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Analysis of the Characteristics of Natural Materials as Adsorbents in Air Conditioning Adsorption

Aqsal Raja Bramastha[1*], Made Sucipta[2], Hendra Wijaksana[2]

[1]Undergraduate Student of Machine Engineering Study Program, Faculty of Engineering, Universitas Udayana, Denpasar, Indonesia

[2]Machine Engineering Study Program, Faculty of Engineering, Universitas Udayana, Denpasar, Indonesia

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***Corresponding author:**
Aqsal Raja Bramastha

E-mail address:
aqsalraja.bramastha@yahoo.com

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ABSTRACT

The use of an air conditioner (AC) increases the use of compressors and electricity supply quite significantly. This will increase global warming and the occurrence of an energy crisis. Referring to this, a cooling system that is more energy-efficient and environmentally friendly is needed. One alternative is to use natural materials as adsorbents in adsorption air conditioning. In this system, changes in humidity levels occur due to the process of absorption of air moisture in each test material in the packed bed. The purpose of this research is to determine the regeneration characteristics of natural materials and activated carbon, as well as their performance against moisture. The characteristics tested also include contact angle test and proximate test. In addition to the type of material, mass variations of 200gr, 400gr, and 600gr are also carried out as well as variations in the combination between materials. The results obtained from the regeneration test 9 times, natural ingredients affect air conditioning. The larger the mass tested, the greater its ability to reduce humidity. In another sense, 600gr activated carbon provides the most optimal performance among other natural materials, both in mass variations and combined variations.

1. Introduction

Coal, oil, and natural gas are one of the most frequently used natural resources, so they are experiencing a crisis of availability. Another impact is global warming. Global warming is increasing in number due to increased greenhouse gas emissions in the atmosphere. These emissions come from the process of burning fossil fuels (petroleum and coal). One of the causes of global warming is the use of air conditioners (AC). This is because the air conditioner requires refrigerant, one of which is CFC (chlorofluorocarbon). Chlorine (chlorine), fluorine (fluorine), and carbon (carbon) are chemicals contained in CFCs. CFCs have a bad impact because they have properties that can damage the ozone layer. CFCs will decompose when they reach the stratosphere due to the intensity of ultraviolet light from the sun, then release chlorine atoms (Cl). Thousands of ozone molecules can be dissociated or disassociated due to one chlorine atom molecule, resulting in the depletion of the ozone layer.[1]

60% of the electricity used in hotels in the city of Jakarta is used to supply energy to the cooling machine.[2] To overcome and reduce the impact of the energy crisis and global warming, an adsorption air conditioning system can be developed.[3] The process that occurs when a fluid (liquid or gas) is bound to a solid (absorbent or adsorbent), and the formation of a thin layer or film (absorbed substance: adsorbate) on its surface is called adsorption.[4,5] In this test, the adsorbent used as adsorption air conditioning material is an adsorbent of natural materials, such as activated carbon made from coconut shell, zeolite, and pumice, which will be combined later.

The regeneration test in this study was repeated 5 times to determine the regeneration with a duration of 2 hours in the air conditioning test room. With a heating temperature of 120°C in the oven, the duration is 30 minutes. To find out more about the properties of each test material, a contact angle test and also a proximate test was carried out.

2. Literature Review

Adsorption is an event where the molecules of a compound are adsorbed or bonded to the surface of a solid. Adsorption is a process that occurs when a fluid is bound to a solid and then forms a thin layer on its surface. The existence of an attractive force between an adsorbate molecule and the active site on an adsorbent surface causes adsorption (Figure 1).

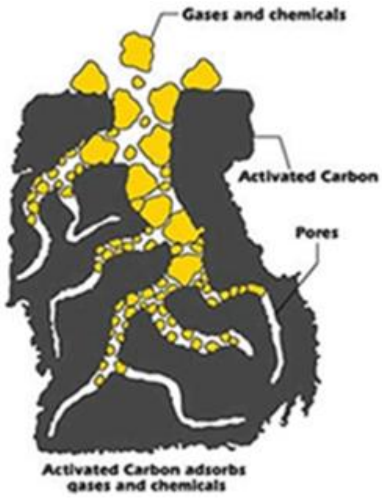

Figure 1. Schematic of the adsorption process.

An adsorbent is a substance or material/material that can bind and maintain a liquid or gas in it. An adsorbent is a material that has pores, and adsorption occurs on the pore wall or certain areas in the pore. There are two types of adsorbents, namely polar adsorbents and nonpolar adsorbents. Polar adsorbents or also called hydrophilic, such as zeolite, silica gel, and active alumina. In contrast, for non-polar or hydrophobic adsorbents, examples of adsorbents belonging to the group are activated carbon and polymer adsorbents.

The type of adsorbent that is often used in adsorption systems and also the adsorbent that will be used in this test is activated carbon. This is because the surface area, as well as the adsorption ability of activated carbon, is better than other types of adsorbents. The large surface area of activated carbon is due to its porous structure. The pores are what make activated carbon able to absorb.[6-8]

Zeolites have several properties, such as being easy to release water due to heating, but zeolites are also easy to bind and attract water molecules in moist air. The nature of zeolite as a type of adsorbent and as a molecular filter occurs because the zeolite structure is hollow. That's why zeolite can absorb a large number of molecules that have a size smaller than or equal to the size of the cavity it has. Pumice or pumice is a natural material and also a type of adsorbent that has a more economical price or cost and has a good level of effectiveness. The structure of the pumice itself is porous and contains many fine capillaries. This causes the adsorbate to be adsorbed on the capillaries.[9]

The contact angle is the angle formed between the flat plane of the test material and the surface of the liquid or droplet that is dropped on the test material.

From direct observation of the contact angle, it will be known that the tested material has hydrophilic or hydrophobic properties. Material can be called hydrophobic if it is difficult for water to flow on the surface of the material, and it is called hydrophilic if water flows easily on the surface.[7] Figure 2 shows an illustration of the contact angle value.

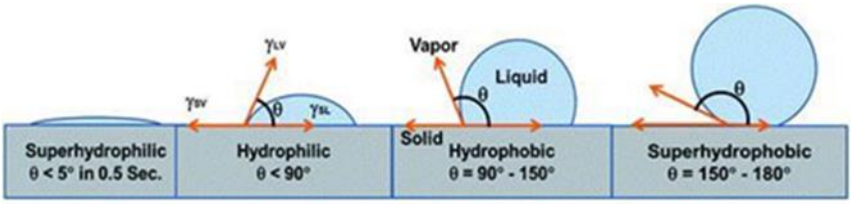

Figure 2. Contact angle.

3. Methods

This research is an experimental study. The tools and materials needed and used in this air conditioning research consist of an air conditioning test room, electric oven, digital scale, inclined manometer, hygrometer, packed bed, mesh filter, and stopwatch. This research was carried out through several stages of the testing process, the first being the heating process using an oven, regeneration testing in the test chamber, contact angle testing, and finally, proximate testing. Each of these tests has its testing procedure and is different from one another. At this stage, the materials in the form of activated carbon, zeolite, and pumice that have been obtained commercially are combined in a ratio of 1:1 or with a total mass of the combined material of 600gr. The combined material was tested for its absorbency against air humidity in a test room model with air circulation through the prepared, packed bed pile.

The combined material of activated carbon + zeolite + pumice stone (KA+ZE+BA) was tested for regeneration and its ability to absorb moisture until it reached a saturated condition. The saturated condition is characterized by the absence of mass gain and changes in humidity. Figure 3 below is the test room used in this study.

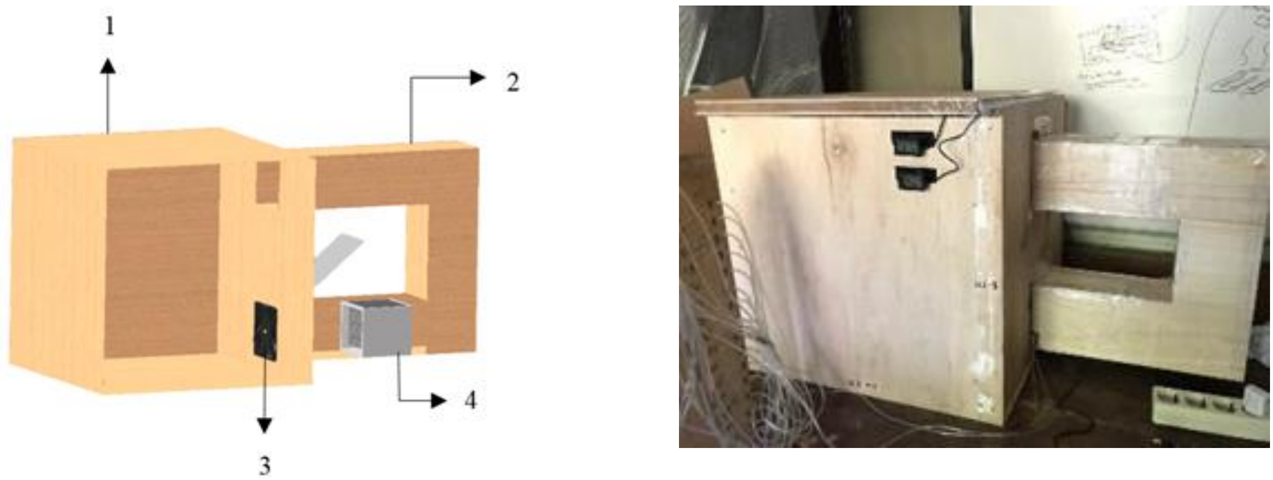

Figure 3. Air conditioning test room. Notes: (1) The test room is built using plywood with dimensions of 50cm x 50cm; (2) The test chamber channel is 40cm x 8cm; (3) The computer fan measures 8cm x 8cm; (4) The test material container or packed bed.

Each material is tested for its ability to absorb air humidity at certain time intervals with several stages, namely heating, weighing, and absorption. Before testing, all test materials were dried simultaneously by heating them in the oven at the same temperature and duration of time, namely 30 minutes at a temperature of 120ºC. After being in the oven, the combined material would be allowed to stand until the temperature equals room temperature.

In this study, all materials were tested in groups or combined, then weighed according to a predetermined mass with a ratio of 1:1, with each mass per material of 200 grams, where the total combined weight of the material is 600 grams. Materials that have been combined and weighed were tested for regeneration for 2 hours for the test chamber created. Each test was repeated 5 times, starting from the drying process to determine the regeneration. The final results were observed and measured in the temperature and humidity of the test room.

4. Results and Discussion

The value of the contact angle of a material surface against a liquid drop is obtained by direct observation using a digital camera with a high-speed setting. The shooting results are processed using the Image J software application to determine the angle accurately. The results of the contact angle test and its illustrations can be seen in Figure 4.

Figure 4. The value of the contact angle on each surface of the material.

Figure 4, which has been described, shows that all of the test materials have hydrophilic properties, meaning that water can flow on the surface of the material. That's because the value of the contact angle that is owned has a value below 90°. It can also be seen in the form of a table in Table 1 below.

Table 1. The value of the contact angle.

Material	Contact angle	Cosθ
Activated carbon	85.8º	0.147
Zeolite	12.3º	0.977
Pumice	16.1º	0.96

Table 2. Proximate test results.

Material	Moisture (%)	Volatile (%)	Ash (%)	Fixed carbon
Activated carbon	7.86	16.29	1.19	74.65
Zeolite	5.5	9.47	85.2	0.01
Pumice	6.73	7.86	85.37	0.03

In Table 2, the material with the lowest moisture content is natural zeolite material, which is 5.5%, while the material with the highest content is 7.86%, namely activated carbon. Referring to the standard SNI 06-3730-1995 moisture content for activated carbon maximum of 15%. For the volatile content of natural materials, pumice has a fairly low content of 9.47% and zeolite 9.47%. If we look further, the fixed carbon in Table 2 obtained in the activated carbon sample is quite high, namely 74.65%. The minimum limit for fixed carbon content in activated carbon is 65%. It is concluded that the activated carbon used in this air conditioning study complies with the SNI standard and shows that the carbon left behind is quite large, even though the moisture, ash, and volatile levels have been determined.

The group variation test was repeated 5 times because after the fifth test, the material did not tend to give a significant change, and there was no decrease in the humidity of the test room. Table 3 below is the result of research from testing groups or combined variations.

Table 3. The results of the combined regeneration.

Material	**Regeneration test**	**Temperature (°C)**		**Moisture (%)**		**Mass (gram)**		**Pressure (cmHg)**	
		Beginning	**End**	**Beginning**	**End**	**Beginning**	**End**	**Beginning**	**End**
KA+BA+ZA	1	32.3	30.05	70.5	68	600.6	601.9	2.2	2.2
	2	29.7	29.7	69.5	65.25	600.4	601.7	2.2	2.2
	3	29.15	27.25	68	66.5	601.5	603.1	2.2	2.2
	4	29.75	29.65	65.5	63	601.2	602.4	2.2	2.2
	5	29.5	29.3	62.5	60	601.4	602.9	2.2	2.2
	Average	30.08	29.19	67.2	64.55	601	602.4	2.2	2.2

The test results in Table 3 above, the level of moisture reduction that occurred in the variation of the KA+BA+ZE group touched the lowest number, namely 60%. Based on table 3, the performance of the combined material of activated carbon, pumice, and zeolite (KA + BA + ZE) is quite good. The level of humidity reduction achieved was 3.94%, from 67.2% to 64.55%, accompanied by the largest decrease in temperature, which was 2.96%. The regeneration characteristics that occurred in the combined group KA+BA+ZE were quite good. However, they could only reduce the humidity by 3-4%, and the temperature at 1-2°C only compared to the air mass in the test room. When the material is tested, before the testing time is over, the material is already saturated to absorb water vapor in the test chamber so that the decrease in temperature and humidity that occurs is not too large.

5. Conclusion

The combination of activated carbon, zeolite, and pumice to increase the air moisture absorption capability of each material can be classified as unsuccessful. In connection with this, the level of temperature reduction produced is not significant, which is only 2.96% or 0.89°C. The decrease in temperature that is not too significant occurs because when water vapor in the air is trapped on the surface of the material, a condensation process occurs, which causes a decrease in temperature even though the number is not large.

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