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Experimental Analysis on Effects of Cycling Operation of Methane Adsorption and Desorption on Monolithic Activated Carbon

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Abstract

Adsorbed natural gas (ANG) provides a method of storing gas as one of the important resources of energy on suitable adsorbents at moderate pressures and ambient temperature. In this research study, an ANG system as a potential alternative to compressed natural gas (CNG) has been applied to store methane as one of the important component of natural gas on monolithic activated carbon. The present experimental study provides an experimental investigation of adsorption and desorption cycles of natural gas in a prototype storage vessel filled with monolithic activated carbon and the effect of the gas cycling on the adsorption and desorption capacity has been discussed. Many studies are devoted to the characterization of suitable adsorbent materials to optimize the methane storage capacity. Nevertheless, in this study the deterioration of the storage performance is observed after successive operating cycles of the ANG system. In the present study, the changes of the methane capacity of a 10 cycling operations is experimentally measured.

Keywords: Adsorption, Activated carbon, Cycling, Monolith, Desorption

1. Introduction

Natural gas is a possible alternative as a transportation fuel. Moreover, natural gas vehicles (NVGs) provide benefits as cleanliness and safety [1, 2]. However, the disadvantage of NG is its low volumetric energy density compared to that of conventional liquid fuels. Three different categories are known for on-board natural gas storage: liquefied natural gas (LNG), compressed natural gas (CNG), and adsorbed natural gas (ANG). In the case of LNG, the cost of liquefaction, the special insulated vessels required and the potential fire hazard make it unsuitable for use on a small scale. CNG has been commercialized worldwide, but there are difficulties related to its high operating pressure [3]. It is also known that the adsorbed natural gas (ANG) system is a thinkable process, which can solve several problems in natural gas storage [4, 5]. At a comparatively low pressure (3-4MPa) achievable by single-stage compression, ANG has almost the capacity of CNG [6]. Among the adsorbents explored, microporous carbon adsorbents are the most attractive for the storage of natural gas. The majority of carbon adsorbents are granular,

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powder, or fibers [7]. Carbon adsorbents usually have several advantages such as high surface area (BET) and high pore volume on a mass basis. A monolithic activated carbon without loss of micropore volume is preferred to traditional granular activated carbon because it can be manufactured with higher bulk density and can be adapted to the shape of the storage vessel [8, 9]. The monoliths can be produced using a binder, which helps to keep the carbon particles in a compressed form. Conventional preparation methods [10, 11] consist of mixing the activated carbon with a binder, compression and moulding using a hydraulic press and, finally, using pyrolysis process to improve the binder properties and decrease the weight of binder in the monolith. One of the aspects occurs in ANG storage performance is the durability of adsorbents in cycling operations. Pupier et al. [12] considered the influence of the composition of natural gas during successive cycles of charge and discharge. On the other hands, Ridha et al. [13] investigated thermal behavior of ANG storages filled with activated carbons during dynamic charge condition at room temperature.In this study, to predict durability of monolithic activated carbon and the effect of cycling operations on adsorption and desorption capacity of methane on the adsorbent are considered.

Nomenclature

C	capacity
n	mole
P	pressure
T	temperature
V	volume
Z	compressibility factor

2. 2 Experimental Method

2.1. Apparatus

In this work, a volumetric based apparatus was used to obtain the adsorption isotherm of methane on activated carbon. The schematic diagram for the apparatus is shown in Figure 1. As can be seen, the apparatus consists of a calibrated sample cell as well as a reference cell, rated up to 130 MPa and temperature of 423.15 K, in which methane can be stored.

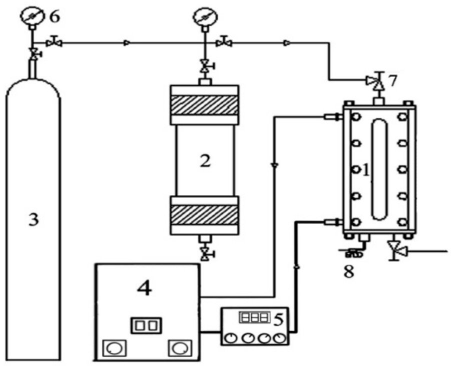

Figure1. Schematic diagram of the apparatus

1- Adsorption cell, 2- Reference cell, 3- Methane 99.995% cylinder, 4- Air circulator bath, 5- Controller, 6-Pressure Regulator, 7- 1/4" valve for methane inlet, 8- Thermometer

This set up has a portable pressure indicator rated up to 10 MPa and temperature ranging from 223.15 K to 473.15 K, which consists of a pressure transducer to measure the equilibrium pressure with the accuracy of 10 mbar. This apparatus also has an air circulator bath that can keep adsorption and desorption temperature at a constant value from 263.15 K to 344.15 K with deviation of 0.1 K.To record the sample cell temperature, a thermometer with an accuracy of 0.1 K was used.

2.2. Materials

One type of activated carbon as powdered is used in this study. The physical specifications of the sample are listed in Table1.