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Plastic Waste Processing to be Alternative Fuels to Create Clean and Healthy Environment

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***Abstract*—Plastic waste is non-organic material that is difficult to destroy even if it is burned and is often found in the environment around us. This waste comes from households, traditional markets, shops, terminals, and others in the form of plastic food packaging, beverage bottles, plastic bags, and others. Lack of public awareness of environmental cleanliness and irregular waste processing makes the environment dirty. So far, only certain types of plastic are collected by scavengers for recycling such as plastic bottles and cups of mineral water, while other types of plastic are left alone so that they pollute the environment around us. Meanwhile, in rural areas kerosene is still difficult to obtain and even though it is expensive, so that for cooking purposes every day uses firewood taken from the surrounding forest. If this is allowed to continue, the environment will become damaged and will cause new problems such as floods because there are no more forests to absorb rainwater. The aim of this research is to improve the plastic waste processing design that has been made before, where the production capacity is not maximal due to leakage. Each type of plastic will be subjected to a pyrolysis process, then measurements will be made of oil production, the length of the pyrolysis process for each type of plastic, the density of the oil for each type of plastic, the length of time to burn the oil produced by each type of plastic, the flash point of oil produced by each type of plastic. The method used is the method of action and experimental method, which begins with the design of the reactor, manufacture and testing of tools, data collection of experimental results in accordance with predetermined variables. The results showed that, 1) The reactor was designed to function properly, there were no more leaks so that the plastic pyrolysis oil production capacity increased to 155 ml / 500 grams. 2) The density of oil produced by plastic pyrolysis of the type of oil packaging is slightly higher than diesel, which is 0.9 gr / ml while the plastic bag is much higher than kerosene, diesel, or oil from pyrolysis of oil packaging, which is 1.1 gr / ml because there are still many impurities. 3) Solar power burns the longest burning time compared to kerosene, oil from pyrolysis of plastic oil packaging and oil from pyrolysis of plastic bags, which is 3.18 minutes. 4) The oil from pyrolysis of plastic oil packaging has a flash point that is almost the same as kerosene (47.8°C) while the oil from plastic pyrolysis plastic bags has a flash point that is high enough to carry the flash point of diesel fuel (55°C). 5) The highest volume of evaporated water was produced from air cooking using diesel oil (6 ml), followed by kerosene and oil from the pyrolysis of each plastic bag (5 ml) and oil from plastic pyrolysis oil packaging (3 ml).**

***Keywords*—plastic waste, processing equipment, fuel, environment, oil**

I. INTRODUCTION

Plastic waste is non-organic material that is difficult to destroy even though it is burned, and it is often found in our environment. This garbage comes from households, traditional markets, shops, terminals, and others in the form of plastic food packaging, beverage bottles, plastic bags, and others. Lack of public awareness of environmental cleanliness and irregular waste management has an impact on environmental filth.

Data from the Central Statistics Agency (BPS) in 2018 showed an increase in imports of plastic waste in Indonesia by 141 percent (283,152 tons). This figure is the highest peak of plastic waste imports for the last 10 years, where in 2013 Indonesia's plastic waste imports were around 124,433 tons. However, the increase in plastic waste imports has not been accompanied by export figures. In fact, in 2018 the export rate decreased by 48 percent (98,450 tons). This figure shows that there are 184,702 tons of plastic wastes in Indonesia.

The resulting waste continues to increase in line with the increasing level of public consumption. In addition, the increasing industrial activity cannot be separated from the issue of environmental damage. Apart from producing products, industrial activities also produce waste. If this industrial waste is disposed of directly into the environment, it will cause environmental pollution. Based on the type of product, there are 6 types of plastics namely Polyethylene Terephthalate (PET), High Density Polyethylene (HDPE), Polyvinyl Chloride (PVC), Low Density Polyethylene (LDPE), Polypropylene (PP), Polystyrene (PS) and Other [1].

The bad impact of plastic waste mentioned above in line with the results of research conducted by Nurhenu. Karuniastuti, with the title The Dangers of Plastic to Health and the Environment [2].

Various scientific disciplines have carried out various research and actions, through scientific studies such as conducted by Kadir [3] regarding the use of plastic waste as a source of liquid fuel. Nasrun [4] and his friends have also treated plastic bag waste into fuel using a pyrolysis process. In general, approximately 950 ml of fuel oil can be obtained from the pyrolysis of 1 kg of Polyolefin plastics such as Polypropylene, Polyethylene and Polystyrene, Thorat [5] and Wahyudi [6] conducted research on processing polypropylene (PP) plastic waste into fuel oil with a different method, namely the Catalytic Cracking Method Using Synthetic Catalysts. Another study conducted by Nugroho [7] was about processing Polypropylene plastic waste into oil by varying the reactor temperature from 300 0C, 3500C and 4000C. Apart from that, Pribadyo and Firmanto [8] have designed and made a plastic waste processing tool with biomass fuel. Aprian Ramadhan P. and Munawar Ali [9] have also designed a pyrolysis reactor and observed temperature and residence time on the quality of pyrolysis products and how much oil is produced. Another research conducted by Wahyudi et al [10] is about processing polypropylene (PP) plastic waste in the form of bottled mineral water into fuel oil using the pyrolysis method. Rafael Mado et al [11] on their previous research, with the title: *Rancang Bangun Alat Pengolah Sampah Plastik Kapasitas 70 Liter Menjadi Bahan Bakar Pengganti Minyak Tanah*, by testing 5 types of plastic materials, namely: plastic pellets, plastic bags, mineral water packages, jerry cans of cooking oil and oil packaging. The production capacity of the tool is not optimal due to a gas leak in the cover of the reactor tube. Based on previous studies, I was interested in taking the title: "Plastic Waste Processing to be Alternative Fuels to Create Clean and Healthy Environment".

II. Research Methodology

A. Tool Design

This research was preceded by the design of a plastic waste processing tool which was a development from previous research, as shown in figure 1 below:

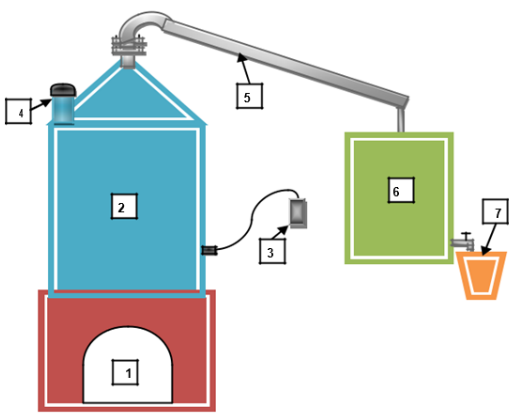

Fig. 1. Plastic waste treatment plant.

Description:

1) Heating Furnace
2) Reactor Tube
3) Digital Thermocouple
4) Input Channels
5) Gas Pipeline
6) Condenser
7) Oil reservoir

The heating stove is made using a red brick arrangement with an inner diameter of 57 cm and a height of 40 cm, so that the volume of the combustion chamber is 102,018.6 cm3. The fuel used is firewood. The reactor tube is made of 1 mm thick stainless plate in the shape of a cylinder with a diameter of 40 cm, a height of 50 cm and a conical lid with a height of 15 cm, so that the overall volume of the reactor tube is 64,800 cm3 Digital Thermocouple is used to control the temperature inside the reactor tube, where the end of the cable is plugged through the reactor tube wall. The intake channel functions to enter the plastic material that has been cut into the reactor cane and remove plastic charcoal from the reactor tube. Hot gas distribution pipe is made using galvanized pipe Ø 1 inch with a length of 2 m. Capillary/condenser pipe and cooling water box: the capillary tube uses a Ø ¼ "Stainless pipe rolled in a spiral with a diameter of 40 cm and a length of 45 cm, placed in a large bucket filled with cooling water with a volume of 150 litres. The function of this condenser or inverter is to convert pressurized hot gas into liquid. The purpose of the reservoir is to accommodate the oil from plastic pyrolysis.

B. Tool Making

The equipment for processing plastic waste into fuel is carried out at the Laboratory for Maintenance and Repair of the Department of Mechanical Engineering, Kupang State Polytechnic, because the facilities are quite complete, and the technicians are skilled. The materials and tools needed in making this tool are as follows:

1) Material: The materials used in this study were a sheet of 1 mm thick stainless plate; a Ø 1 inch galvanized pipe; two knees Ø 1 inch; a straight shock Ø1 inch; 6 m Ø 1/4 inch stainless pipe; a bar of angle iron measuring 4 x 2 x 6000 mm, an electrode box Ø 2.6 mm; 2 kg of paint; two tubes of silicon glue; two cans of epoxy glue; two tubes of iron glue; a box of cut grinding stones; ten pieces of finishing grinding stones; two rolls of sealtape; firewood.

2) Tools: The tools used in this research is welding machines, lathes, drilling machines, hand saws, compressors, grinders, roller meters, elbows, digital scales, stopwatches, measuring cups, digital thermometers, pipettes, combustion stoves, saucers.

C. *Tool Assembly and Function Test*

After all the parts have been done, it is followed by assembly (Figure 1) and testing the function of the tool which aims to determine the performance of the plastic waste processing equipment that is made. If a technical problem (gas leak) is found during the test, it will be repaired, as necessary.

D. *Research Variables*

1) Independent variables: The independent variables in this study are the results of the design and manufacture of plastic waste processing equipment and types of plastic (plastic bags and oil packaging bottles).

2) Dependent variables: The dependent variables in this study are the function of the tool, the density of the oil for each type of plastic, the length of time to burn the oil produced by each type of plastic, the flash point of the oil produced by each type of plastic, and the temperature of the water that is heated using the oil produced by each type of plastic.

E. *Data Collection Methods*

The method used is an experimental method with independent variables which is the result of the design and manufacture of plastic waste processing equipment and types of plastics. The types of plastic being tested are plastic bags and oil bottles. Before testing, the plastic materials were cut into small pieces, approximately 1x1 cm or 1x2 cm, and then weighed 500 grams for each type of plastic. This type of plastic is ready to be fed into the reactor after being preheated to a temperature of 2000C. The heating process is continued until it reaches the melting temperature of the plastic which is 3000C - 4000C, where the pyrolysis oil starts to come out. The test results for each type of plastic were observed and recorded. The density of oil from pyrolysis of each type of plastic is calculated using the equation $\rho = m / v$ where ρ is the density, m is the mass of the sample and v is the volume of the sample. The results of these calculations are then compared with soil and diesel oil including the burning time and flash point.

F. *Research Flowcharts and Fishbone Diagrams*

Figures 2 and 3 are research flowcharts and fishbone diagrams, respectively.

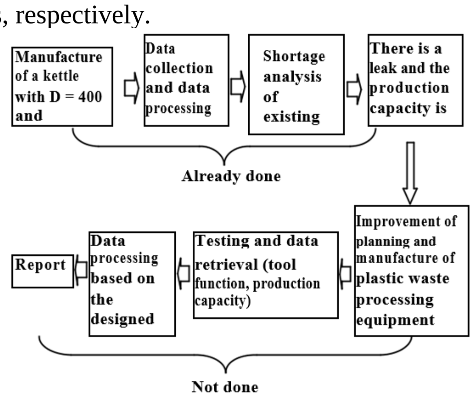

Fig. 2. Research flowcharts.

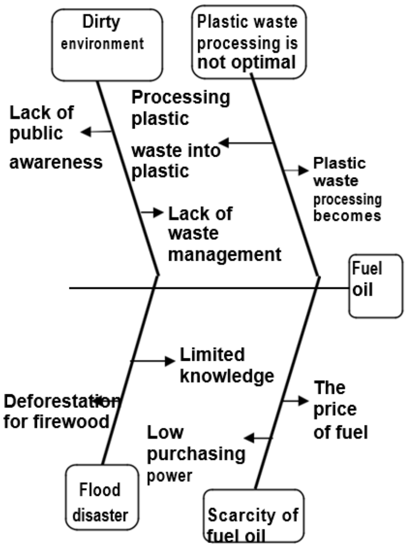

Fig. 3. Fishbone diagram.

III. Results and Discussion

The reactor tube, which was originally planned to use a 3 kg LPG tube, turned out that after being tested it could no produce oil because the area that was in direct contact with the heat source was too small, so that little heat was absorbed and was unable to melt the plastic material. For this purpose, it is replaced by a stainless tube measuring 40 cm in diameter and 50 cm in height, where the top cover is welded to prevent leakage. After testing, there were no more leaks and oil production from pyrolysis increased. The results of testing on 2 plastic samples (oil packaging bottles and plastic bags), can be seen in table 1 below:

TABLE I. Data from Test Results

No	Plastic Type	Duration Process (minutes)	Temperature (°C)	Results (ml)	Charcoal (gr)
1	Oil packaging	60	300-337	160	42
2	Plastic bags	60	340-390	150	61

Table 1 shows the test results on 2 plastic samples. The heating process of plastic oil packaging for 60 minutes at a heating temperature range of 3000C - 3370C produces 160 ml of oil and 42 grams of charcoal residue. The process of heating the plastic bag for 60 minutes at a heating temperature range of 3400C - 3900C, produces 150 ml of oil and 61 grams of charcoal residue. The results of this test indicate that the more oil produced the less charcoal remains. The amount of oil from the pyrolysis of these two types of plastics shows a significant increase in production capacity compared to previous studies conducted by Rafael Mado, et al. in 2017, where the pyrolysis yield of oil packaged plastic increased from 95 ml / kg to 160 ml / 500 gram and the pyrolysis yield of plastic bags increased from 45ml / kg to 150 ml / 500 gram.

A. Density

The density of the oil from pyrolysis of these two types of plastic is done by measuring the volume and mass of each sample. Each sample was taken 10 ml with a measuring cup and then the sample was weighed to obtain the mass of the sample. The density of the sample is calculated by equation (1).

$$\rho = m/v \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \qquad (1)$$

Where, ρ is the density, m is the mass of the sample and v is the volume of the sample. The results of the calculation of the density of plastic bags, kerosene and diesel fuel packaging are presented in Figure 4.

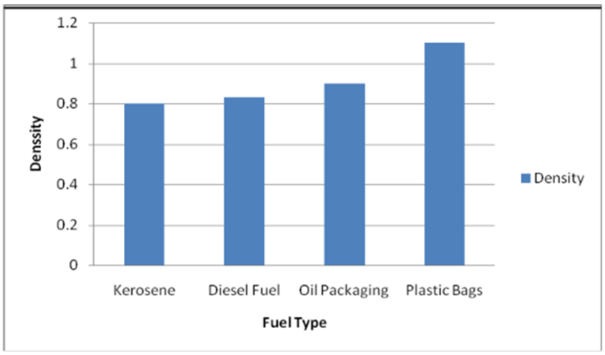

Fig. 4. Density graph of oil.

Figure 4 shows that the density of oil resulting from pyrolysis of plastic types of oil packaging is slightly higher than Diesel fuel, which is 0,9 gr / ml, while the plastic bags are much higher than the oil produced by pyrolysis of oil packaging, which is 1,1 gr / ml because there are still many impurities. The density of diesel fuel and kerosene is included in the standard specification range according to the Ministry of Energy and Mineral Resources (2006), namely 0,815 – 0,87 gr ml for diesel fuel and 0,79 – 0,83 gr / ml for kerosene. Objects that have a high density, the greater the mass of each volume. The pyrolysis oil from oil packs and plastic bags has a much higher density than kerosene and Diesel fuel. This indicates that the oil from pyrolysis still has a lot of impurities, so it still requires further processing.

B. Color Comparison

The colour comparison of the four types of oil is as shown in Figure 5 below:

Fig. 5. Comparison of oil colors.

Figure 5 shows a clear colour comparison where kerosene is the clearest compared to the other three types of oil. Diesel fuel is slightly yellow, the results of pyrolysis of oil packaging are brown and the results of pyrolysis of plastic bags are greyish yellow and have a lot of impurities. Burning Duration

The burning duration is used to determine the length of time it takes for each type of oil to burn down an object. The analysis of the duration of combustion was carried out by taking 10 ml from each sample of fuel which was fed into 4 different furnaces. The time it takes for each fuel sample to burn the material to the end will be measured and analysed.

The results obtained can be seen in Figure 6 below:

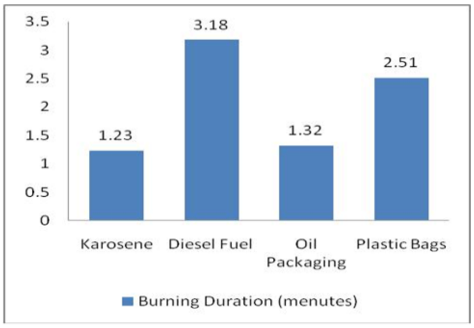

Fig. 6. Oil burning duration graph.

Based on Figure 6, it is known that diesel fuel requires the longest burning time compared to kerosene, while the burning duration of the oil from pyrolysis of plastic oil packaging and oil from pyrolysis of plastic bags is 3,18 minutes. This is because diesel fuel has the highest flash point among the three other oils, which is 52°C, while the flash point for kerosene is 47,8°C.

The flash point is directly related to whether or not a fuel can burn. A low flash point makes the substance more flammable, so this physical property is very important as a condition for a substance to be said to be a fuel. Although in this study the flash point of pyrolysis oil was not calculated, Figure 3.3 could imply that the oil from pyrolysis of plastic oil packaging has a flash point that is almost the same as kerosene, while the oil from pyrolysis of plastic bags has a flash point that is quite high and is almost close to the flash point of diesel fuel.

C. Water Temperature

In this study, the oil from plastic pyrolysis was tested by using it as fuel to boil 15 ml of water for 4 minutes so that it can be seen the amount of water temperature, the amount of water remaining and the water that evaporates, as shown in table 2 below.

TABLE II. DATA OF WATER HEATING TEST RESULTS

No	Type of Fuel	Temperature (°C)	Residual Water (ml)	Evaporated Water (ml)
1	Kerosene	99,8	10	5
2	Diesel fuel	99,6	9	6
3	Oil from pyrolysis of the oil pack	89,2	12	3
4	Oil from pyrolysis of the plastic bag	85	10	5

Table 2 shows that the highest water temperature is the result of heating using kerosene (99.8^{0}C), followed by diesel (99.6^{0}C), packaged oil (89.2^{0}C) and plastic bag oil (85^{0}C). Meanwhile, the highest evaporation occurs when heating water using diesel fuel, which is 6 ml.

The water temperature from heating using pyrolysis oil will be compared with the water temperature from heating using kerosene and diesel fuel. Comparison of water temperatures is presented in Figure 7 below.

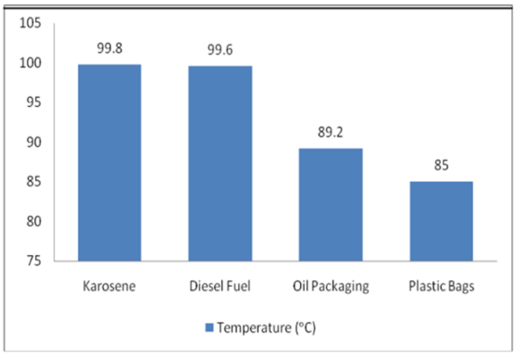

Fig. 7. Graph of heated water temperature.

Figure 7 shows that the temperature of water heated using kerosene and diesel fuel is almost the same, which is 99,8 0C and 99,6 0C, because the flash points of these two types of oil are not much different, they are 47,8 °C and 55 °C, while the pyrolysis oil from plastic packaging oil and plastic bags produce water temperatures of 89,2 0C and 85 0C.

D. Volume of Lost Water

The performance of the fuel sample in evaporating water was done by heating 15 ml of water for 4 minutes. Furthermore, the volume of water remaining after heating with 4 different fuel samples is measured and analysed.

The volume of water lost due to heating using each fuel sample is presented in Figure 8.

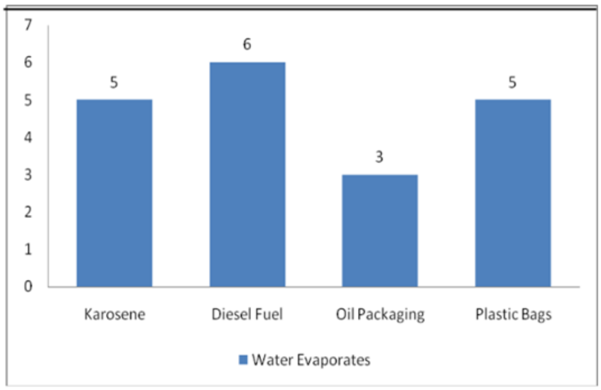

Fig. 8. Graph of evaporating water volume.

The highest volume of evaporated water resulted from boiling water using diesel fuel (6 ml), followed by kerosene and oil from the pyrolysis of each plastic bag (5 ml) and oil from plastic pyrolysis oil packaging (3 ml). The volume of water that evaporates has a relationship that is directly proportional to the temperature of the water in Figure 4.4, where if the water temperature is higher, the evaporation will also be higher.

IV. CONCLUSION

Based on the results of data analysis from existing tables and graphs, several points can be concluded as follows:

The results of the design and manufacture of Reactor Tubes measuring 40 cm in diameter, 50 cm high of 1 mm thick stainless material, can function properly, no more leaks so that the pyrolysis oil production capacity increases, where the result of pyrolysis of plastic oil packaging increased from 95 ml / kg to 160 ml / 500 grams and the result of pyrolysis of plastic bags also increased from 40 ml / kg to 150 ml / 500 grams.

The density of oil produced by plastic pyrolysis of the type of oil packaging is slightly higher than diesel fuel, which is 0,9 gr / ml while the plastic bag is much higher than kerosene, diesel oil and oil from pyrolysis oil packaging, which is 1,1 gr / ml because it is still lots of dirt.

Diesel fuel produces the longest burning time compared to kerosene, oil from pyrolysis of plastic oil packaging and oil from pyrolysis of plastic bags, which is 3,18 minutes.

The oil from pyrolysis of plastic oil packaging has a flash point that is almost the same as kerosene (47,8°C) while the oil from pyrolysis of plastic bags has a flash point that is quite high, almost close to the flash point of diesel fuel (55 °C)

The highest volume of evaporated water was produced from boiling water using diesel fuel (6 ml), followed by kerosene and oil from pyrolysis of plastic bags (5 ml) and oil from pyrolysis of plastic oil packaging (3 ml).

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