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The design of furnace for biochar production by using vacuum pump and temperature manual control

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Abstract. Temperature control is very prominent to be done in producing biochar, because the quality of biochar depends on combustion temperature and the amount of oxygen existing when the combustion process is happening. In this research, the designing of furnace for biochar production by using vacuum pump and temperature manual control had been done. The fuel used was LPG gas. The furnace was designed by having two parts which are cylinder tube for biochar production and tube feet as the holder of the kiln. The calibration of the furnace for biochar production was done to find out the temperature and the pressure that can be generated and its effect toward produced biochar. The calibration was done by using vacuum pump to vacuum the combustion chamber and temperature manual control as temperature indicator. There were two steps for this furnace calibration, first, the leakage test and second, combustion test of biochar production. The leakage test was done by using bubble test method. The result showed that there were still some leakages happened, but they were fixed with glue on the leak parts. As the final result of the leakage calibration, the vacuum condition obtained was -25 cmHg. And as the result of biochar combustion as long as one and two hour, the temperature reached 280°C and 250°C.

1. Introduction

Biochar is carbon-rich solid material that is formed through combustion process of organic material or biomass without or with a little bit of oxygen (*pyrolysis*) at the temperature around 250-500°C. Not common with organic material, biochar is stable for hundreds even thousands of years when it is mixed into soil and able to sequester carbon in the soil [1]. The term *biochar* is used because *biochar* comes from the remaining of biomass and hopefully it is safe and eco-friendly. There are some differences between ordinary charcoal known among people and biochar as soil corrector. One of them is in the combustion process where biochar is obtained from imperfect combustion (*pyrolysis*), which is combustion with oxygen limited in temperature range 350 – 800 °C [2].

To produce biochar, the furnace that can minimize or abolish oxygen in the combustion chamber is needed. The quality of produced biochar is very affected by the combustion temperature and the amount of oxygen existed during the combustion process itself [3]. Due to that reason, it is very important to control the combustion temperature and decrease the amount of oxygen during



combustion process. The control itself can be managed from the furnace used. Research result from Adam [4] in India and South Africa has been able to produce the combustion tool in the form of more eco-friendly retort kiln especially in emission production (Eco charcoal). Adam's retort kiln furnace is based on the use of separated furnace box to produce combustion heat and open space pyrolysis where the pyrolysis take places [5]. Retort kiln is designed to accommodate raw material with capacity as much as 3 m^3 , and the temperature reached is $200\text{--}300^\circ\text{C}$ [5]. Furthermore, Scmidth in his research also designed Kon Tiki furnace with conical iron plate measured 2 m^3 and top diameter is $2,4 \text{ m}$, producing biochar as much as 500 kg in 3 hours. The quality of biochar produced from Kon Tiki has fulfilled the international quality standard like IBI and EBC. Gas emission and aerosol are very low compare to other charcoal and biochar tools [6].

In this research, the making of combustion chamber of furnace or tube will be vacuumed to eliminate oxygen level by using vacuum pump. To vacuum the combustion chamber, an adjustable compressor can be used supported with monitoring tool and temperature manual control so that the combustion temperature of biochar can be controlled. After the furnace is designed, the calibration is needed to find out the temperature and pressure that can be produced and their effect toward produced biochar from combustion. The test is done in two steps which are leakage test and combustion result test.

2. Methods

This research took place in Science and Technology Faculty of Jambi University. It was started from June until August 2019. The furnace as a whole consists of two parts which are vacuum tube and its feet. The diameter of vacuum tube is 50 cm , its length is 70 cm , and its dense is 2 mm . Iron plate as the tube cover is 70 cm in width and its dense is 3 mm . The frame of vacuum tube was made of $4 \times 4 \text{ mm}$ holo iron with 70 cm in height. The other material used in the making of the furnace is bolt as the tube door's flap, bumble rubber for tube door's vacuum, pressure detector, temperature detector, and LPG gas. The design of furnace for biochar production is showed in the figure 1.

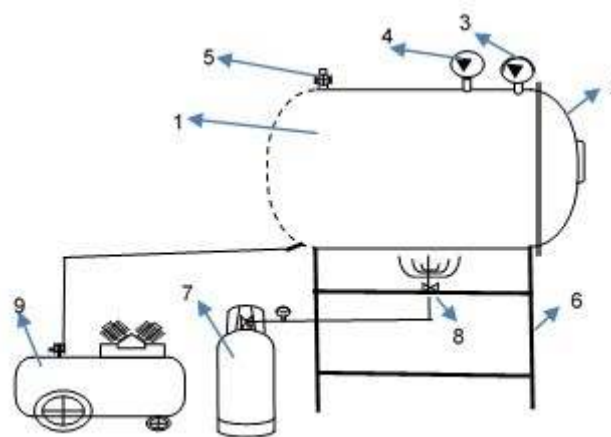


Figure 1. The design of furnace for biochar production.

Figure 1 shows the layout of furnace for biochar production. Parts of this furnace are; 1) Combustion tube. 2) Combustion Tube Door. 3) Temperature indicator. 4) Pressure Indicator. 5) Pressure relief valve. 6) Tube feet. 7) LPG tube. 8) LPG fuses. 9) Compressor Pump. The combustion was done based on the design of the furnace, where the furnace has compressor pump as its vacuum pump and LPG gas as the fuel.

The procedures done in designing were assembling the furnace and doing vacuum pump test. The furnace us assembled based on its layout. Vacuum pump is 70 cm in length with 50 cm iron plate

closing door. At the vacuum tube, temperature and pressure indicator were assembled. Vacuum tube feet are made of 70 cm iron pipe. The source of fuel for furnace is LPG gas.

The furnace calibration was done in two kinds of test, leakage test and combustion test. The procedure for leakage test of vacuum tube was made to reduce or eliminate oxygen level by vacuuming the combustion chamber using vacuum pump. The result of this test is to confirm that the tube is in vacuum state and to get the vacuum value of tube. The combustion test was done in two steps. The first combustion was done for one hour by using compressor as the vacuum pump. The second test was done for two hours without using vacuum pump. For these two combustion tests, it can be seen how high the temperature that can be reached by the furnace. The samples used to test this tool are coconut shell and empty bunches of palm oil.

3. Results and discussion

The tool was assembled based on its design. The furnace was assembled and connected through welding in every connection. Also, for the furnace feet, every piece of iron also connected through welding. After the furnace was assembled, then the test was executed toward the furnace. The shape of the furnace can be seen in Figure 2.



Figure 2. The furnace for biochar production.

Figure 2 shows the form of the furnace. It is cylinder with square door. To ensure the combustion tube is in vacuum condition, inside the door, bumble cable is plugged. On the tube, there are temperature and pressure indicator that have to be observed manually. At the back of the tube there is a valve to dispose the pressure, and the other valve for vacuum pump. Below the tube, there is combustion fuse, where the fuel for the furnace is LPG gas.

The furnace was tested by doing combustion and doing observation about temperature that can be reached. There are two kinds of test toward the furnace. The first one is leakage, it was to ensure that the furnace is in vacuum condition. The second was combustion test, the purpose of this test is to observe the temperature that can be reached and biochar that can be produced.

3.1. The furnace leakage test

The leakage test was done to ensure that the furnace vacuum from oxygen. It was done by doing bubble test where the air was injected inside the furnace. In order to vacuum the combustion chamber, the compressor that its pressure can be adjusted, supported by monitoring device and manual temperature control can be used, so that the temperature of biochar combustion chamber can be controlled.

From this test, the result was some leakage still happened, it was shown by the existence of air bubble that came out from the tube door and the hose of temperature and pressure indicator. The leakages happened at the vacuum tube were fixed by attaching glue along the side lines of the tube

door and its indicator. After the fixing process, the leakage test then was executed again. The result was the vacuum condition that can be reached was -25 cm Hg.

3.2. Biochar combustion test

The combustion test was done in two times, for one hour and two hours. The purpose of this test is to observe how the temperature device function, the temperature that can be reached, temperature and combustion time effect towards produced biochar. The vacuum condition used was -15cmHg.

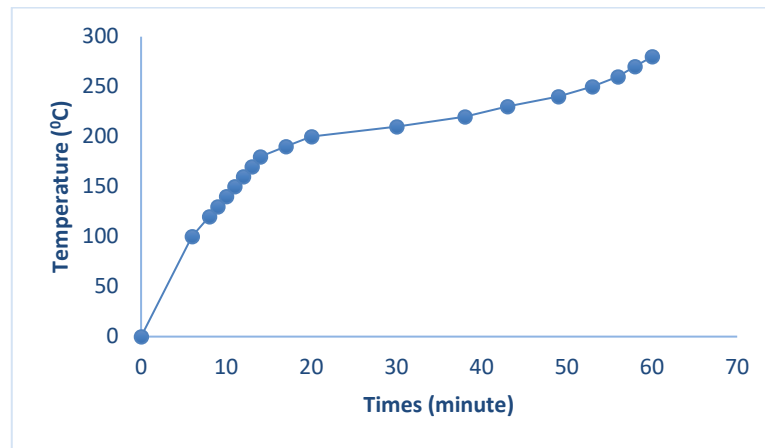


Figure 3. Chart of relationship between one hour combustion with measured temperature.

Figure 3 shows the relationship between the time length of biochar combustion with the measure temperature when the combustion process happened for one hour and the maximum temperature measured was 280 °C. The measured temperature was suitable with pyrolysis temperature to produce biochar because biochar is carbon-rich solid material formed through the combustion of organic material or biomass without or with a bit of oxygen (pyrolysis) at temperature ranged between 250-500°C [1]. From the obtained data, it also can be seen that the longer the combustion time is, the higher the temperature.

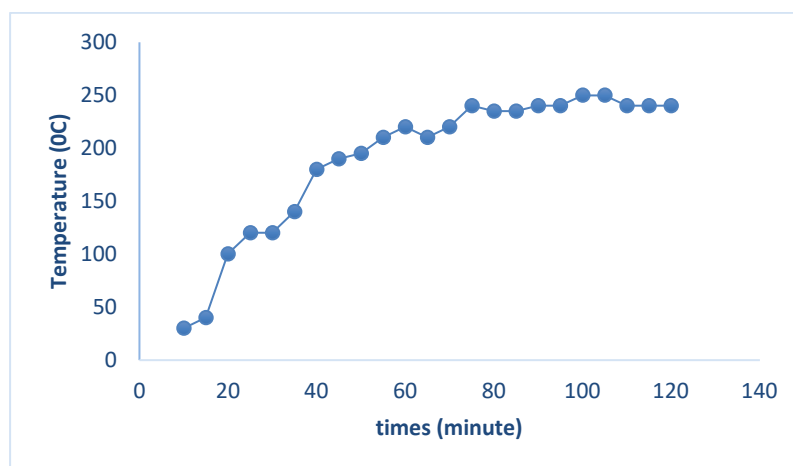


Figure 4. Chart of relationship between two hour combustion with measured temperature.

Figure 4 shows the relationship between two hour biochar combustion with measured temperature. Because it is known from the one hour combustion test that the temperature is getting higher as the combustion time is getting longer, so it is necessary to increase the combustion time to be two hours. In this process, reached temperature and time indicator were also observed. The pressure was released when it already filled the tube, the indicator was the smoke came out from the side line of tube door.

In the combustion process, every time the pressure was released from the furnace tube when the maximum pressure reach 20 psi, the measure temperature would decrease. In the other hand, if the furnace tube had pressure, the temperature would increase again. It is suitable with the Gay Lussac theory who stated that at the fixed volume, gas pressure is directly proportional with its temperature [7]. From figure 4, it can be seen that the maximum temperature reached in two hour combustion was 250°C. When the pressure was released, the maximum temperature decreased into 240°C. So based on figure 3 and 4, the measured temperature was still below 300°C. It was caused by much heat energy lost. The lost heat was caused by the condition of the furnace where the gas was placed was at the open space and have not coated with heat resistant yet.

The longer the combustion time, the time needed to release the pressure was also increase because water content of raw material used was decrease. Due to the temperature that could be reached was 250°C, the pyrolysis in this research is categorized as slow primer pyrolysis. This kind of pyrolysis happens at 150-300 °C temperature range. It usually used in the process of charcoal production. That is why it takes days even weeks to produce charcoal with good quality and in a big amount [8]. *Pyrolysis* is decomposition process of organic material thermally at high temperature without the existence of oxygen at all [9]. There is a linkage between time and temperature of pyrolysis towards produced biochar by seeing at the level of biochar ashes [10], so for the next research, the test towards ashes level of biochar need to be done to see the quality of biochar.

4. Conclusion

The furnace for biochar production without oxygen by using vacuum pump was successfully created, in which it consists of vacuum tube and its feet. The result of measurement showed the measured temperature was suitable with biochar pyrolysis temperature. The longer the biochar combustion time, the higher the measured temperature was, resulting the production of biochar meet the expectation.

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