Energy Yield from Waste Tires Using Pyrolysis Method

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Abstract

The demand for energy in the world has increased with the rapidly developing industry. In contrast, today fossil fuel resources used as primary energy ones have been also decreased quickly. On the other hand, one of the greatest environmental issues of the era is the rise in the amount of the solid waste. Used tires are one of the solid wastes caused the increase in question. Waste tire has an important energy potential. The aim of this study is to produce liquid fuel from waste tires using pyrolysis method. For this purpose, some tests are carried out to determine optimal temperature and pressure values when liquid yield is the highest. In the conclusion of tests completed, it is found out that liquid yield can be provided from waste tires and the provided yield can be used by different organizations as fuel.

Keywords
Energy, Pyrolysis, Recovery, Waste Tire

Introduction

Worldwide, 1.5 billion tyres are produced per year and the majority of these eventually end up as waste tyres contributing a significant portion of the solid waste stream (ETRMA, 2011). Tyres are designed to withstand harsh mechanical and weather conditions as ozone (the most damaging factor on rubbers), light and bacteria, making difficult their recycling and/or further processing. Also they are bulky and do not degrade in landfills (Leung and Wang, 1998). The tyre lifetime in a landfill is considered to be between 80 and 100 years (Clark *et al.*, 1993). Therefore, the increasing numbers of used tyres constitute a serious threat to the natural environment (Sugözü and Mutlu, 2009; Sienkiewicz *et al.* 2012). On the other hand, since rubber from tires have a calorific value higher than coal as well as considerable amount of carbon black, it seems reasonable to find a route to take advantage of its high energetic and raw material potential in order to progress in the search of alternative fuels, CO_2 emission mitigation and the reduction/recycling on raw materials (Martinez *et al.* 2013).

During the past 10–15 years, several fundamental and applied studies showed that if carefully controlled, tyre pyrolysis can produce a number of valuable yields. By pyrolysis, the rubber portion of used tires is transformed into gas, oil and char. Pyrolysis is the thermal decomposition of organic materials in the absence of oxygen, cracking them down to simpler organic compounds. It relies on the addition of heat to break chemical bonds, providing a mechanism by which organics decompose and vaporize. Most tyre pyrolysis processes operate within a temperature range of 250-500ºC, although some processes are reported to operate at up to 900ºC. At temperatures above approximately 250ºC, shredded tyres release higher amounts of liquid oil yields and gases, while above 400ºC, the yield of oil and solid tyre-derived char may decrease relatively to gas yieldion. Pyrolysis can be classified as atmospheric, vacuum, catalytic, fast or slow according to the operation parameters applied. According to pressure applied, pyrolysis can be atmospheric or vacuum. The operating parameters of pyrolysis are temperature, heating rate and particle size (Antoniou and Zabaniotou, 2013). The pyrolysis temperature is one of the main governing variables on waste tire pyrolysis (Martinez *et al.*, 2014).

Waste tire pyrolysis seems to be more attractive in comparison with other thermo-chemical processes because of its minor environmental impact and the recovery of solid and liquid material. Its yields are easily manageable and then valorised separately according to different objectives. The production of a liquid fuel yield, the major yield in waste tire pyrolysis, increases the ease of handling, storage and transport and hen-

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ce the yield does not have to be used at or near the recycling plant (Martinez *et al.*, 2013). Also the application of pyrolysis technology to the treatment of waste tyres was found to be economically feasible (Pilusa *et al.*, 2014). Because of these advantages, pyrolysis method has recently received renewed interest and attention to tackle the waste tyre disposal problem while allowing energy recovery. Therefore, the aim of this study is to produce liquid fuel from waste tires using pyrolysis method.

Material and Methods

Pyrolysis unit is cylindrical, stainless steel and has a capacity of 1000 m^3. A thermometer showing a maximum of 600ºC and a barometer working up to 15 bar is set up on the unit. The unit has three outlet valves. The opening of the unit is surrounded by a circular seal to provide leakage (Figure 1).

In tests, three Soxhlet extractor with 360 mm in length is used for condensing gas. To collect condensed gas, a conical flask is added to extractor with pipes. Gases that can not be liqufied are collected in the gas collection bags at the end of the test.

Before starting the test, waste tires used as raw are cut into small pieces and separated from wires. Sample quantity is taken as 300g and it is put to pyrolysis unit. After tightly closing the opening of pyrolysis unit, argon gas is passed through the unit to provide anaerobic conditions necessary for the pyrolysis. Then, pyrolysis test is begun by heating of a gas tube.

Firstly, gas tube is set to 4.5 degree. Pressure and temperature measurements are done in each 3 minutes. It has taken 33 minutes to get the first liquid yield. When the pressure is 5 atm liquid yield is filled to glass bottles. After getting the first liquid yield when the pressure is zero the second treatment is continued. For second treatment, pressure and temperature measurements are done in each 4 minutes. After 44 minutes when the pressure is 3.72 atm the second liquid yield is gotten. When the pressure is zero third treatment continues. For this treatment pressure and temperature measurements are done in each 10 minutes. After 30 minutes when the pressure is 0.6 atm the third liquid yield is obtained. At the end of the pyrolysis test, the obtained yields are weighed.

Results and Discussion

The observed temperature and pressure values related to the time for all liquid yields are presented

Figure 1 – Pyrolysis unit

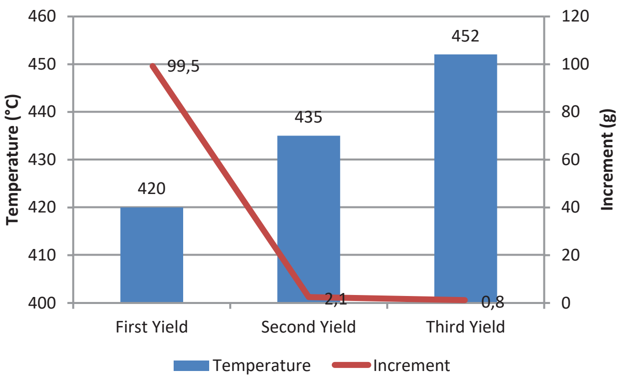
in Table 1. Heating rate are 4.5 degree for the first yield and 5 degree for the other yields. Reaction durations for yields are 33, 44 and 30 minutes, respectively. Catalyzator is not used for all yields.

The increase or decrease in the temperature and pressure depending on the time is important for liquid yield. In this study, it is found out that the yield increment decreases with the increase of temperature and decrease of pressure (Figure 2-3). As a matter of fact, Akyıldız (2011) has stated that the optimum pyrolysis temperature and heating rate are 400°C and 5°C/min for liquid yield. Rodrigues (2001) and Laresgoiti *et al.* (2004) have also reported that pyrolysis temperature over 500°C has no effect on the increment of liquid yield. On the other hand, Karthikeyan *et al.* (2012) have stated that pyrolysis temperature beyond 375°C lead to decrease of liquid content in most of the pyrolysis processes and also liquid yield obtained is relatively greater volume in presence of catalyst as compared to pyrolysis in the absence of catalyst. The results of these studies mentioned above are similar to those obtained in the current study. In contrast, the general trend is an increase in liquid yield as the temperature increases (Juma *et al.*, 2006; Suhanya *et al.*, 2013). Pangaliyev (2014) has determined that the highest liquid yield is obtained at 700-800°C for the pyrolysis. Also, Islam *et al.* (2008) has indicated that the lower temperature causes decrease in the liquid yield.

Liquid yields obtained at the end of the pyrolysis process are weighed and yield increments are calculated (Table 2). In addition, samples taken from these yields are sent to related institution for determining their composition. Figure 4 has showed liquid yields and outletwater.

The First Yield T			he Second Yield			The Third Yield		
Time (Minute)	Temperature (ºC)	Pressure (atm)	Time (Minute)	Temperature (ºC)	Pressure (atm)	Time (Minute)	Temperature (ºC)	Pressure (atm)
0	175 0	.5 0		351 0	.8 0		437 0	.0
3	180 0	.7 4		364 1	.3 1	0	440 0	.2
6	230 0	.9 8		375 1	.7 2	0	445 0	.5
9	255 1	.5 1	2	389 2	.0 3	0	452 0	.6
12	286 2	.0 1	6	393 2	.5			
15	293 2	.5 2	0	404 2	.7			
18	306 3	.0 2	4	412 2	.9			
21	311 3	.5 2	8	415 3	.2			
24	330 4	.0 3	2	425 3	.4			
27	340 4	.3 3	6	428 3	.6			
30	360 4	.8 4	0	432 3	.7			
33	420 5	.1 4	4	435 3	.7			

Table 1 – The observed temperature and pressure values related to the time for all liquid yields



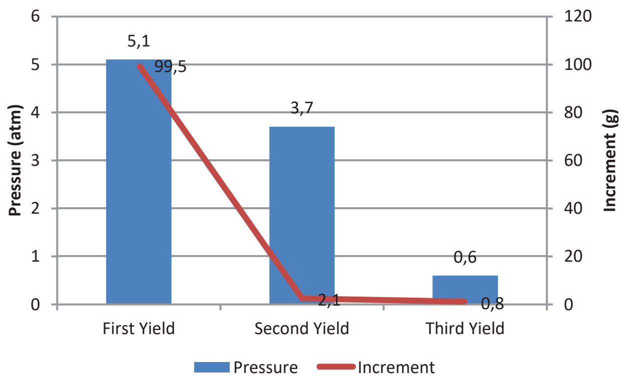


Figure 2 (Left) – The relation between yield increment and temperature
Figure 3 (Right) – The relation between yield increment and pressure

Conclusions

Tests in the current study has showed that energy can be produced from waste tires. The yields obtained by pyrolysis techniques can be a suitable alternative to fossil fuels and natural gas. The wastes occurring after energy yieldion can be removed by applying various methods without damaging the environment and also used as a material in the construction field. The development and use of advanced technologies are required for both the development and utilization of new energy sources, and effective waste disposal all over the world. To provide contribution to national economy, plants used pyrolysis techniques should be encouraged and also enterprisers should be supported for establishing new pyrolysis plants. The issues related to the regulations should be resolved.

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Yields	The first weighing (Empty container) (g)	The last weighing container+ ield y	Increment (g)
Outlet water (OW)	696.8	704.6	7.8
First	237.0	336.5	99.5
Second	226.3	228.4	2.1
Third	205.7	206.5	0.8

Table 2 – The weighing results for all yields

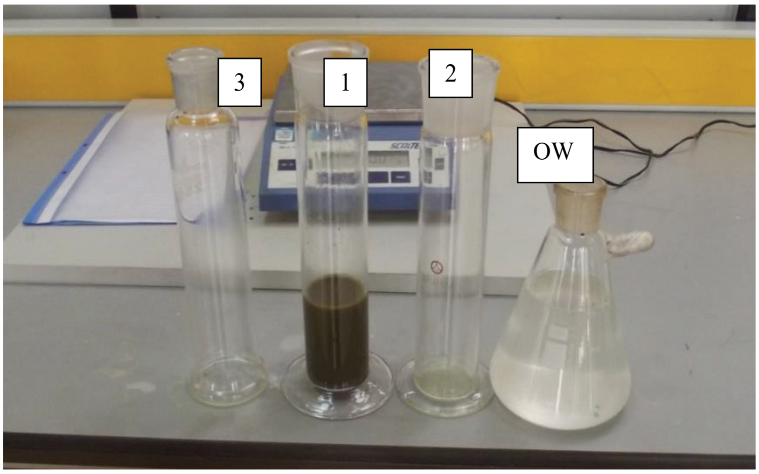

Figure 4 - Liquid yields and outlet water (OW) obtained at the end of the pyrolysis test

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