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Adsorption of CO_2 on the special adsorbents

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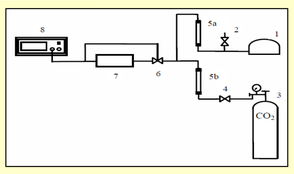
Abstract:
Biogas is one of the most important renewable energy sources in the Czech Republic (together with solid biomass, hydro-, solar- and wind energy). Biogas stations are working environmental friendly according to the emissions of greenhouse gases and other pollutions generated by production of heat and electricity from biogas. Biogas can be also used as a fuel in engines of motor vehicles.
For using in motor vehicles CO_2 and H_2S have to be removed from biogas to achieve similar properties compared with natural gas (methane content higher than 95 % and compared caloric value).

Theoretical part:
Carbon dioxide can be separated from biogas by adsorption, absorption, membrane separation or condensation. Using of the adsorption process is favourable due to its simplicity. The application of this technology at various pressures eases the the desorption process using vacuum or adsorbent heating to the elevated temperature.
For using of adsorption methods in practice it is important to find a suitable type of adsorbent which can be used at pressures up to 30 bar and is able to capture a sufficant quantity of CO_2. Very important is the finding of suitable method for regeneration of saturated adsorbents which enables to recover CO_2 at high concentration from the saturated adsorbent and to use the regenerated adsorbent in the following adsorption step.
For adsorption tests in the laboratory scale were used special adsorbents based on carbon molecular sieves. (produced in cooperation with research institute VÚHU, a.s. Most).

Aim of the work:
The aim of this work is testing of special types of adsorbents based on carbon molecular sieves. These adsorbents were tested for the removal of CO_2 from model gas mixtures at pressures up to 30 bar.
The next objective is measurement of BET surface area, pore volume, and pore size distribution of used adsorbents.

Experimental part:
For the laboratory tests were used six kinds of special adsorbents of the trademark Petsorb® based on carbon molecular sieves. These adsorbents were prepared by pyrolysis of waste PET (polyethylene terephthalate) and its following activation using the water steam.

Laboratory apparatus:



Legend: 1 - air pump, 2 - govering valve, 3 - pressure bottle with CO_2, 4 – govering valve, 5 - rotametr for air, 5b - capillary flow meter for CO_2, 6 – three-port valve, 7 -- glass adsorber 8 - CO_2 analyzer

Fig. 1 Laboratory apparatus used for the adsorption of CO_2

PET:
Polyethylene terephthalate is a thermoplastic linear polymer which is produced by the reaction terephthalic acid with ethyleneglycol or ethyleneglycol with dimethylterephthalate.

$C_6H_4(COOH)_2 + 2HOCH_2CH_2OH \rightarrow C_6H_4(COOCH_2CH_2OH)_2 + 2H_2O$
$C_6H_4(COOCH_3)_2 + 2HOCH_2CH_2OH \rightarrow C_6H_4(COOCH_2CH_2OH)_2 + 2CH_3OH$

Photo of adsorbent:

Fig. 2 Adsorbent Petsorb 1hŠ

Results:

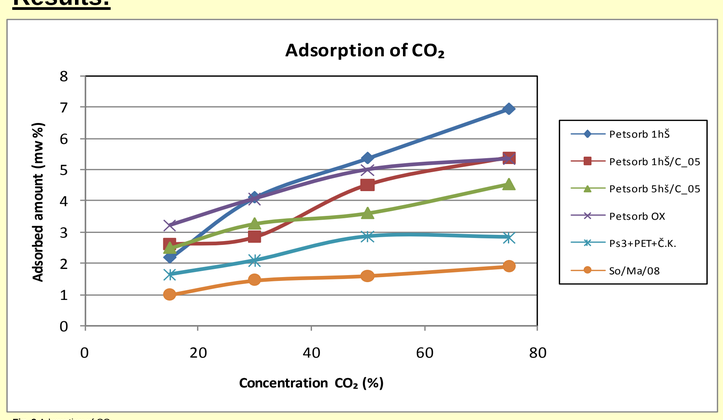


Fig. 3 Adsorption of CO_2

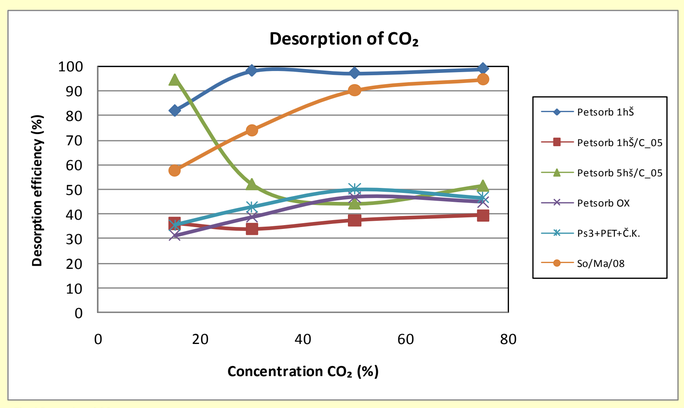


Fig. 4 Desorption of CO_2

Properties of adsorbents:

Adsorbents	BET surface area (m^2/g)	Total pore volume (ml/g)	Pore size distribution (%)							
			Under 6 (nm)	6 – 8 (nm)	8 – 10 (nm)	10 –12 (nm)	12 – 16 (nm)	16 – 20 (nm)	20 – 80 (nm)	Over 80 (nm)
Petsorb 1hŠ	438,18	0,2157	56,71	22,54	0	0,36	0,62	1,32	13,98	4,48
Petsorb 1hŠ/C^{05}	405,70	0,2149	79,28	3,10	1,61	1,66	1,90	1,83	8,23	2,38
Petsorb 5hŠ/C^{05}	728,78	0,4185	52,22	10,01	5,85	6,59	7,64	7,05	9,48	1,17
Petsorb OX	506,50	0,2585	74,58	4,16	2,12	2,10	2,26	2,28	9,68	2,82
P$_s$3 + PET + Č.K.	244,31	0,1626	54,65	5,72	3,31	3,68	4,46	4,92	19,24	4,02
So/Ma/08	236,04	0,1778	57,53	5,63	3,15	3,63	4,18	4,5	17,34	4,03

Fig. 5 Properties of adsorbents

Elemental analysis:

Adsorbents	Content (mass. %)			
	Nitrogen	Carbon	Hydrogen	Sulphur
Petsorb 1hŠ	0,0607	91,5589	0,5772	0,0075
Petsorb 1hŠ/C^{05}	0,0845	84,1642	0,5260	0
Petsorb 5hŠ/C^{05}	0,0839	93,9092	0,6222	0,0032
Petsorb OX	0,0585	91,6326	0,6483	0,1690
P$_s$3 + PET + Č.K.	0,2568	52,9569	0,3676	0,3094
So/Ma/08	0,1432	37,0672	0,3169	0,3834

Fig. 6 Elemental analysis

Conclusion:

The laboratory tests were provided for CO_2 concentrations of 15 %, 30 %, 50 % and 75 % resp. in the gas mixtures with the air.
From tested adsorbents the best adsorption capacity for CO_2 shows the Petsorb 1hŠ. Its adsorption capacity is 7 wt. % of CO_2. The adsorbents Petsorb 1hŠ/C^{05} and Petsorb OX adsorbed roughly the same amount of cca 5 wt. % CO_2. Carbon adsorbent Petsorb 1hŠ/C^{05} showed higher increase of adsorbed amount at 30 % of CO_2 in the gas mixture. Higher growth of adsorption capacity for CO_2 at the gas concentration 30 % is visible for adsorbent Petsorb 5hŠ/C^{05}. The adsorption capacity at concentration 75 % of CO_2 was 4.5 wt. %. Combined adsorbent consists of Ps3+PET+Č.K. has the highest adsorption capacities at concentrations 15 %, 30 % and 50 % of CO_2. Its accrual was almost 3 wt. % of CO_2. At 75 % of CO_2 the adsorption capacity wasn t changed. The lowest adsorption capacity of these adsorbents showed adsorbent So/Ma/08. The adsorption capacity at concentration 75% of CO_2 was cca. 2 wt. % of CO_2.
The highest desorption efficiency shows the adsorbent Petsorb 1hŠ, whose efficiency was 99 % by the desorption of saturated adsorbent using gas mixture containing 75 % of CO_2. Adsorbent So/Ma/08 had 57 % efficiency by the desorption of saturated adsorbent (at concentration 15 % of CO_2). Desorption efficiency was higher by growth of concentrations. At 50 % of CO_2 this efficiency was 90 % at 75 % CO_2 efficiency was 94 %. For Petsorb 5hŠ/C^{05} the desorption efficiency at 15 % of CO_2 was almost 95 %. In this case, the desorption effeciency was lower because of the increase 44 % at the concentration 50 % of CO_2. At concentration 75 % of CO_2 desorption effenciency was 47 %. Desorption effeciency for adsorbents Petsorb OX and Ps3 + PET + Č.K. were almost the same. The lowest desorption efficiency of about 39 % was measured for adsorbent Petsorb 1hŠ/C0^{05}at 75 % of CO_2.