

Determination the Carbon Adsorbents Effectiveness on Adsorption and Desorption Processes of LPG

Imanurezeki bin Mohamad¹, Safarudin Gazali Herawan¹, Mohd Yusoff bin Sulaiman¹, and Farid Nasir Ani²

¹Faculty of Mechanical Engineering, Kolej Universiti Teknikal Kebangsaan Malaysia, Locked Bag 1200, 75450 Ayer Keroh, Melaka, Malaysia

²Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor D.T., Malaysia

¹Email : safarudin@kutkm.edu.my

ABSTRACT

The current research focuses on the experimental investigation of carbon adsorbent produced from oil palm shell as a raw material. These carbon materials can be used for catalyst supports and adsorbents because of its prominent characteristics, such as high surface area, relatively uniform pore size, ordered pore structure and good thermal and mechanical stabilities. The objective of the present research is to develop a liquefied petroleum gas (LPG) gas storage based upon the carbon adsorbents. Carbon adsorbent as a gas storage media for LPG is an alternative way to overcome the disadvantages of pressurized vessel such as high-pressure flammable gas content, dimension of gas tank, and other dangerous aspects. The effect of activation in carbon adsorbent was observed on adsorption and desorption processes of LPG gas. This research will be conducted by designing and developing the experimental rig for preparing carbon adsorbent, which are consisted of a reactor, tube furnace, suction blower and some accessories. Other process, which is activation carried out in a same reactor, which blanketed by tube furnace where the pyrolysis take place. These research aims are used to the extending application of proposed framework to problem arising in the alternative fuel for vehicles.

Keywords: Carbon Adsorbent, LPG, Gas Storage, Adsorption, Desorption

1.0 INTRODUCTION

Carbon adsorbents are versatile adsorbents. Their adsorptive properties are due their high surface area, microporous structure and a high degree of surface reactivity. As similar with carbon adsorbent, the commonly known is an activated carbon. In its broadest sense, the activated carbon includes a wide range processed amorphous carbon-based materials. Activated carbons have a highly developed porosity and an extended interparticulate surface area. Their preparation involves two main steps: the carbonization of the carbonaceous raw material at temperature below 800°C in an inert atmosphere and the activation of the carbonized product. Thus all carbonaceous raw materials can be converted into activated carbon, although the properties of the final product will be different, depending on the nature of the raw material used, the nature of the activating agent, and the conditions of the carbonization and the activation processes (Mohan, et al.,

2002). Potential natural precursors for carbon adsorbents include coconut shells (Auvil, et al., 1993), coal (Mohan et al., 2002), walnut shell, palm date pits (Al-Attas, 2003) and oil palm shell (Zainuddin, et al., 2005; Herawan, 2000). Their advantages as carbon feed stocks include high density, availability as renewable resources, low cost, low ash content, and they are capable of producing activated carbons of high adsorption capacity.

The research is focused on the experimental investigation of carbon adsorbent, which prepared from oil palm shell as a raw material and other commercial activated carbon for comparison. These carbon materials can be used for catalyst supports and adsorbents because of its prominent characteristics, such as high surface area, relatively uniform pore size, ordered pore structure and good thermal and mechanical stabilities. Herawan (2000) produced carbon adsorbents from oil palm shell in order to achieve the desired application of gas separation such as nitrogen from air or CH₄ from CO₂. This study indicate that the char modified has a potential for use in O₂/N₂ separation whereas high temperature char prepared at 900°C is expected to be useful for the separation of CH₄ from CO₂/CH₄ mixture.

The experimental procedures and results obtained are comprehensively and systematically presented. The objective of the present research is to develop a liquefied petroleum gas (LPG) gas storage based upon the carbon adsorbents from palm oil shell as raw material. Additionally, this research aims are used to overcome the extending application of proposed framework to problem arising in the alternative fuel for vehicles such as LPG and natural gas.

2.0 LIQUEFIED PETROLEUM GAS (LPG)

Liquefied Petroleum Gas (LPG) have been widely used in commercial vehicles, and promising results have been obtained from fuel economy and exhaust emissions points of view (Beer, et al., 2002). LPG can be produced from natural gas and crude oil (Bayraktar and Durgun, 2005; Beer, et al., 2002). Dagaut and Ali (2003) stated that LPG mainly consists of propane and butane, and it may also include different hydrocarbons such as propane, iso-butane and n-butane in various proportions. Bayraktar and Dungun (2005) reported that LPG and other gaseous fuels have common properties that provide them some advantages and disadvantages relative to gasoline. On the basis of these considerations, their work in the case of using LPG in SI engines resulted that, the burning rate of fuel is increased, and thus, the combustion duration is decreased. In recent years, the development of an economical carbon adsorbent has been widely investigated for natural gas storage. Carbon adsorbent as a gas storage media for LPG is an alternative way to overcome the disadvantages of pressurized vessel such as high-pressure flammable gas content, dimension of gas tank, and other dangerous aspects. Hence, the effect of activation in carbon adsorbent was observed during the adsorption and desorption processes of LPG gas.

3.0 METHODOLOGY

The raw material is oil palm shell. This research will be conducted by designing and developing the experimental rig for preparing carbon adsorbent, which are consisted of a reactor, tube furnace, suction blower and some accessories. At the same time, the carbon adsorbent test bed is designed and developed, which has a column adsorber for carbon adsorbent and is connected online with a Gas Detector to determine the breakthrough

curves for hydrocarbon gases that can lead to determine adsorption selectivity for certain gas. The resulting carbon products are defined as;

- i) C300 was prepared at 300°C (this char is used as the based char);
- ii) C500 was prepared at 500°C; and
- iii) C700 was prepared at 700°C.

Next stage is preparing activated carbon from char products. By varies the peak temperature, heating rate, and residential time of the sample, the optimization of it can be achieved. This process is carried out in a laboratory scale, single step fixed bed reactor, which blanketed by tube furnace where the pyrolysis take place. Nitrogen gas is used to obtain an inert atmosphere in the reactor and CO₂ gas is used to activate the sample. A suction blower is used to remove volatile matter as well as other gases during the process. The resulting mixed char and plastic bag is defined as; i) C300-10-60 was prepared at 300°C; ii) C500-10-60 was prepared at 500°C; and iii) C700-10-60 was prepared at 700°C.

Final stage, all the sample will be characterized using a constant volume adsorption apparatus (N₂ adsorption) is used for determining Average Pore Diameter, Surface area, Micropore Distribution, Micropore Volume of carbon adsorbent. For application, a carbon adsorbent test bed is used to observe the adsorptive and desorptive capacity of hydrocarbon gas at carbon adsorbent. The resulting of analysis is reviewed as; i) C300-CO₂-60 was prepared at 300°C; ii) C500-CO₂-60 was prepared at 500°C; and iii) C700-CO₂-60 was prepared at 700°C.

4.0 RESULTS AND DISCUSSIONS

Figure 1 show the difference conditions applied in term of weight sample from the adsorption and desorption process. Sample C700-CO₂-60 adsorbed 0.54 g LPG gas, C500-CO₂-60 adsorbed 0.42 g gas and C300-CO₂-60 adsorbed 0.02 g gas.

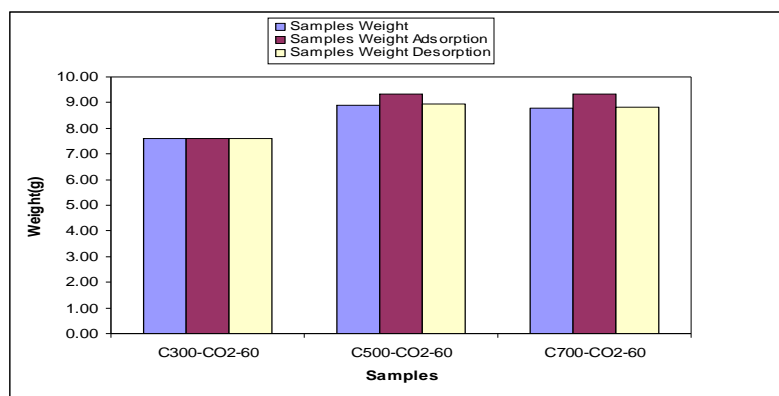


Figure 1: The samples weight on conditions: Before Adsorption, Adsorption, and Desorption

Figure 2 shows the adsorption of LPG with different temperature of activated char. In all cases, activated chars reach their maximum adsorption, however, in certain time the adsorption is inconsistent. This dependence is a result of selected temperature of CO₂ activation and residence time. The results indicate that the increasing of temperature will increase the adsorption process. The sample activated carbon C700-CO₂-60 have a good adsorbed component tends to the stable adsorption value that show it takes a long time to

reach 0.5% gas in 685 seconds (s) and to maximum adsorption 0.4% gas in 3610 s. Meanwhile, sample C300-CO2-60 show that this carbon adsorbent has small opened pore which is desirable to a gas since it just take short time to reach 0.5% gas in 205 s. Sample C500-CO2-60 shows an average adsorption action and unstable that takes 645 s to reach 0.5%. It might be happened since this sample is adsorbents of nonporous solids with an almost completely uniform surface that not all of its adsorbent has a good adsorption capability that result the data inconsistent.

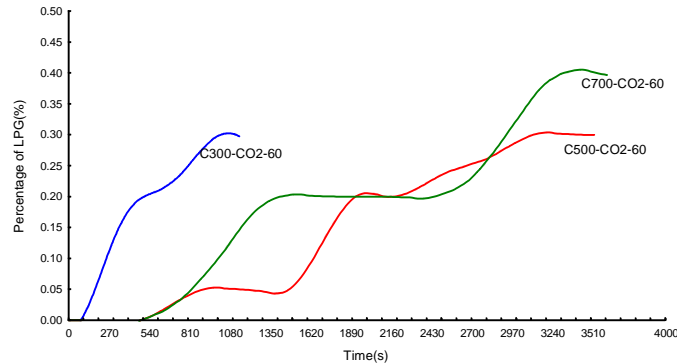


Figure 2: Graph Activated Carbon Due LPG gas Adsorption

The results of the desorption process from the various samples are shown in Figure 3. From the graph it is apparent that the samples which have a good adsorption capability does not mean that the samples have a good desorption capability. For instance, Sample C300-CO2-60 has small value of adsorption however, shows a good behavior in desorption of LPG gas, which takes 1210 s to reach 0% gas. Sample C700-CO2-60 demonstrated slow action of desorption process that takes 1595 s to reach 0% gas. This results was confirmed that the desorption of carbon adsorbents follow the breakthrough curve pattern, which start from 0% and will increase to maximum 0.25% gas and then decrease until 0% gas. Sample C300-CO2-60 takes short times to desorb since it just adsorbed a small volume of LPG gas during adsorption process, while sample C700-CO2-60 takes longer time to desorb because its adsorbed more volume of LPG gas than other samples. These result supports by BET surface area analysis using micrometric ASAP 2010, that show C700-CO2-60(A700) has 369.5947 m²/g, and follow by decreased number of BET surface area result continue with samples C500-CO2-60(A500) with 317.35 m²/g and C300-CO2-60(A300) with 0.3175 m²/g, which are shown in Figure 4.

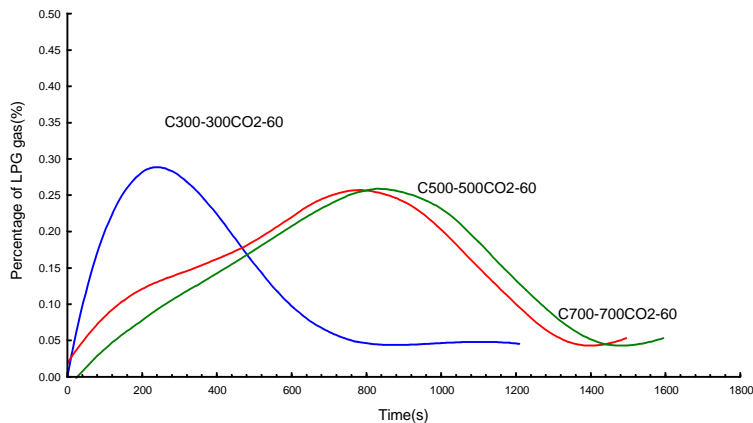


Figure 3: Graph Activated Carbon Due LPG gas Desorption

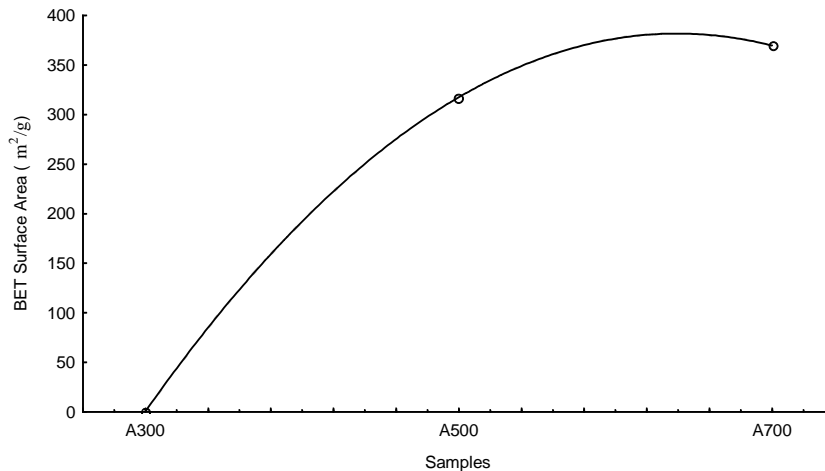


Figure 4: Graph Result BET Surface Area for samples

5.0 CONCLUSIONS

It has been demonstrated that the activation process in carbon adsorbent indeed affects the capacity of LPG adsorption. In this regard, the higher peak temperature can contribute more capability to adsorb LPG gas. The best sample is C700-CO2-60 which shows a higher capability to adsorb LPG and consistent data than the other samples. The desorption of carbon adsorbents follow the breakthrough curve pattern, as similar with a normal distribution curve. It is recognized that the smaller amount of LPG adsorbed in the carbon adsorbent, the faster desorption process occurs, and more amount of LPG adsorbed in the carbon adsorbent, results takes longer time to desorb the gas

ACKNOWLEDGEMENTS

This study was funded by a grant from Ministry of Higher Education.

REFERENCES

1. Al-Attas, O. G. O. *The Production of Activated Carbon from Local Palm-Data Pits for Pollution Removal Process*. Master Thesis. King Fahd University of Petroleum and Minerals. 137pp. (2003).
2. Auvil, Steven R., Schork, Joan M. and Srinivasan, R. *Air Separation by Pressure Swing Adsorption With A High Capacity Carbon Molecular Sieve*. (U.S. Patent No. 5240474.) (1993).
3. Bayraktar, H., and Durgun, O. Investigating the effects of LPG on spark ignition engine combustion and performance. *Energy Conversion and Management*. 46: 2317-2333 (2005).
4. Beer, T., Grant, B., Williams, D., and Watson, H. Fuel-cycle greenhouse gas emissions from alternative fuels in Australian heavy vehicles. *Atmos Environ*; 36: 753-763 (2002).
5. Dagaut, P., and Ali, H. Kinetics of oxidation of a LPG blend mixture in a JSR: Experimental and modeling study. *Fuel*; 82: 475-480 (2003).
6. Herawan, S. G. *Characterisation and Analysis of Carbon Molecular Sieve from Oil Palm Shell*. Master Thesis. Universiti Teknologi Malaysia (2000).

7. Mohan, S. V., Rao, N. C., and Karthikeyan, J. Adsorptive removal of direct Azo dye from aqueous phase onto coal base sorbents: A kinetic and mechanistic study. *J. Hazard. Mater.*, 90: 189-204 (2002).
8. Zainudin, N. F., Lee, K. T., Kamaruddin, A. H., Bhatia, S., and Mohamed, A. R. Study of adsorbent prepared from oil palm ash (OPA) for flue gas desulfurization. *Separation and Purification Technology*. 45: 50-60 (2005).