Specific heat capacity of mangrove and waste palm trunk in raw, carbonized and activated form

Islam, Md. Amirul
Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University | International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University | Bangabandhu Sheikh Mujibur Rahman Science & Technology University

Thu, Kyaw
Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University | International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University

Saha, Bidyut Baran
Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University | International Institute for Carbon-Neutral Energy Research (WPI-I2CNER), Kyushu University | Mechanical Engineering Department, Kyushu University

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Specific heat capacity of mangrove and waste palm trunk in raw, carbonized and activated form

Md. Amirul Islam[1,2,4], Kyaw Thu[1,2], Bidyut Baran Saha[1,2,3,*]

[1] Kyushu University Program for Leading Graduate School, Green Asia Education Center, Interdisciplinary Graduate School of Engineering Sciences, Kyushu University, Kasuga-koen 6-1, Kasuga-shi, Fukuoka 816-8580, Japan

[2] International Institute for Carbon-Neutral Energy Research (WPI-I²CNER), Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

[3] Mechanical Engineering Department, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

[4] Bangabandhu Sheikh Mujibur Rahman Science & Technology University, Gopalganj 8100, Bangladesh

*Corresponding author email: saha.baran.bidyut.213@m.kyushu-u.ac.jp

Abstract: *Commercial activated carbon (AC) has been extensively employing as an adsorbent in the field of the separation process, purification of gases and adsorption cooling system in the last few decades. Recently synthesized activated carbon from mangrove or WPT have higher adsorption uptake than commercial ACs. Moreover, the specific heat capacity of such porous materials is another significant controlling parameter in adsorption characteristics simulation and system design. This research work is focused on the experimental evaluation of the specific heat capacities of raw, carbonized and activated carbon derived from mangrove and waste palm trunk (WPT). The apparatus used in this measurement is a heat flux type differential scanning calorimeter (DSC) from 30°C to 100°C temperature range. The specific heat capacity values are in the range of 0.7 – 1.1 kJ kg^{-1} K^{-1} for activated carbons depending on the carbonization condition during synthesis. No phase transition or thermal anomaly is encountered within the measurement conditions.*

Keywords: Activated carbon, KOH activation, Mangrove, Specific heat capacity, Waste palm trunk (WPT).

1. INTRODUCTION

Adsorbents have wide-ranging applications in heating ventilation and air conditioning (HVAC), refrigeration, gas separation, CO_2 capture and so on [1–4]. Adsorption cooling systems can be driven by low-grade waste heat at temperatures below 100 °C, and the adsorbent-refrigerant pairs are environmentally benign [5,6]. Surface area, pore volume, average pore size are the parameters which affect maximum adsorption uptake. Moreover, thermal conductivity and specific heat capacity are the governing parameters which influence adsorption kinetic. Table 1 shows typical value of these critical parameters:

Table 1. Properties of various activated carbon

	A	V_p	$\overline{w}$	k	W_0
Commercial Maxsorb III [7,8]	3045	1.70	1.12	0.360	1.20
M-AC [1]	2924	2.13	1.47	0.052	1.65
WPT-AC [1]	2927	2.41	1.68	0.044	1.90

Specific heat capacity of commercial Maxsorb III is reported 0.844 to 1.068 kJ kg^{-1} K^{-1} within the temperature ranging from 30 °C to 150 °C [9]. However, specific heat capacity of mangrove and WPT derived activated carbon is not available in the literature. In this research work, we have measured specific heat capacity of Mangrove, and WPT derived raw, carbonized (at 500 °C and 600 °C) and activated (at 900 °C with KOH6) carbon samples.

Nomenclature

A	total surface area	[m^2 g^{-1}]
C_p	specific heat capacity	[kJ kg^{-1} K^{-1}]
k	thermal conductivity	[W m^{-1} K^{-1}]
T	temperature	[°C]
V_p	micropore volume	[cm^3 g^{-1}]
$\overline{w}$	average pore width	[nm]
W_0	maximum adsorption capacity	[kg kg^{-1}]

2. METHODOLOGY

The apparatus used in this investigation was a differential scanning calorimeter (DSC). It had a heat flux cell enclosed by a heating block to dissipate heat to the samples via a constantan disc attached to the block. Temperature sensors were attached on the bottom of the discs to determine the temperature change of the samples. The schematic diagram of the differential scanning calorimeter is shown in Fig.1. One blank sample comprised of Aluminum pan and lid was always kept on one disc as the reference. The sample to be measured was put in another aluminum pan and sealed with the lid. The pan was then placed on the other disc. Both the discs were heated/cooled at a constant temperature increment/ decrement rate of 10 K/min. Three heating/cooling cycles were performed at 30 °C to 100 °C for the measurement. The sample was always maintained in an inert environment by flowing nitrogen gas at a controlled flow rate of 50ml/min.

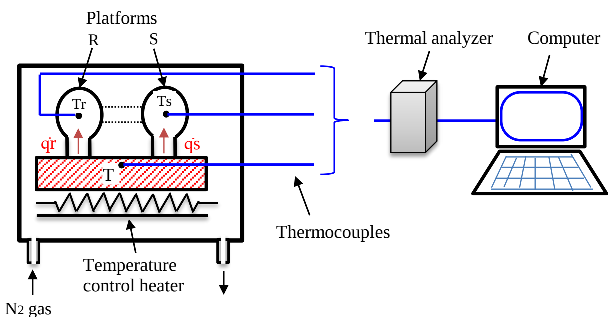

Fig. 1. Schematic diagram of the DSC apparatus [9]

A complete experiment to measure the specific heat capacity comprises of a blank run, a reference sample (α-Al_2O_3) run and the sample run.

3. RESULTS AND DISCUSSION

Three cycles of heating and cooling at 10 K/min rate is shown in Fig. 2. Isothermal period of 1 hour is maintained after each heating/cooling period. DSC curve in the first heating phase has a higher peak than next two heating phases. This peak indicates energy consumption of water vapor and other foreign materials trapped inside the sample pores. Next two heating periods have similar but smaller DSC peaks which indicate that the impurities are removed with heating and nitrogen flow. DSC data of the third heating phase was used to determine specific heat capacity of the sample. In this measurement, cooling phases cannot be precisely controlled because the cooling process is natural. Hence, the temperature decrement rate is not as accurate as the heating periods. Thus, specific heat capacity is not measured for cooling periods.

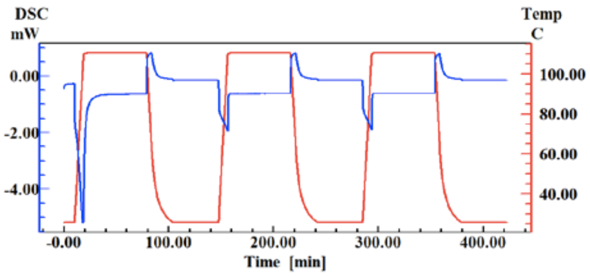

Fig. 2. Temperature program and DSC graph

Specific heat capacity of mangrove based five samples are shown in Fig. 3. Specific heat capacity is highest for the raw form of mangrove. Carbonized sample at 500 °C shows higher specific heat capacity than carbonized mangrove at 600 °C. Both the carbonized samples were activated at 900 °C, and specific heat capacity further decreases after activation. In the activated state, C500 °C – A900 °C shows higher specific heat capacity than C600 °C – A900 °C.

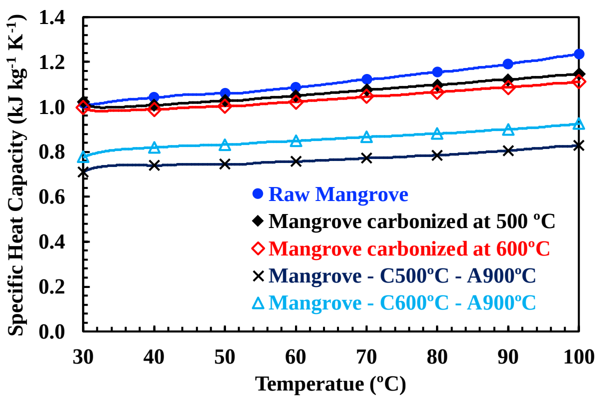

Fig. 3. Specific heat capacity of mangrove samples

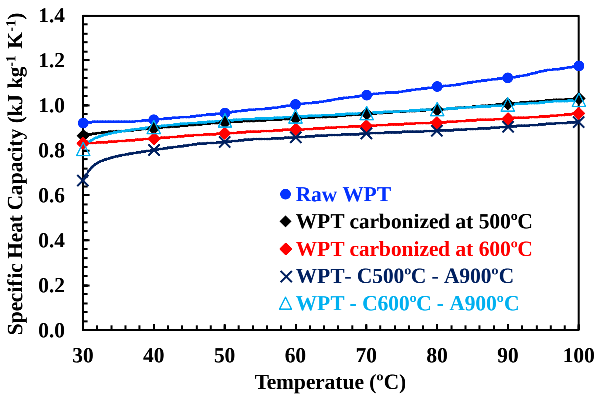

Fig. 4. Specific heat capacity of WPT samples

Specific heat capacity of WPT synthesized five samples are shown in Fig. 4. Specific heat capacity pattern of raw WPT is similar to raw mangrove sample. The value is highest among the five samples. Specific heat capacity decreased after carbonization for WPT samples too and the pattern is similar to mangrove based samples. However, after activation at 900 °C of both the samples, specific heat capacity did not decrease significantly like mangrove samples.

4. CONCLUSION

Specific heat capacity of ten samples synthesized from mangrove and waste palm trunk were measured in this study. In both cases, raw material shows highest specific heat capacity. Higher the carbonization temperature lower the specific heat capacity value. Activation of carbonized samples further decreases specific heat capacity. Specific heat capacity of mangrove derived activated carbon samples are 0.71 – 0.81 (C500-A900) and 0.78 – 0.93 (C600-A900) kJ kg^{-1} K^{-1}. On the other hand, specific heat capacity of WPT synthesized samples are 0.70 – 0.93 (C500-A900), 0.81 – 1.03 (C600-A900) kJ kg^{-1} K^{-1}. Both mangrove and WPT derived activated carbon have lower specific heat capacity than commercial Maxsorb III. Hence, these two adsorbents are better than commercial activated carbon.

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