properties of carbon monoxide

Carbon monoxide is an odorless, colorless gas, lighter than air and highly toxic too. Its lower limit of concentration permitted in mine air is 0.0026% (Polish Mining Law, Ministry of Mining 2002). In CO molecules carbon and oxygen atoms are linked by triple bonds, namely one δ bond and two π bonds (Dzięgielewski 1985).

According to the orbital theory, in CO molecule it can be distinguished one σ bonding orbital, two π bonding orbitals with electrons and not bonding orbitals without electrons. A CO molecule has also outer, not bonding orbital with a pair of electrons present, that determines chemical properties of the molecule. This pair of electrons shifted towards carbon atom and being on the highest energetic level determines the donor properties of CO molecules. According to Bielański (Bielański 2002) this not bonding pair of electrons is located in orbital created as a result of so called “digonal hybridisation”, during which the 2s orbital of carbon atom is blended with one of oxygen orbitals.

A CO molecule has the ability to form coordination bonds chiefly in complex compounds, where it plays the role of a donor and forms carbonyls of metals belonging to the lateral groups.

Sorption of carbon monoxide can occur on positive ions located on surface of solids. It is probable that a carbon monoxide molecule, due to its properties as a donor and a weak acceptor, can interact with π -electrons of solids. This can be of some importance in the process of CO sorption on polymeric complexes build from condensed benzene rings, occurring in the aromatic structure of hard coal. There is a lot of free π -electrons in the aromatic part of coal matter. Also there is high possibility of electrostatic interaction of carbon monoxide molecules with energetic center in hard coal being the result of the presence of hydroxyle and carboxyle groups in coal matter. Note, that carbon monoxide is a weak dipole; its dipole moment is $0.3 \cdot 10^{-30}$ C·m.

It is known that during low-temperature sorption of nitrogen or argon the molecules of these gases do not penetrate fully into the system of micro-pores in coal matter (Prinz et al. 2004; Cygankiewicz et al. 2006) which is probably caused by the feature of thermo-lability of hard coal – shrinking of coal matter occurring at low temperatures is the cause of reduction of mesopores diameter resulting in elongation of the period during which sorption equilibrium can be reached. Because of some constraints of the available measurement equipment carbon monoxide sorption tests were carried out at the temperature of liquid nitrogen. Low temperature of sorption enabled to determine sorption isotherms for full range of relative pressure. The problem of sorption of carbon monoxide molecule was discussed by Cygankiewicz (Cygankiewicz et al. 2007), where it was demonstrated that sorption of carbon monoxide is rather low, and is dependent on carbon and oxygen content within coal matter. Also, in this paper it was demonstrated that the process of sorption of carbon monoxide was to some degree irreversible for the samples tested. The quantity of carbon monoxide remaining within coal diminish with increasing content of carbon within hard coal matter. There is possibility that the not-desorbed yet molecules of carbon monoxide can be desorbed under conditions of changing ambient temperature and the molecules of CO can be liberated into the ambient atmosphere thus elevating its concentration in it. It seems that the most hazardous is carbon monoxide adsorbed on coal dust particles, because coal dust has well developed outer surface thus enabling adsorption of large amounts of CO, that when liberated can significantly increase its concentration in air.

Such phenomenon can occur both during transport of coal and its storage; under conditions of insufficient ventilation the carbon monoxide concentration in air can be significantly elevated. In the scientific literature dealing with sorption and desorption of carbon monoxide there is lack of studies on the influence of the size of coal particles or grains on quantity of carbon monoxide sorbed. Because of that in this paper the results of laboratory tests are presented performed on samples of hard coal of three grain size classes. Another reason why this study was undertaken is the toxicity of carbon monoxide that poses a serious threat to the health of miners. During fires and as a result of spontaneous heating of coal the concentration of carbon monoxide can reach significant levels above the legally permitted limit. The results of the presented tests can increase awareness about the problem of coal dust accumulated in mine workings, that can contain significant amounts of carbon monoxide adsorbed on its well-developed outer surface system.

2. The experimental part of the study

The tests on carbon monoxide sorption were carried out on samples of hard coal, having different carbon contents, collected in six Polish coal mines, namely: Jaworzno mine (seam 209), Wesoła mine (seam 501), Zofiówka mine (seam 404), Chwałowice mine (seam 404/4), Pniówek mine (seam 360), Sośnica mine (seam 413). The samples were collected in accordance with the Polish standard PN-90/G-04502, then crushed in a jaws crusher. From each sample, by means of a Fritsch set of sieves, three sub-samples were formed having the following three coal grain size classes: 0.063–0.075 mm, 0.125–0.25 mm and 0.5–0.7mm. The parameters characterizing coal samples are listed in Table 1.

A volumetric method was applied during laboratory tests of CO sorption with the use of ASAP 2010 Micromeritics. This apparatus enables to determine sorption and desorption isotherms of numerous gases, among others carbon monoxide, it enables also good preparation of samples for tests by degassing them under vacuum of up to $5.06 \cdot 10^{-7}$ Pa. Furthermore, very precise measurement under preset relative pressures is possible till the moment of reaching sorption equilibrium. Sorption tests were carried out on each of sub-samples at 77.5 K temperature, although the kinetic energy of carbon monoxide molecules at that temperature can be too low for them to penetrate into micro- and sub-micro-pores structure of coal. Also, additional sorption tests on three selected coals were carried out at 308 K.

TABLE 1

Chemical and petrographic characteristics of coal samples

TABELA 1

Charakterystyka chemiczna i petrograficzna węgla kamiennych

Sample	C _t ^a [%]	S _t ^a [%]	H _t ^a [%]	N ^a [%]	O _d ^a [%]	W ^a [%]	A ^a [%]	V ^a [%]	V _t [%]	R ₀ [%]	L [% vol.]	I [% vol.]	M [% vol.]
Pniówek	84.24	0.39	4.58	1.52	4.58	1.75	3.01	27.12	73	0.92	7	20	1
Wesoła	79.46	0.32	4.55	1.27	8.07	3.69	2.86	30.40	38	0.72	9	53	2
Chwałowice	79.29	0.35	4.97	1.07	8.47	3.39	2.65	35.62	60	0.70	10	30	1
Zofiówka	78.62	0.35	4.37	1.15	6.17	0.60	8.92	27.93	91	1.01	1	8	4
Sośnica	70.82	3.50	3.35	1.28	6.29	1.85	14.18	29.88	60	0.78	9	31	14
Jaworzno	57.83	1.10	3.37	0.87	11.30	11.11	14.45	28.39	67	0.51	5	28	11

C_t^a [%] carbon; S_t^a [%] total sulfur; H_t^a [%] hydrogen; N^a [%] nitrogen; O_d^a [%] oxygen; W^a [%] moisture; A^a [%] ash; V^a [%] volatile matter; V_t [%] vitrynite; R₀ [%] reflexivity of vitrynite; L [% vol.] liptynit; I [% vol.] inertynite; M [% vol.] mineral subs.

3. Discussion of the results of the tests

In order to determine the relation between sorption capacity of bituminous coal and its sample particles size the isotherms of carbon monoxide sorption were determined for three classes of grains size prepared from each of the six samples of coal, having different carbon and oxygen content. It is known that sorption of gases and vapors on sorbents having an accessible system of micro- and submicropores does not depend on particles size of the adsorbent (Żyła, Kreiner 1993; Stachurski, Żyła 1995). On samples characterized as not porous or having low porosity the molecules of adsorbate are adsorbed only on the outer surfaces of samples. The measured values of specific surface area are the representation of adsorption phenomena occurring in very small micro-pores. The samples of adsorbents having low values of specific surface area constitute the structures of very low micro-porosity share or very limited accessibility of adsorbate molecules to micro- and sub-micro-pores. In such cases the values of specific surface area are very low and are distinctively dependent on coal particles size.

Figure 1 depicts the sorption isotherms of carbon monoxide, determined for samples of coal crushed into the finest particles size class (0.063–0.075 mm). The shape of the obtained isotherms represents the quantity of CO sorbed on coals tested. Sorption of carbon monoxide is related to oxygen and carbon content within coal matter. Basing on these isotherms (Fig. 1) and employing the equation from BET theory, the values of the specific surface area were calculated; that is treated by the authors of that paper as the manifestation of changes in sorption capacity of bituminous coal in the range of relative pressures $p/p_0 = 0.05–0.35$ (Table 2). These values of surface area determined for five samples were very low, that can be attributed to the lack of ability of molecules of carbon monoxide to penetrate into micropores system of coal – the adsorption of carbon monoxide took place chiefly on the outer surfaces of coal grains. Adsorption of carbon monoxide takes place chiefly on the outer surfaces of coal grains.

The values of specific surface area of below 1 m^2 appear to be typical for sorption on the outer surfaces of coal particles. The confirmation of this assumption is the distinct increase of specific surface area for more finely ground samples – namely, for the middle class of grains size (0.125–0.25 mm) specific surface area of four samples is even two times higher (in the case of the sample from Chwałowice mine) than in the coarsest sample. The samples of coal more finely ground (0.063–0.075 mm) have even greater specific surface area – 3 or even 7-times greater than the coarsest sample of coal. It can be concluded that in the case of the samples of the finest coal (0.063–0.075 mm) adsorption takes place not only on the outer surface but also, to a small degree, in the macro- and mesopores, whereas the micro- and sub-micro-pores are still inaccessible for molecules of carbon monoxide molecule.

Comparing two grains size classes, namely 0.063–0.075 mm and 0.5–0.7 mm for samples of coal collected from Pniówek and Zofiówka one can observe five and six-fold increase of CO sorption. It is probable that coal ground below 0.063 mm grains size is even more prone to adsorption of CO, thus increasing the hazard in the case of its desorption.

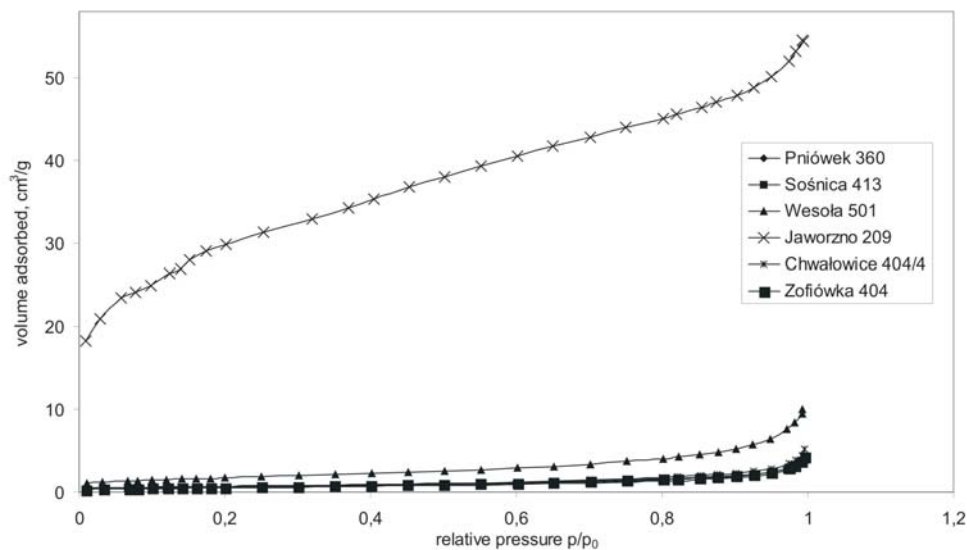


Fig. 1. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different coals of 0.063–0.075 mm particle size

Rys. 1. Izotermi sorpcji tlenu węgla wyznaczone w temp. 77,5 K na poszczególnych węglach rozdrobnionych do klasy ziarnowej 0,063–0,075 mm

TABLE 2

Specific surface area [m^2/g] determined from sorption of carbon monoxide at 77.5 K for samples of coal from given mine, breakdown according to particle size class

TABELA 2

Powierzchnia właściwa [m^2/g] wyznaczona z sorpcji tlenu węgla w temp. 77,5 K dla prób węgla z poszczególnych kopalń w zależności od wielkości klasy ziarnowej

Sample	C_t^a [%]	Particle size class [mm]		
		0.5–0.7	0.125–0.25	0.063–0.075
Pniówek	84.24	0.51	0.98	2.56
		1.00	1.9x	5.0x
Wesoła	79.46	2.75	3.96	7.58
		1.00	1.4x	2.7x
Chwałowice	79.29	0.88	1.67	3.10
		1.00	1.9x	3.5x
Zofiówka	78.62	0.42	0.43	2.64
		1.00	1.0x	6.3x
Sośnica	70.82	0.78	0.85	2.23
		1.00	1.1x	2,9x
Jaworzno	57.83	222.9	177.9	133.5
		1.00	0.8x	0.6x

x – multiple of specific surface area in relation to initial surface area of sample.

The problem of sorption of CO on samples of coal from Jaworzno mine should be discussed separately. The sample of that coal of the coarsest grains size class of 0.5–0.7 mm showed the highest ability to sorption, as it can be said from the very high measured value of specific surface area 223 m²/g. Therefore, this coal is very porous and its systems of meso-, micro- and sub-micro-pores are open thus resulting in high value of specific surface area. Comparing that value with the specific surface areas measured for samples of finer particle size classes one could note a surprising phenomenon, namely the finer coal particles size of a sample the lower was the specific surface area, contrary to the trend observed in the tests performed on the other four coal samples. The diminishing values of specific surface area for the finer particles size samples can be attributed to the blocking of the transport pores of the finer sub-samples by dust particles created during crushing of coal. Similar phenomenon was observed in the case of crushing of globules of synthetic zeolite 4A type (Ciembroniewicz 1973).

Figure 2–7 depicts sorption isotherms determined for samples of all three particles size classes of the tested coals. The isotherms are smooth, the measurement points are well aligned on the curves. Also, there were no major deviations observed, so it can be stated that measurement process was well done.

Analyzing the shape of the curves one can observe the change of their slope at the relative pressure value of $p/p_0 = 0.8$. Also, the quantity of CO sorbed under relative pressure in the range of $p/p_0 = 0.8–1.0$ are 3 or even 7 times greater than the quantities of CO sorbed in the range $p/p_0 = 0.01–0.8$.

The change of shape of the sorption isotherms indicated that the type of sorption process involved was different for different values of relative pressure. In the first part of the isotherms monolayer adsorption took place, where molecules of carbon monoxide reacted only with the outer surface reaction centers on the surface of coal particles, whereas in the second part of the isotherm, namely at $p/p_0 > 0.8$ the condensation of carbon monoxide molecules in the spaces between coal particles became apparent, being the result of lateral interaction of intermolecular type. Under higher relative pressures monomolecular adsorption gives way to multi-molecular one.

Condensation of carbon monoxide between coal particles has is realized by filling up the free spaces between coal particles. The volume of between-particle spaces is proportional to the degree of coal sample break-up, thus the quantity of adsorbed carbon monoxide rises with rising disintegration of coal.

Bearing in mind high toxicity of carbon monoxide and its explosivity potential (lower explosivity threshold of CO is its concentration of 12.5% vol. in air) and relatively large volumes of it stored in spaces between coal particles, it can be stated that the described phenomenon can be hazardous for humans because carbon monoxide can be easily desorbed and liberated into the ambient atmosphere.

The phenomenon of CO storage in the spaces between coal particles was not observed during tests of coal from Jaworzno mine, whose distinct feature is the adsorption of carbon monoxide taking place mostly in micro- and submicropores. In the isotherm determined for that

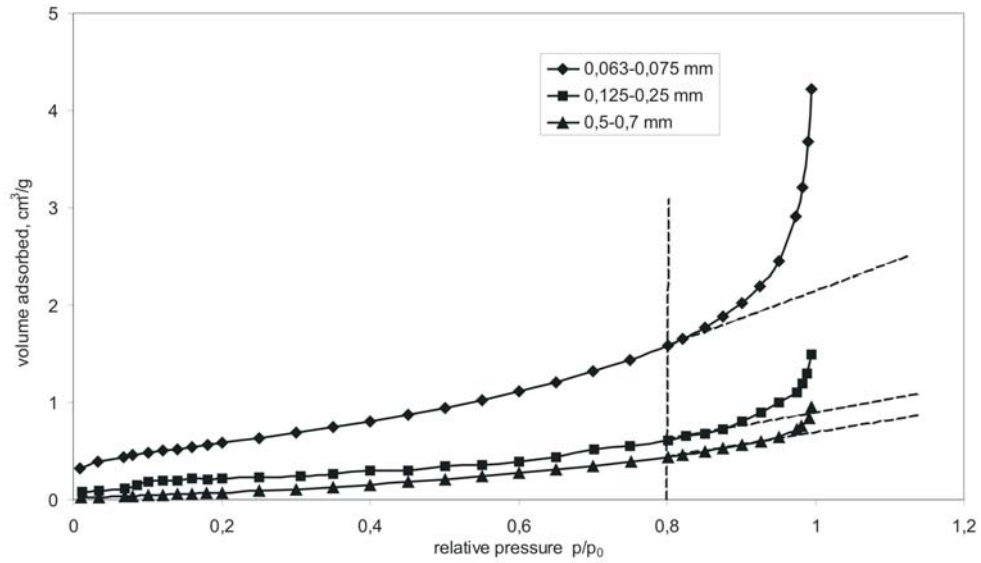


Fig. 2. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different particle size samples from Zofiówka mine

Rys. 2. Izotermy sorpcji tlenku węgla wyznaczone w temperaturze 77,5 K dla próbek węgla z kopalni Zofiówka dla poszczególnych klas ziarnowych

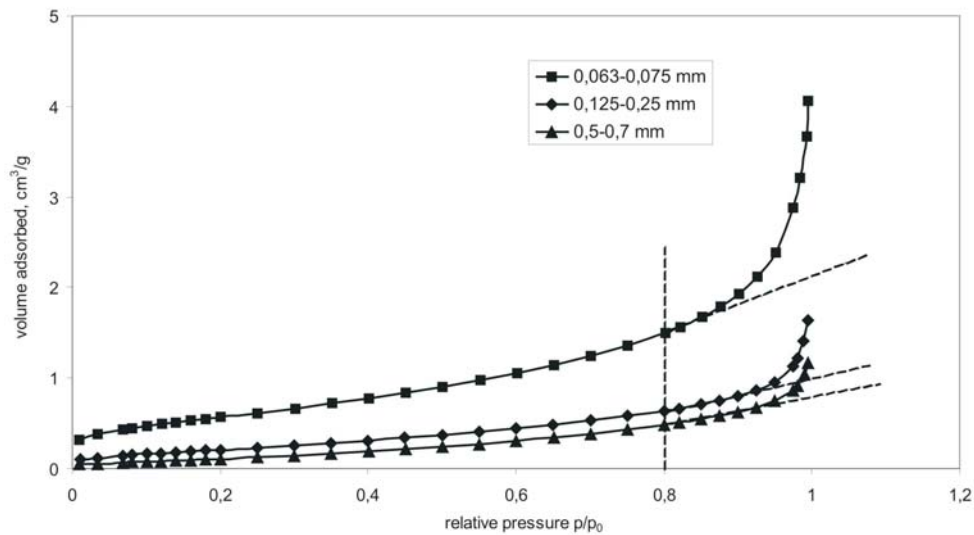


Fig. 3. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different particle size samples from Pniówek mine

Rys. 3. Izotermy sorpcji tlenku węgla wyznaczone w temperaturze 77,5 K dla próbek węgla z kopalni Pniówek dla poszczególnych klas ziarnowych

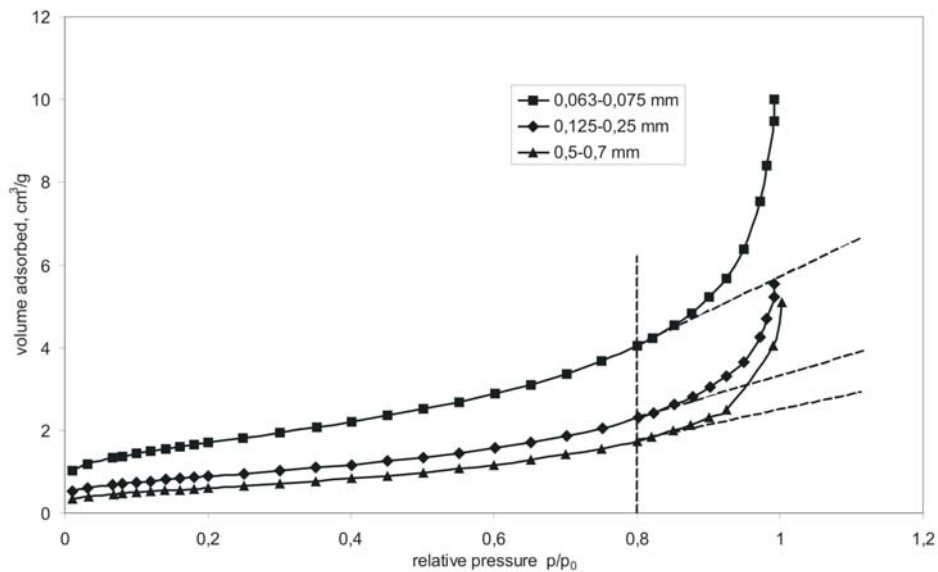


Fig. 4. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different particle size samples from Wesola mine

Rys. 4. Izotermi sorpcji tlenu węgla wyznaczone w temperaturze 77,5 K dla próbek węgla z kopalni Wesola dla poszczególnych klas ziarnowych

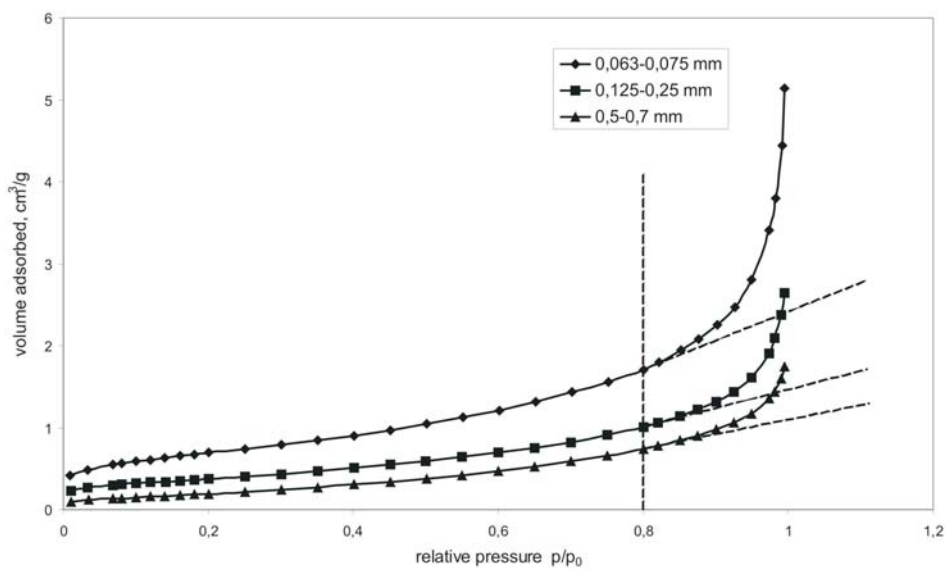


Fig. 5. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different particle size samples from Chwałowice mine

Rys. 5. Izotermi sorpcji tlenu węgla wyznaczone w temperaturze 77,5 K dla próbek węgla z kopalni Chwałowice dla poszczególnych klas ziarnowych

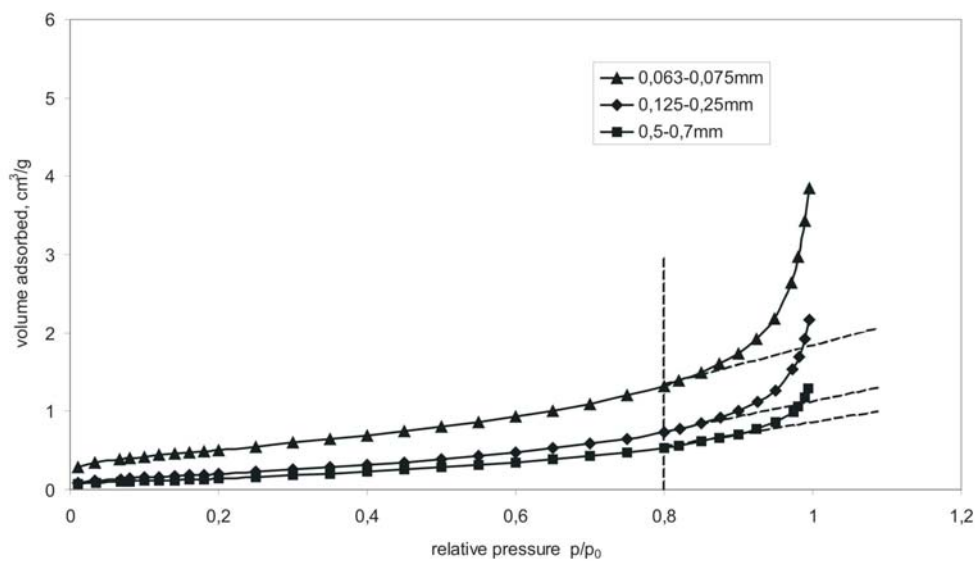


Fig. 6. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different particle size samples from Sośnica mine

Rys. 6. Izotermy sorpcji tlenku węgla wyznaczone w temperaturze 77,5 K dla próbek węgla z kopalni Sośnica dla poszczególnych klas ziarnowych

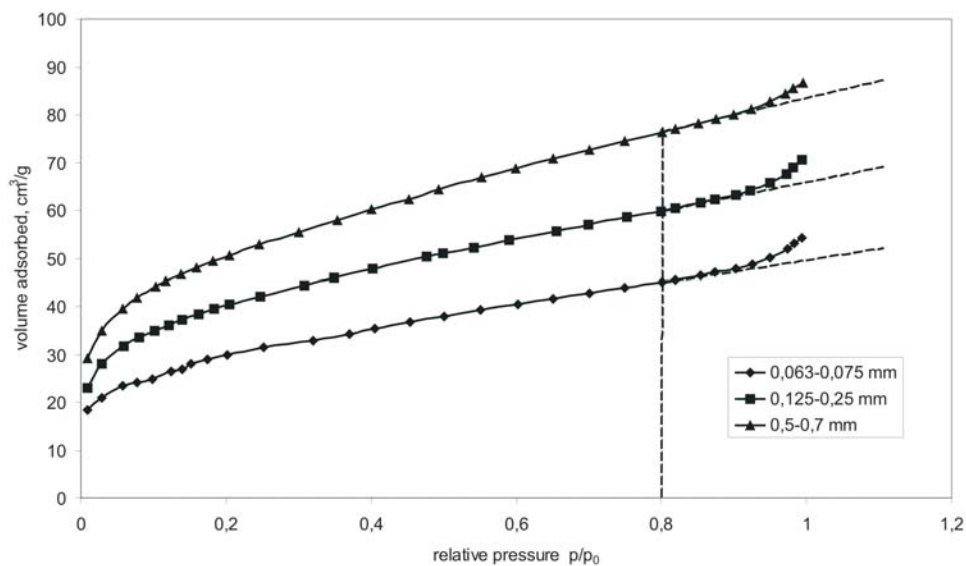


Fig. 7. Isotherms of carbon monoxide sorption at 77.5 K on coal samples of different particle size samples from Jaworzno mine

Rys. 7. Izotermy sorpcji tlenku węgla wyznaczone w temperaturze 77,5 K dla próbek węgla z kopalni Jaworzno dla poszczególnych klas ziarnowych

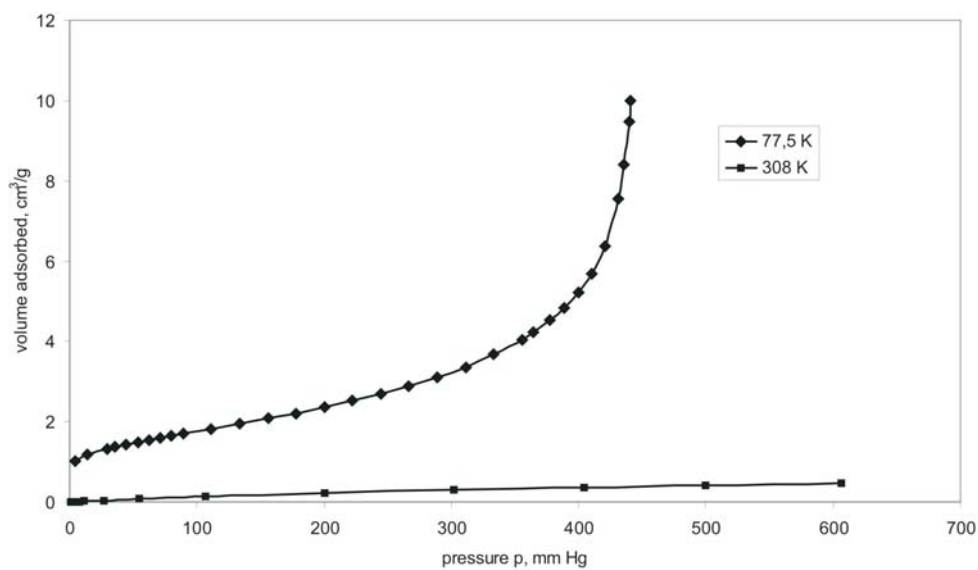


Fig. 8. Isotherms of carbon monoxide sorption at 77.5 K and 308 K on coal samples from Wesola mine (0.063–0.075 mm)

Rys. 8. Izotermie sorpcji tlenku węgla wyznaczone w temp. 77,5 K i 308 K na próbkach węgla z kopalni Wesola (0,063–0,075mm)

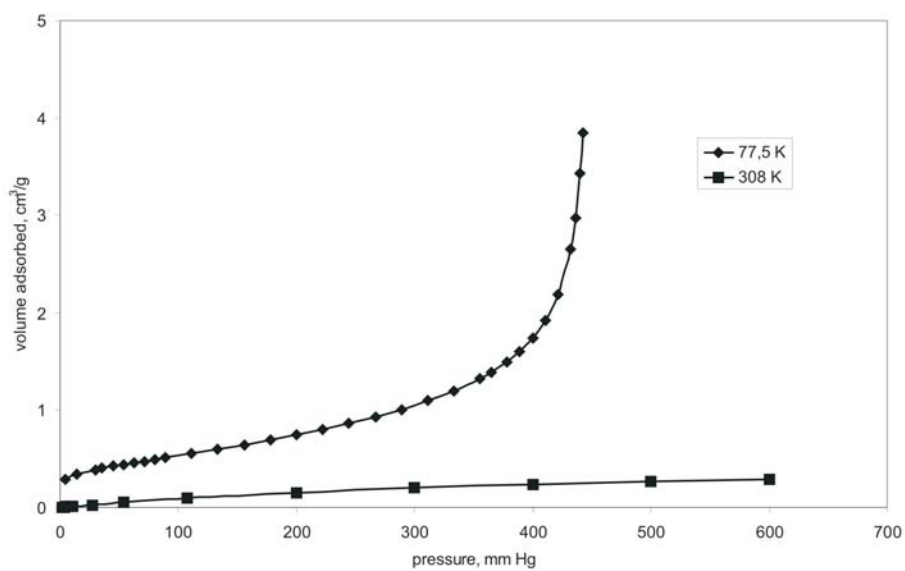


Fig. 9. Isotherms of carbon monoxide sorption at 77.5 K and 308 K on coal samples from Sosnica mine (0.063–0.075 mm)

Rys. 9. Izotermie sorpcji tlenku węgla wyznaczone w temp. 77,5 K i 308 K na próbkach węgla z kopalni Sosnica (0,063–0,075mm)

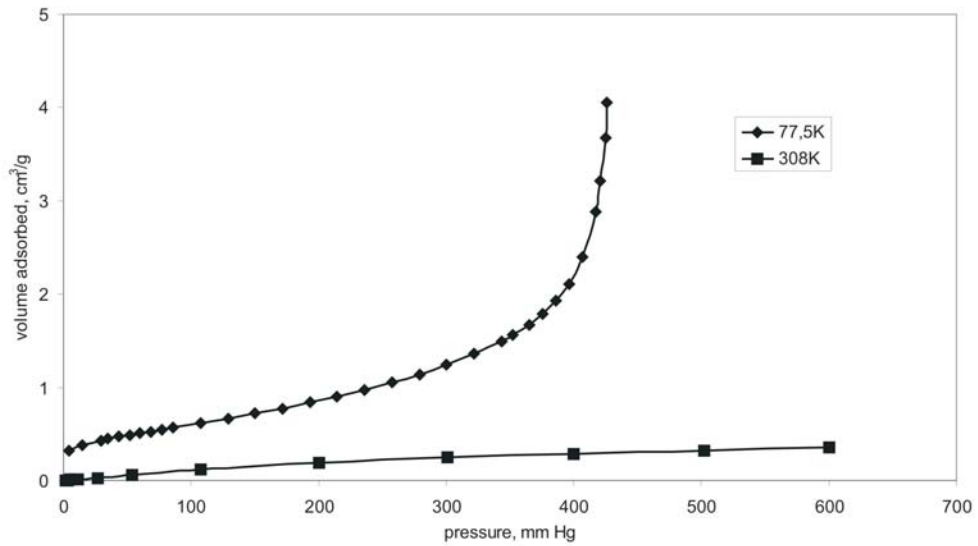


Fig. 10. Isotherms of carbon monoxide sorption at 77.5 K and 308 K on coal samples from Pniówek mine (0.063–0.075 mm)

Rys. 10. Izotermy sorpcji tlenku węgla wyznaczone w temp. 77,5 K i 308 K na próbkach węgla z kopalni Pniówek (0,063–0,075mm)

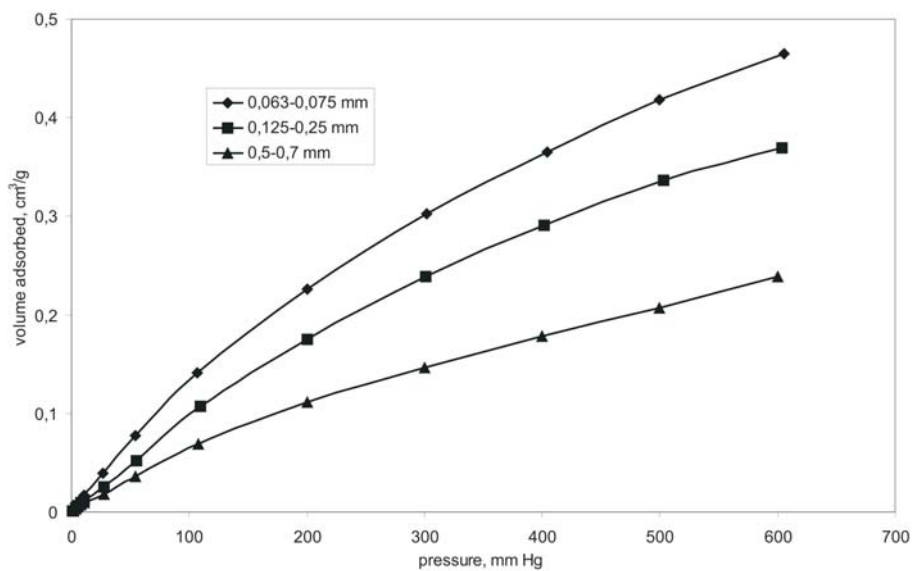


Fig. 11. Isotherms of carbon monoxide sorption at 308 K on coal samples from Wesola mine

Rys. 11. Izotermy sorpcji tlenku węgla wyznaczone w temp. 308 K na próbkach węgla z kopalni Wesola

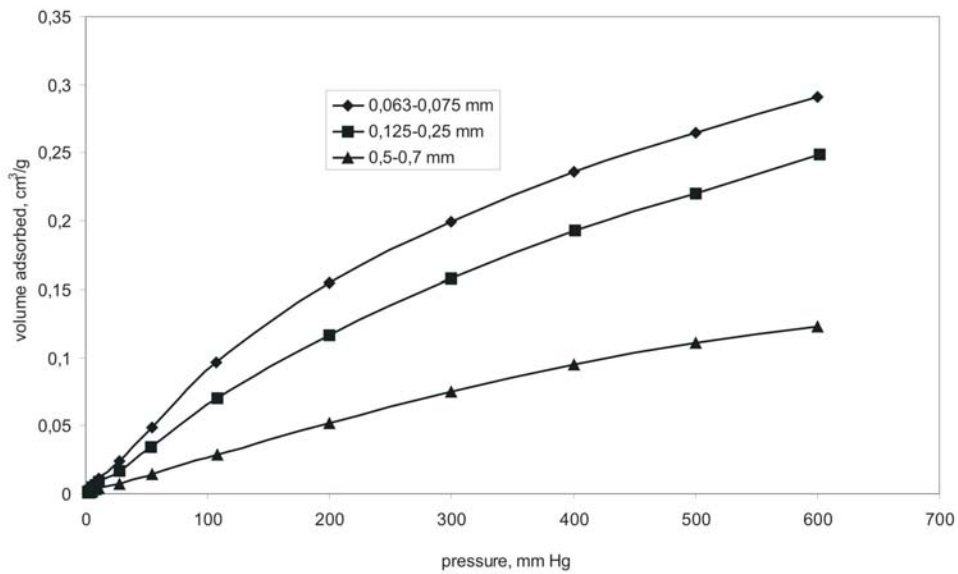


Fig. 12. Isotherms of carbon monoxide sorption at 308 K on coal samples from Sośnica mine

Rys. 12. Izotermi sorpcji tlenku węgla wyznaczone w temp. 308 K na próbkach węgla z kopalni Sośnica

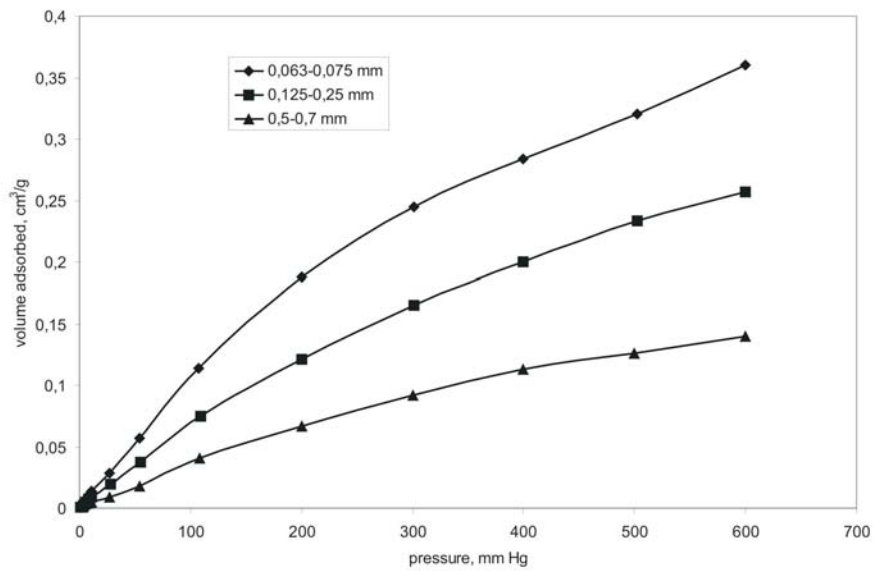


Fig. 13. Isotherms of carbon monoxide sorption at 308 K on coal samples from Pniówek mine

Rys. 13. Izotermi sorpcji tlenku węgla wyznaczone w temp. 308 K na próbkach węgla z kopalni Pniówek

coal the rising part is missing – that can be the result of the adsorption taking place in pores of coal rather than in the spaces between particles. In the case of that coal the number of molecules of carbon monoxide adsorbed on the outer surfaces of particles is much lower than the number of CO molecules located in pores of that coal. The desorption of carbon monoxide from micro- and sub-micro-pores is much more difficult than the desorption from outer surfaces of coal grains but in some favorable thermal conditions it can be a significant phenomenon.

Coal samples collected from Wesoła, Sośnica and Pniówek mines were chosen as the object of additional tests of CO sorption at the temperature of 308 K, much closer to typical values of temperature encountered in ambient air in mines. The maximal values of sorbed gas under laboratory conditions were respectively: 0.46 cm³/g, 0.29 cm³/g and 0.36 cm³/g.

The isotherms of CO sorption on the coal samples from the above mentioned mines at 77.5 K and 308 K are compared in Figures 8, 9 and 10. From the shapes of these isotherms it is evident that the sorption of CO at temperature 308 K is lower, but still distinct, and is caused by weaker dispersion forces during interaction of CO with coal surfaces than it is the case for sorption of CO at 77.5 K. It is also clear some relation between the type of coal and CO sorption at temperature 308 K.

It should be underlined that at temperature of 308 K sorption of CO is different for different particles size classes, that can be easily seen in Figures 11, 12 and 13. Analogically to the case of sorption at 77.5 K sorption of CO increases with coal matter disintegration. The quantity of CO adsorbed is the highest for the most finely crushed coal sample, of grain diameter in the range of 0.063–0.075 mm. That is another indication of hazard involved with sorption of CO on coal dust.

Conclusions

1. The results of sorption tests, carried out both at temperature of liquid nitrogen and at 308 K do reveal clear relation between coal grains size and quantity of carbon monoxide adsorbed on it. The samples of coal more finely crushed adsorb a couple times much more carbon monoxide than the coarsest ones.
2. In the case of non-porous coals or coals of low porosity sorption of carbon monoxide takes place mostly on the outer surfaces of coal particles. Under higher relative pressures $p/p_0 = 0.8-1.0$ for the samples of well disintegrated coal the phenomenon of adsorption between coal particles is observed, the quantity of carbon monoxide adsorbed in this way is a couple times greater than in the case of adsorption under lower relative pressure of $p/p_0 = 0.01-0.8$.
3. Porous coal of low carbon content (Jaworzno mine) adsorbs carbon monoxide in its micro and mesopores system. Because of this the between-particles sorption was not observed on that type of coal.
4. Carbon monoxide located in the spaces between coal particles is hazardous for humans because it can be released easily into the ambient atmosphere during desorption.

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WPLYW ROZDROBNIENIA WĘGLI KAMIENNYCH NA SORPCJĘ TLENKU WĘGLA

Słowa kluczowe

Węgiel kamienny, tlenek węgla, sorpcja, granulacja

Streszczenie

Badania sorpcji tlenku węgla zostały wykonane głównie w temperaturze 77,5 K. Załączono również izotermy sorpcji tlenku węgla wyznaczone na trzech próbkach węgla w temperaturze 308 K. Każda badana próbka węgla została rozdrobniona, a następnie stosując analizę sitową uzyskano trzy obustronnie zamknięte klasy ziarnowe. Wyniki otrzymanych badań wykazały wyraźny wpływ zawartości pierwiastka węgla i tlenu na sorpcję tlenku węgla. Sorpcja tlenku węgla zachodzi głównie na zewnętrznej powierzchni próbek węgla kamiennego zarówno w temperaturze pokojowej jak również w temperaturze ciekłego azotu. W przypadku węgla pobranego z kopalni Jaworzno charakteryzującego się dużą mikroporowością nie zauważono wpływu rozdrobnienia na sorpcję tego gazu. Jest to spowodowane sorpcją w mikroporowatym układzie węgla. Analizując przebieg izoterm sorpcji omawianego gazu w temperaturze ciekłego azotu pokazano możliwość kondensacji cząsteczek tlenku węgla w międzyziarnowych objętościach rozdrobnionego węgla. Kondensacja międzyziarnowa ujawnia się w przebiegu izoterm sorpcji CO przy wyższych wartościach ciśnienia względnego $p/p_0 = 0,8-1,0$.

THE RELATION BETWEEN THE SIZE OF BITUMINOUS COAL PARTICLES AND THE SORPTION OF CARBON MONOXIDE

Key words

Hard coal, carbon monoxide, sorption, size grade

Abstract

The tests of carbon monoxide sorption on hard coal were carried out mostly at room temperature whereas three hard coal samples were tested also at the temperature of liquid nitrogen – 77.5 K. Prior the tests the coal samples were crushed and separated into three grain sizes. The results of sorption tests demonstrated that there is significant correlation between the level of carbon content within a coal sample and its carbon monoxide sorption ability. Both at room temperature and at the temperature of liquid nitrogen sorption of carbon monoxide takes place mostly across the outer surfaces of coal grains. In the case of coal sample collected in Jaworzno mine, having high micro-porosity share, no clear correlation between grain size of that coal and its sorption ability was observed; that can be attributed to sorption processes occurring in the system of micropores within that particular coal. The specific changes of shapes of isotherms of CO sorption at the liquid nitrogen temperature indicated that condensation of carbon monoxide molecules occurred in the free spaces between coal grains. Such condensation manifests itself by specific changes in isotherm shapes at higher values of relative pressures – $p/p_0 = 0.8-1.0$.