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Temperature distribution of the plastics Pyrolysis process to produce fuel at 450°C

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Abstract

This paper aims to investigate the temperature distribution in the reactor of a plastics pyrolysis process from waste bottles of beverage to produce fuel. This process is considered an alternative technology to replace fossil fuel. This experiment was conducted using a cylindrical reactor, which has dimension of 0.31 m in diameter and 1 m high. In order to understand the temperature distribution in the reactor, five thermocouples were placed to measure temperature at the bottom and the top of the reactor as well as in the middle, with the different position of each thermocouple of 0.19 m respectively. The temperature outside the reactor and outside the condenser was also measured. Data Acquisition recorded all temperature data. The reactor was used to process 1,500 g plastics. The Computational Fluid Dynamic (CFD) was also used to know the contour of temperature inside the reactor. The result showed that to increase temperature from the ambient temperature to 450°C, 72 minutes of time were needed. The lowest temperature of 310°C was measured at the top of the reactor, whereas different temperature in the middle of the reactor was found to be 46°C respectively. The pyrolysis process of 1,500 g plastics was completed in 110 minutes to produce 21 g of fuel. This fact shows that the pyrolysis process of plastics can produce fuel at 450°C in the reactor and 75°C outside the reactor.

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*Keywords:*Pyrolysis;Plastics;Temperature;Reactor; CFD

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1. Introduction

Consumption of drinking water in packages increases and almost all its packaging is made from plastics. There are six plastics categories in the world: High Density Polyethylene (HDPE), Low Density Polyethylene (LDPE), Polypropylene (PP), Polyvinyl Chloride (PVC), Polystyrene (PS) and Polyethylene Terephthalate (PET). Drinking water packaging is included in Polyethylene Terephthalate (PET). Plastic is made from petroleum derivatives and considered to be difficult to parse and to be a pollutant (air, land and water)[1]. This phenomenon will become a potential problem in the future. On the other hand, the amount of fuel decreases and a solution is needed to overcome this condition. Plastic is a potential ingredient to be converted into fuel by a pyrolysis process.

Pyrolysis is a thermal process with less or absence of oxygen. In the pyrolysis process (heating in an oxygen-free atmosphere), the organic components of the decomposed material generate liquid and gaseous products, which can be used as fuels and/or a source of chemicals[2]. The process is influenced by some important parameters such as temperature and time. Some papers report that the pyrolysis process happened at the temperatures of 350^{o}C, 460^{o}C, 500^{o}C, 520^{o}C, 600^{o}C, 650^{o}C, 685^{o}C, 730^{o}C, 780^{o}C, 850^{o}C, 900^{o}C and within the duration of 15 minutes, 30 minutes, 60 minutes, or 120 minutes[2,3,4,5,6]. However, the discussion about the temperature distribution in the reactor is not included. Temperature distribution is important to be recorded because it can estimate the area in which thermal cracking occurs. Thermal cracking is the most important step in pyrolysis of plastic to produce fuel.

Several researchers have studied the pyrolysis process to produce fuel from waste plastics. Toshiro et al[7] has investigated the thermal cracking of household waste plastics with variation of temperatures at 700^{o}C, 750^{o}C, 800^{o}C and 850^{o}C. Kyong et al studied about the comparative result of catalytic and non-catalytic degradation of waste polymer plastics[8]. N. Miskolczi et al reported about the pyrolysis process of two types of plastics (HDPE and PP) from agricultural and packaging sectors[3] at 520^{o}C. E. Butler et al discussed the review of waste polyolefin plastics[9]. Research on the use of waste plastic bottles made from PET for producing fuels using the pyrolysis process is less conducted.

The aim of this research is to study temperature distribution in the pyrolysis process of waste plastic bottles as drinking water packages (PET), which are immensely available in Indonesia. This research used lab-scale reactor experiment to analyze temperature distribution in the reactor. The simulation of Computational Fluid Dynamic (CFD) was also used in this research to know the temperature contour inside the reactor.

2. Materials And Method

2.1. Materials

Plastics used in this research werewaste plastic bottles of drinking water. Firstly, the bottleswere dried and chopped into small pieces. For the pyrolysis process, 1,500 g of plastic pieces were then put into the reactor.

2.2. Method

The layout of the experiment can be seen in Fig 1. The experiment was performed in a cylindrical reactor made from steel with the dimension of 0.31 m in diameter and 1 m high. Five K type thermocouples were placed in the reactor from the bottom to the top, while the distance of each thermocouple was 0.19 m. The condenser was made from a copper tube with diameter of 3/8 inch and length of 2.5 m. The temperature was recorded using Data Acquisition every 2 seconds. Power of the electrical heater was 2700 Watt. The reactor was sealed with ceramic fiber with thickness of 2 cm. The boundary condition in Computational Fluid Dynamic (CFD) simulation can be seen in Table 1:

Table 1. Boundary Condition in CFD

No	Parameters	Condition	Value
1	Type of flow	Laminar	-
2	Operating Pressure	Absolute Pressure	101,325 Pa