Investigation of Carbon Black Production from Waste Tyre Burning

By

Nurfarah Liyana Binti Bistamam

14941

Dissertation submitted in partial fulfilment of

the requirements for the

Bachelor of Engineering (Hons)

Mechanical Engineering

JANUARY 2015

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

Investigation of Carbon Black Production from Waste Tyre Burning

By

Nurfarah Liyana Binti Bistamam

14941

A project dissertation submitted to the

Mechanical Engineering Department

Universiti Teknologi PETRONAS

In partial fulfilment of the requirement for the

Bachelor of Engineering (Hons)

Mechanical Engineering

Approved by,

_____

Dr. Mior Azman Bin Meor Said

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained here have not been undertaken or done by unspecified sources or person.

_____

NURFARAH LIYANA BINTI BISTAMAM

ABSTRACT

Many different alternatives have been use throughout the years in order to recover energy from used tyres. Among the alternatives are grinding, incineration, pyrolysis and reclaiming. However, research show that all the alternatives mentioned above have few drawbacks that resulted in the lack in usage of used tyres as fuel energy. There are two objectives of this study. Firstly is to conduct parametric test on carbon black production using small in-house fabricated incinerator and the second objective is to fabricate on a functional prototype of an incinerator that can further applied for usage of community. Target people was also identified which is villagers that often do open burning of their daily waste. For the experiment, the incinerator is designed and fabricated especially for the experiment. The result shown that the period of burning is linear to the amount of fuel burned but the amount of carbon black collected does not produce a pattern which is believed due to the effects of wind speed and direction during open burning session. However, it is concluded that the carbon produced during burning can be trapped by using simple carbon filter.

ACKNOWLEDGEMENT

The author would like to say her utmost and deepest appreciation to the following individuals that had helped her in completing her Final Year Project.

First and foremost, author would like to extend my most humble gratitude to the Almighty, Allah s.w.t for giving the opportunity to complete this Final Year Project as part of requirements for Bachelor of Engineering (Hons.) in Mechanical Engineering at Universiti Teknologi PETRONAS.

Not to forget, her respectful supervisor, Dr. Mior Azman Bin Meor Said, and also co-supervisor, Ir. Dr. Masri Bin Baharom that has been more than helpful by giving continuous guidance and support throughout the duration of this Final Year Project.

Millions of appreciation the author would also like to be directed towards the Mechanical Engineering department of Universiti Teknologi PETRONAS for giving a platform for us students to further enhance our researching and technical skills.

Special thanks also go to all of author's university friends especially Mr Azri Rahman and those who has helped directly or indirectly throughout this project, by sharing their advices and comments to make the author improve during the stages of my project. Not to forget the author's family for their never ending moral support and guidance from the very beginning. Thank you very much.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background

Significant increase in the volume of used polymer products are mostly contributed by used automobile tyres. Based on the records from rubber product manufacturer and major associations of tyres, the amount of tyres produced all over the world every year can be estimated to be 1.4 billion units. This information corresponds to the estimation of 17 million tonnes of used tyres each year[1].

Used tyres have created a major problem during its disposal since it takes up space and the tyres continue to accumulate almost on every part of the world today[2]. The nature of the tyre itself makes it difficult to process them for recycling purpose.

Tyres are mainly made up of rubber which is a chemically cross-linked polymer. This property has made tyres a very stable polymer which cannot be remoulded into other shapes without thorough degradation. Other common materials of tyres are steel, carbon black and textile components as strengthening agent [3] [4]. Basically, tyres are a complex mixture of different materials that represents different properties.

Differences in properties of the tyres have made it hard to be recycled thus creating piles of disposed tyres all over the world nowadays. Therefore it is a kind of urgency to figure out the best possible ways to reuse or recycle the tyre.

1.2 Problem Statement

Many different alternatives have been use throughout the years in order to recover energy from used tyres. Among the alternatives are grinding, incineration, pyrolysis and reclaiming. However, research show that all the alternatives mentioned above have few drawbacks that resulted in the lack in usage of used tyres as fuel energy.

Researches done previously shows that combustion is one of the process that can be used for energy recovery from waste tyres. Combustion of scrap tyres must be done in a very carefully planned as the emissions of gases are hazardous as reported by previous researchers all over the world.

Combustion of tyres involves discovering the many potentials it may bring. These potentials are yet to be discovered by conducting experiments and varying temperature of the combustion.

1.3 Objectives

- To conduct parametric test on carbon black production using small in-house fabricated incinerator
- To fabricate on a functional prototype of an incinerator that can further applied for usage of community.

1.4 Scope of Study

In order to investigate on the incineration process, there are few area of studies that needs to be covered. First of all is the basis of the burning process. The equipment, the amount of used tyres that is reasonable for usage of the experiment, and also the behaviour of by-product of burning process.

Secondly, it is vital to learn on the hazardous materials that will be produced during combustion of waste tyres as for safety measures. This is to ensure that the experiment will be completed successfully without any injuries.

Thirdly, basis of the chemical composition of waste tyre burning products is to be studied do that it is easier to process the data gathered at the end of experiment. By learning on the chemical composition, the experimenter will be able to find the usage of the products of waste tyre burning.

Last but not least is the designing knowledge of an incinerator. Thorough readings and studying had been done before the sketching and drawing stage of designing the incinerator. Once the drawing had been approved, fabrication process is done and the incinerator were used for the investigation of using tyre as fuel for burning.

CHAPTER 2

LITERATURE REVIEW AND/OR THEORY

2.1 Importance of Material Recovery from Waste Tyres

The increasing amount of vehicles in this modern era had not only caused good to the society but also few significant issues that needs to be taken care of as soon as possible. This is due to the increasing in the number of waste tyres generated each year.

Many chose to dispose all these waste tyres by disposing them in landfills. This is because it is actually the easiest way to dispose the tyres since it is very difficult to be recycled and decomposed [5]. Used tyres usually would not degrade in landfills because they are highly resistant to biological, physical and chemical properties but if it were to be degraded, its process would take a very long time to be completed.

Besides that, in case of fires, tyres can emit highly polluting smoke. The relatively large sizes of tyres prevents waste compaction, thus indicating loss of important landfills [6]. Used tyres may also be a habitat for unwanted creatures such as rodents and mosquitos. Smoke produced by burning of tyre are also very hazardous to health.

2.2 Pyrolysis, Incineration and Combustion of Used Tyres.

Among the most researched ways of energy recovery from tyres is pyrolysis. Pyrolysis means breaking down the composition of waste tyres in terms of thermal without the presence of air. The absence of air is purposely done to avoid oxidation. Although this topic had been discussed often in published papers from all the world,

the application in industry is yet to be at large due to difficulty in market availability and lack of product standardization [7].

The end product of pyrolysis mainly made up of three components which are gases (carbon dioxides, hydrogen and methane), liquid (tar, oils and water), and solid (ash, char and metals) [8].

Generally, incineration of waste tyre means to reduce the combustible wastes of used tyres to inert residue by high temperature combustion. Incineration process is highly exothermic. Due to its high calorific value, waste tyres are used as fuel in the incinerators [9].

Leung et al. [10] had investigate on combustion of tyres in dry air atmosphere for temperature range between 20-900°C. The heating rate is fixed to be 10°C per minute. They also compare on the effects of pyrolysis compared to the combustion of tyre fiber char. From the investigation, it is found out that for the same period of heat application, about only 12% total weight loss during combustion and 82% of total weight loss during pyrolysis. Besides that, it is also suggested that more attention should be paid to the combustion process compared to pyrolysis since the apparent activation energy and frequency factor is larger in combustion compared to pyrolysis process.

According to Sharma et al. [9], incinerators with energy recovery system is one most the most suitable method to be used for energy recovery for shorter term of perspective compared to pyrolysis. Although incineration process is believed to be more profitable both economically and technically, certain problems such as production of damaging combustion products and excessive heat generated need to be paid attention more to. From this paper, it can be concluded that, incineration for energy recovery is quite complicated and more suitable for large power plants.

Juma et al. [11] mentioned in their paper that combustion behaviour and emissions of waste tyres are mostly depend on particle sizes, temperature, oxygen introduced and also reactor type. Atal and Levendis [12] stated that char burnout times can be considered as shorter for tyre particles if compared to coal.

According to Conesa et al. [13], total weight loss of tyre combustion can be as high as 89%. He also concluded that the weight loss occurred in four steps which corresponds to firstly the natural rubber. Secondly is the decomposition of the oil fraction. The third and four steps is through combustion of carbonaceous fraction and styrene-butadiene rubber.

One of the most interesting paper that were found to be related to combustion of waste tyres is from Oriaku et al. [14]. This paper explains step by step procedure used in the combustion. It also stress on the potential of carbon black that were retrieved from the burning chamber at the end of every cycle of burning if waste tyres.

Oriaku et al. [14] also mentioned on principle of orientation for the burning process whereby it is vital to burn the tyre in limited supply of air to ensure production of thick smoke so that more black carbon can be harvest at the filter of the burning chamber. Although this paper do not stress on the chemical composition of the end product of waste tyre burning, it surely do provide graphical explanations on the relationship between amount time spent and quantity of tyres burned and also the connection between temperature reached and quantity of tyres burned which will be very useful for other researchers that is working on burning of waste tyres as well.

A thorough study on combustion of waste tyres such as the particle sizes and temperature effects on combustion behaviour and harmful emissions are difficult to be found in literature. This indicates that more studies should be done and reported and combustion of waste tyres and conditions that affects the product of it.

2.3 Used Tyres as Burning Fuel

Mokrzycki and Bochenczyk [15] mentioned in their paper that crushed tyres are used as class 4 fuel which is coarse-crushed solid alternative fuels in the cement industry. It is also mentioned in their paper that the substitution of alternative fuels for fossil fuels will help reduce energy costs, providing a competitive edge for a cement plant to use this source of energy.

Some of the attractive options for use of scrap tyres is controlled burning as mentioned by Lemieux et. al [16] in their paper that. Tyres can either be burned alone or with other fuels such as coal. Such method had been applied in cement kilns and utility boilers.

According to Singh et. al, [17] shredded and whole tyres carry a significant fire risk; they are hard to extinguish once ignited and smoke emitted has criteria pollutants and air toxics when combusted. Based on one case study, The Iowa City landfill's shredded tyre drainage layer was accidentally kindled and burned openly for 18 days beginning May 26, 2012.

The Iowa City landfill was close enough to population centres of Johnson County, Iowa to impact people through smoke exposure, including heavily populated neighbourhoods. These types of fires often exceed one month in duration and pose threats to the health and safety of both firefighters and the public. In some cases, fires have prompted voluntary evacuations, school closings, and increased respiratory complaints. This had shown that tyre can be used as burning fuel but its usage must be thoroughly controlled to avoid any adverse effects.

LeBlanc mentioned [18] that about 130 million end-of-life tires, amounting to 45 percent of the industry total, were utilized as tyre derived fuel in 2003. The United States Environmental Protection Agency acknowledges tire-derived fuels as a viable alternative to the use of fossil fuels, as long as proper regulatory controls are in place. Scrap tires are prized for their high heating value, and are used effectively in Portland cement kilns as well as other industrial applications. The United States Environmental Protection Agency notes the following benefits to burning tires for fuel:

- Tires produce the same amount of energy as oil and 25% more energy than coal;
- The ash residues from TDF may contain a lower heavy metals content than some coals;
- Results in lower NOx emissions when compared to many US coals, particularly the high-sulfur coals.

2.4 Adverse Health Effects of Waste Tyre Burning

According to Environmental Law Alliance Worldwide (ELAW) [19], air emissions from open tire fires have been shown to be more toxic (e.g., mutagenic) than those of a combustor.. Open tire fire emissions include "criteria" pollutants, such as particulates, carbon monoxide (CO), sulfur oxides (SO2), oxides of nitrogen (NOx), and volatile organic compounds (VOCs). They also include "non-criteria" hazardous air pollutants (HAPs), such as polynuclear aromatic hydrocarbons, dioxins, furans, hydrogen chloride, benzene, polychlorinated biphenyls (PCBs); and metals such as arsenic, cadmium, nickel, zinc, mercury, chromium, and vanadium.

Besides that, Environmental Law Alliance Worldwide (ELAW) [19] also mentioned that both criteria and HAP emissions from an open tire fire can represent significant acute (short-term) and chronic (long-term) health hazards to firefighters and nearby residents. Depending on the length and degree of exposure, these health effects could include irritation of the skin, eyes, and mucous membranes, respiratory effects, central nervous system depression, and cancer.

According to Allsopp et. al., [20] all types of incinerators discharge pollutants to the atmosphere in stack gases, ashes and other excesses. A countless array of chemicals is released, including immeasurable chemicals that presently remain unidentified. The chemicals present in stack gases are frequently also present in ashes and other residues. Such chemicals include dioxins, polychlorinated biphenyls (PCBs), polychlorinated napthalenes, chlorinated benzenes, polyaromatic hydrocarbons (PAHs), numerous volatile organic compounds (VOCs), and heavy metals including lead, cadmium and mercury.

Many of these chemicals are known to be persistent (very resistant to degradation in the environment), bioaccumulative (build up in the tissues of living organisms) and toxic. These three properties make them uncertainly the most problematic chemicals to which natural systems can be exposed. Some of the emitted chemicals are carcinogenic (cancer-causing) and some are endocrine disruptors. Others such as sulphur dioxide (SO2) and nitrogen dioxide (NO2) as well as fine particulate matter, have been associated with adverse impacts on respiratory health.

2.5 Building a Safer Incinerator

Process of incineration involves combustion that will convert harmful waste to be harmless. The combustion will usually decrease the waste volume and mass by more than 90 percent. If the incineration were properly done, it can transform various wastes into gases and fire-resistant solid deposits that comparatively harmless.

Conversely, under certain circumstances, when the conditions of safe incinerations are not met, toxic composites can be found in the unburned waste, and unsafe gases can be released into the atmosphere. Examples of when conditions of safe incinerations are not met is the waste is not appropriately segregated or the incinerator is not properly designed or fabricated. Thorough planning, technical precision, and sustained supportive regulation of incinerator systems are critical to ensure safe and harmless incineration. [21]

According to Patki and Ajit, incineration is one of the best way for wastes treatment, to reduce or eliminate their unsafe potential and often to convert them to an energy form. Incineration has a lot of advantages compared to other dumping methods such as disposal at sea or in lagoons and land burial. Among the advantages of incineration are as follows: [22]

- The volume and weight of the waste is decrease to a fraction of its original size.
- Waste can be incinerated on site itself, which reduces cost of transportation.
- Waste reduction is immediate; it does not require long-term residence in a landfill or in a lagoon.
- Air discharge can be effectively controlled for minimal impact on the environment.
- Equipment exists to completely destroy even the most hazardous of materials in a comprehensive and effective manner.
- Requires relatively small disposal area.
- Using heat retrieval systems the cost of process can often be reduced or offset by the use of or sale of energy.

Although there are many things can be considered as advantages of incineration compared to other methods, there are still many issues were raised

regarding it. Truth is, incineration may not solve all the waste problems. Among the disadvantages are: [22]

- High initial cost
- Skilled labour is required.
- Not all the materials are incinerable and some require special fuel.

It is a popular misconception that the weight and volume of the original raw waste are reduced during incineration. It is often quoted that the volume of waste is reduced by about 90% during incineration but the actual figure is closer to 45%. The weight of waste is supposedly reduced to about one-third during incineration. However, this refers only to ashes and negates other incinerator emissions in the form of gases, which result in an increased output in weight. In sum, if the mass of all the outputs from an incinerator, including the gaseous outputs, are added together, then the output will exceed the input. [20]

CHAPTER 3

METHODOLOGY / PROJECT WORK

3.1 Flow Chart of Final Year Project I & Final Year Project II

This project is divided into two parts which are Final Year Project I and Final Year Project II. All processes involved in Final Year Project I and Final Year Project II had been carefully planned in ensuring smooth flow of the project. Below is the flow chart of the processes involved.

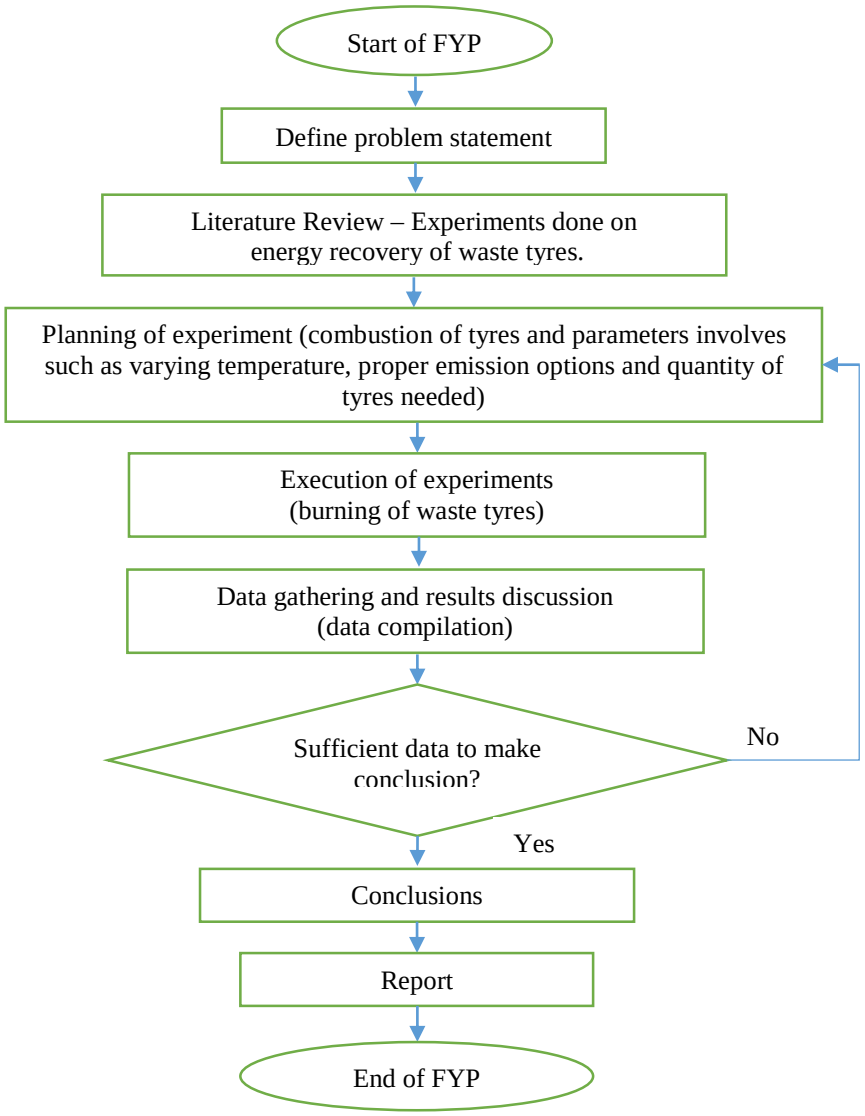

Figure 1 : Flow Chart of Final Year Project I & II

3.2 Design & Fabrication of Incinerator

Final Year Project I processes basically focused on gathering informations and designing the incinerator needed for the experiment. Through research done, it is found out that there are very few research done using tyre as burning fuel in Malaysia. This project also aiming on becoming a foundation study or reference on properties and issues of using tyre as burning fuel.

Firstly, many research papers regarding concerning this Final Year Project is selected and sorted based on the type of information they provide. Target people was also identified which is villagers that often do open burning of their daily waste. By creating a target study as such, this project is also focused on feasibility of duplicating the incinerator by the villagers.

Next is the sketching and drawing of the incinerator that are used for the experiment that is conducted in Final Year Project II. The incinerator design focuses more on the flexibility of its fabrication so that it is simple enough to be fabricated by the target people.

Few designs were given careful thoughts but only one design is chosen to be fabricated. The main criteria of choosing the design are as follows:

- Its size must be suitable for domestic usage of villagers.
- The materials to be used is easily gained.
- Fabrication processes must be practical for rural area usage.
- Smoke emitted must be filtered to ensure health hazard to community surrounding is minimised or eliminated.
- Incinerator must be suitable for experiment on material recovery of waste tyre burning and can be further modified for investigation on energy recovery of waste tyre burning as well.

There are few designs of the incinerator that had been proposed. After few considerations had been made based on the parameters that needs to be studied from the experiment, the design of the incinerator below is selected.

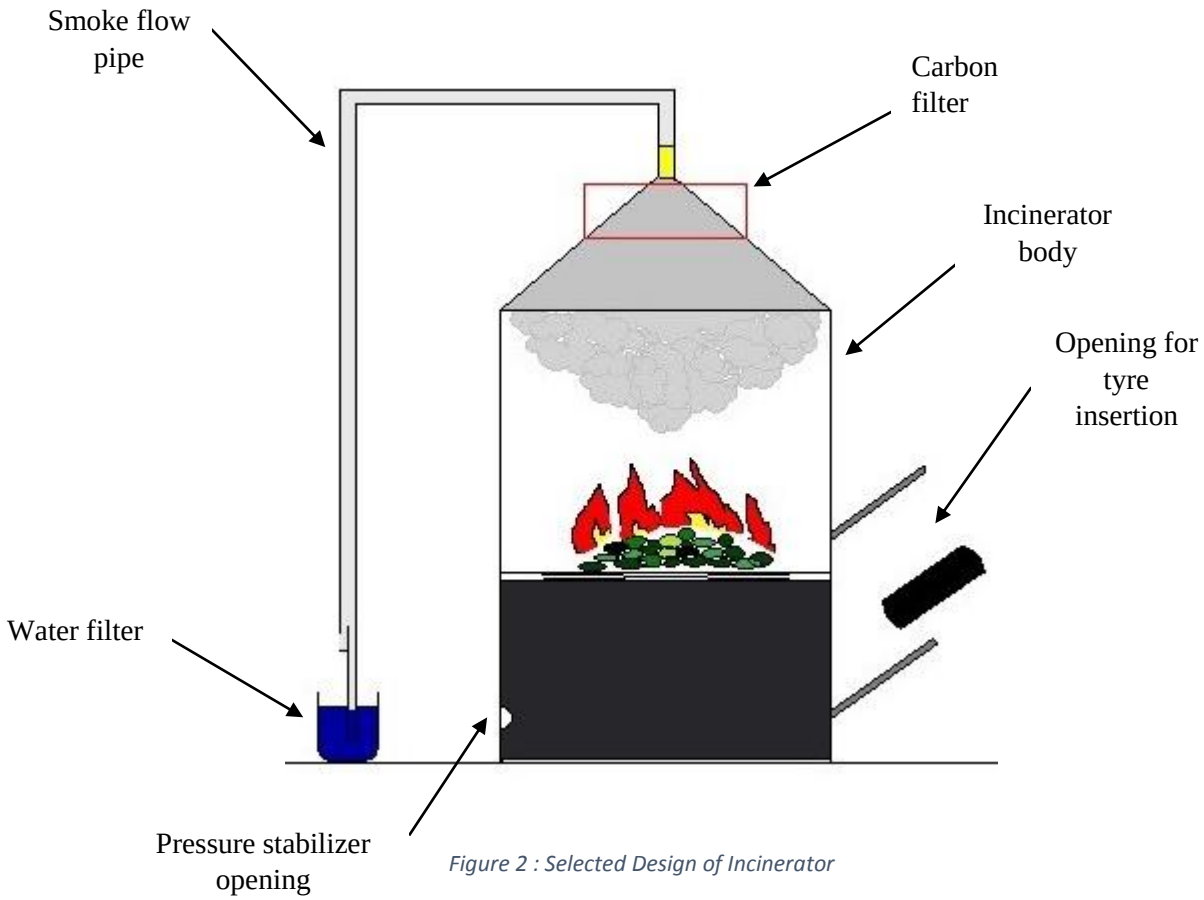

Figure 2 : Selected Design of Incinerator

Detailed design of the incinerator is shown in the figures below:

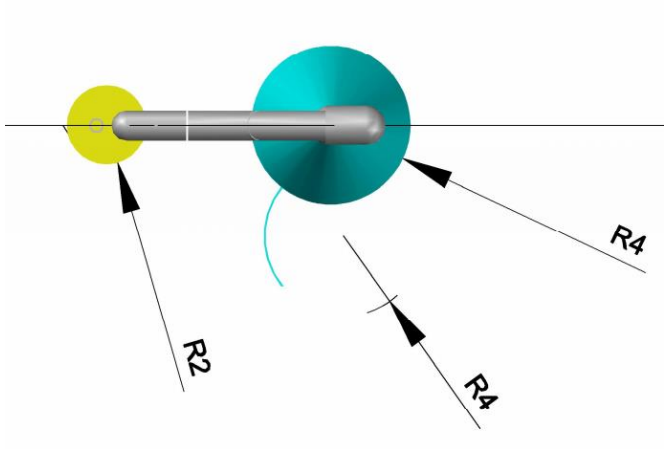

Figure 3 : Top View Drawing of Incinerator Design

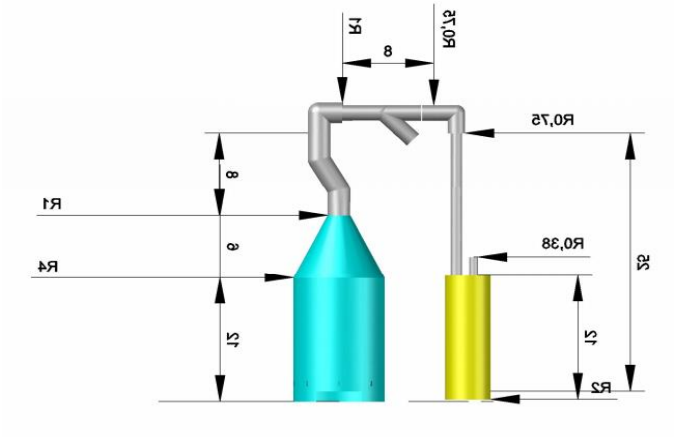

Figure 4 : Back View Drawing of Incinerator Design

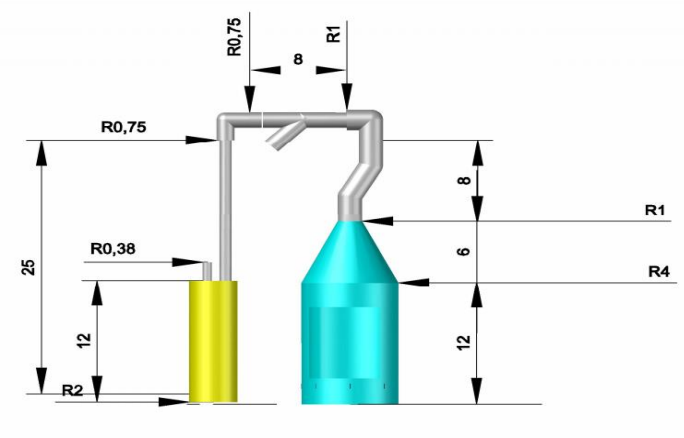

Figure 5 : Front View Drawing of Incinerator Design

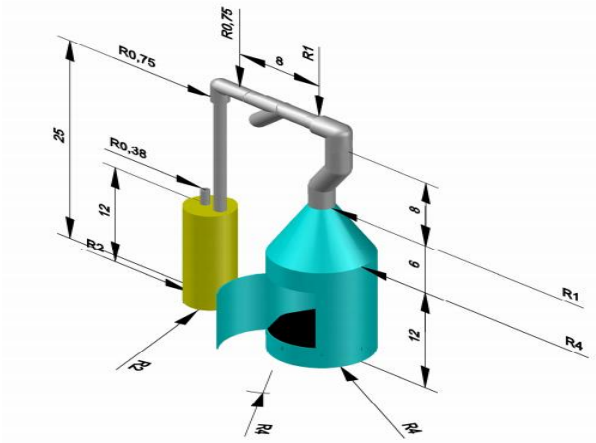

Figure 6 : Isometric View Drawing of Incinerator Design

3.3 Experimental Work on Material Recovery

Final Year Project II however focuses more on the fabrication stage of the approved design of the incinerator and also conducting the experiment itself.

Fabrication stage started by gathering and purchasing all the materials needed. Most of the materials used are comparatively cheap and easy to be found and fabricated. Following is the main process of fabricating the incinerator:

a) Marking of materials for cutting and dimension check.
b) Cutting of metal sheets for body of incinerator and conical head of the incinerator.
c) Rolling and shaping of the metal sheets using rolling machine and hammer.
d) Welding of the metal sheets that fixed the metal sheets into desired shape.
e) Connecting conical head to pipe that contain the filter of carbon black.

The main concern of the experiment to provide a foundation study on waste tyre burning along with designing a simple incinerator that can be duplicated by villagers that often do fire burning.

The experiment were divided into 5 session which is repetition of burning waste by using tyre as fuel in the incinerator fabricated. Based on this idea, few parameters had been set to remain the same or varies throughout the experiment. Among the parameters that are set to remain still throughout the experiment are as follows:

a) The amount of waste burned which in this case is dry grass. 20 gram of dry grass were used as waste that burns for each session.
b) The same incinerator are used for all 5 session of the experiment.
c) Same fire starter are used which in this case is cork fire starter.
d) Place of experiment which is open air burning.
e) Same carbon filter are used throughout the experiment.

The incinerator is brought to an open space away from the housing area or community in order to minimise the risk of inhaling smoke from the burning of waste

tyre. Experimental apparatus is set up carefully to avoid any unwanted incident to happen during the experiment. Experimental procedure are listed out as follows:

a) Firstly, 100 grams of meshed waste tyre are put into the incinerator.
b) A fire starter cork was lighted up and put into the incinerator among the meshed tyre.
c) A wire mesh is put into place that act as divider between the waste and fuel.
d) 20 grams of dried grass is put on top of the wire mesh that act as waste.
e) Door of the incinerator are closed and time taken to complete each burning session is recorded.
f) After the burning session is completed, the trap for carbon is detached and the carbon trapped is retrieved and carefully packed to be transported back to laboratory for weighing purpose.
g) Burning session is repeated by using different amount of tyres burned per session.

Throughout the 5 session of experiment, the amount of tyre used as fuel was varied for each session. First session started off by using 100 gram of tyre as fuel, and the amount of tyre used is increased by 50 gram for each session until it reached 300 gram for the fifth and last session.

3.4 Gantt Chart

Table 1 : Gantt Chart of Final Year Project I

No	Details / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1.	Selection of Project Topic (Energy Recovery from Waste Tyre Burning)														
2.	Preliminary Research Work (Literature review on waste tyre burning)														
3.	Submission of Extended Proposal (Checking by supervisor)														
4.	Proposal Defence (Supervisor and Examiner)														
5.	Project Work Continues (Design of Incinerator)														
6.	Submission of Interim Draft Report (Discussions with supervisor)														
7.	Submission of Interim Report (End of FYP I)														

Table 2 : Gantt Chart of Final Year Project II

No	Details / Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	Project Work Continues (Designing of Incinerator)															
2.	Submission of Progress Report (Checking by supervisor)															
3.	Project Work Continues (Confirmation of Design for Incinerator and Feasibility Check)															
4.	Pre- Sedex (Poster Presentation)															
5.	Project Work Continues (Confirmation of Result)															
6.	Submission of Draft Final Report (Checking by Supervisor)															
7.	Submission of Dissertation (soft bound)															
8.	Submission of Technical Paper															
	Viva															
	Submission of Dissertation (hard bound)															

CHAPTER 4

RESULT AND DISCUSSION

4.1 Fabrication of Incinerator

For Final Year Project I, author have come out with a conceptual design of the incinerator. This incinerator are expected to be fabricated on the early stage of Final Year Project II. The designed incinerator are then successfully fabricated and used for the experiment.

Among the parts of the incinerator are filter for capturing carbon black, water filter, and chimney. A filter for capturing the carbon black produced by smoke during combustion are fabricated into the incinerator. The smoke is directed towards the filter via a channel designed especially for that purpose. The filter will act as trap for the carbon black and at the end of the combustion, the carbon black trapped will then may be collected for further investigation.

Besides that, a water filter is also included in the design of the incinerator. The purpose of the water filter is to filter the smoke produced by the combustion and help in reducing the toxicity of the smoke that will be released into the air.

Figure 7 : Pipe System of Incinerator

Figure 8 : Body of Incinerator

4.2 Experiment on Material Recovery of Waste Tyre Burning

4.2.1 Incinerator Design

Although the experiment are successfully done, there are few concerns on the design of the incinerator. Firstly is most of the smoke are released to the air through the pressure escape hole that were designed at the bottom of the incinerator. The large size of the opening had caused most of the smoke from the burning escaped from there and did not go through the carbon and water filter.

Besides that, it is also noted that the fire produced from the waste tyre is big in size and it can be seen to even burn outside from the incinerator. This shows that waste tyre is a great source of fuel for burning.

Figure 9 :Burning Session

Next is the size of the incinerator body. Based on the experiment done, it is seen that the body of the incinerator is quite small that it can only handle burning of small amount of tyre at one time. The piping of the incinerator however is compatible enough to accommodate the need to burn more tyre if it were to be done in the future.

Although the design of the incinerator is yet to be improved, this incinerator is believed to be economically feasible for the villagers. The material used for the fabrication can be easily found and it is also common materials for building a simple structure. The materials if cannot be found abundantly in the village can also be bought at hardware shop with very low price.

4.2.2 Burning Process Period

It is observed that the time taken for the fire to distinguish for each session increases with the increase in amount of tyres burned. The result is shown in Table 3 below:

Table 3: Data Collected (Time taken to complete burning)

Weight of fuel, tyre (grams)	Weight of waste, dried grass (grams)	Burning process period (minutes)
100	20	12
150	20	12.5
200	20	13
250	20	14
300	20	15.5

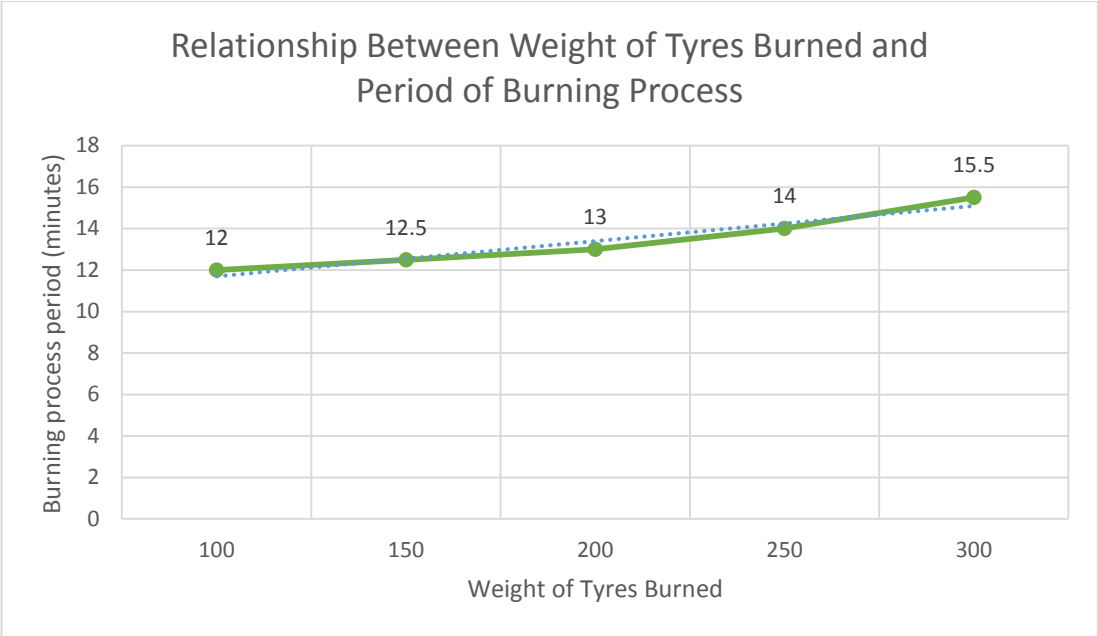

Figure 10 : Graph of Weight of Tyres Burned versus Period of Burning Process

Besides that, during the trial burning, it is observed that at the end of the burning process, quite some amount of oily substance is discharge from the waste tyre burned. The oily substance however is not present during the actual burning session of the waste tyre although the same meshed tyre is used.

4.2.3 Amount of Carbon Black Collected

The amount of carbon black captured at the carbon trap also varies with the variation of amount of tyres burned. The weighted amount of carbon captured are shown in Table 4 below:

Table 4 : Data Collected (Amount of carbon collected)

Weight of fuel, tyre (grams)	Weight of waste, dried grass (grass)	Weight of carbon captured (grams)
100	20	0.3452
150	20	0.0431
200	20	0.3304
250	20	0.06521
300	20	0.2694

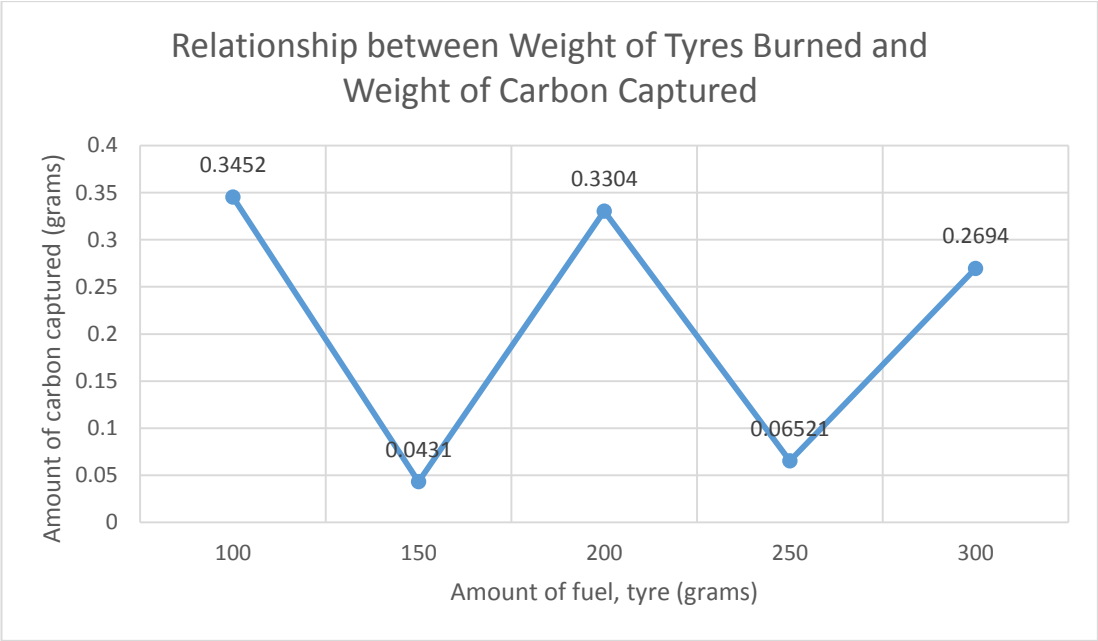

Figure 11 : Graph of Tyres Burned and Amount of Carbon Captured

The amount of carbon produced versus amount of tyres burned produced a non-linear pattern. This is believed to be affected by the uncontrollable wind direction and speed and also the large size of pressure hole at the bottom of the incinerator's body. Escaping of the smoke from going through the carbon filter means less carbon is captured.

The wind affected the flow of smoke out from the pressure hole. When the wind flowed in the direction of the pressure hole, it is observed that less smoke is released through the pressure hole because the outflow is blocked by the wind.

In addition to that, it is also observed that the rate of burning of tyre might also be affected by the wind direction and speed during the burning process. Since the burning is done in an open space and open air, the wind became uncontrollable variable.

The opposite observed when wind passes away from the pressure hole. The wind tend to promote the flow of smoke outside from the pressure hole thus decreasing the amount of smoke flowed through the designed channel and straight to the filters.

Another observation is that the smoke did not even manage to pass through the carbon filter and flow through the water filter. The water in the water filter remain clean and clear of any sediment. Although that is the case with water filter, the opposite things happened to the carbon filter. There are some black carbon trapped at the carbon filter that indicate the smoke that passes through it is filtered.

Figure 12 : Carbon black collected at the inside wall of the carbon trap.

The incinerator that is proposed will help in reducing the amount of smoke that distort the eye sight of its viewer. This is because large amount of solid particles in the smoke is already trapped about the carbon filter in the piping of the incinerator.

Although the smoke did not manage to flow properly through the water filter, it is seen that with the improvement on the design of the incinerator body, the smoke will flow through efficiently.

Although the calorific value of burning of tyre is high, more thorough will need to be done focusing on the hazardous emissions of waste tyre burning. This is essential if this method is to be further commercialised in the future. The effects of filtering the smoke further by using the water filter is yet to be studied but with the available incinerator, it is possible to be done easily

CHAPTER 5

CONCLUSION & RECOMMENDATION

There are quite a number of issue that can be concluded in time with the completion of this project. Firstly is that the incineration process can be designed as to fill the need of the outcome. For this experiment, a small non-industrial sized is produced and can be further improved and duplicated by villagers in need of it.

However, it is concluded that the carbon produced during burning can be trapped by using simple carbon filter. Although the amount of carbon captured is not linear with the increasing amount of tyres burned, there are still amount of carbon trapped.

There are few recommendations for improvement of this project in the future. Following are the recommendations:

a) It is recommended to increase the size of the body of the incinerator to double the size of it is now.
b) Decrease pressure hole size to reduce the amount of smoke escaped through it. By doing so, it is believed to flow the smoke effectively through the piping system if the incinerator and not the pressure hole.
c) It is also recommended to use the exhaust gas analyser to study the amount of toxicity in the smoke before and after it passes through carbon and water filter.

REFERENCES

[1] M. Sienkiewicz, J. Kucinska-Lipka, H. Janik, and A. Balas, "Progress in used tyres management in the European Union: a review," *Waste management,* vol. 32, pp. 1742-1751, 2012.

[2] J.-W. Jang, T.-S. Yoo, J.-H. Oh, and I. Iwasaki, "Discarded tire recycling practices in the United States, Japan and Korea," *Resources, conservation and recycling,* vol. 22, pp. 1-14, 1998.

[3] I. de Marco Rodriguez, M. Laresgoiti, M. Cabrero, A. Torres, M. Chomon, and B. Caballero, "Pyrolysis of scrap tyres," *Fuel processing technology,* vol. 72, pp. 9-22, 2001.

[4] A. Fernández, C. Barriocanal, and R. Alvarez, "Pyrolysis of a waste from the grinding of scrap tyres," *Journal of hazardous materials,* vol. 203, pp. 236-243, 2012.

[5] A. Fullana, R. Font, J. Conesa, and P. Blasco, "Evolution of products in the combustion of scrap tires in a horizontal, laboratory scale reactor," *Environmental science & technology,* vol. 34, pp. 2092-2099, 2000.

[6] E. C. Rada, M. Ragazzi, R. Dal Maschio, M. Ischia, and V. N. Panaitescu, "Energy recovery from tyres waste through thermal option," *UPB Scientific Bulletin, Series D: Mechanical Engineering,* vol. 74, pp. 201-210, 2012.

[7] M. Samolada and A. Zabaniotou, "Potential application of pyrolysis for the effective valorisation of the end of life tires in Greece," *Environmental Development,* vol. 4, pp. 73-87, 2012.

[8] X. Li, H. Xu, Y. Gao, and Y. Tao, "Comparison of end-of-life tire treatment technologies: A Chinese case study," *Waste management,* vol. 30, pp. 2235-2246, 2010.

[9] V. Sharma, F. Fortuna, M. Mincarini, M. Berillo, and G. Cornacchia, "Disposal of waste tyres for energy recovery and safe environment," *Applied Energy,* vol. 65, pp. 381-394, 2000.

[10] D. Leung and C. Wang, "Kinetic study of scrap tyre pyrolysis and combustion," *Journal of Analytical and Applied Pyrolysis,* vol. 45, pp. 153-169, 1998.

[11] M. Juma, Z. Koreňová, J. Markoš, J. Annus, and L. Jelemenský, "Pyrolysis and combustion of scrap tire," *Petroleum & Coal,* vol. 48, pp. 15-26, 2006.

[12] A. Atal and Y. A. Levendis, "Comparison of the combustion behaviour of pulverized waste tyres and coal," *Fuel,* vol. 74, pp. 1570-1581, 1995.

[13] J. Conesa, R. Font, A. Fullana, and J. Caballero, "Kinetic model for the combustion of tyre wastes," *Fuel*, vol. 77, pp. 1469-1475, 1998.

[14] E. Oriaku, C. Agulanna, J. Odenigbo, and N. Nnoruka, "Waste to Wealth through the Incineration of Waste Tyres and Recovery of Carbon Black."

[15] E. Mokrzycki and A. Uliasz- Bocheńczyk, "Alternative fuels for the cement industry," *Applied Energy,* vol. 74, pp. 95-100, 1// 2003.

[16] P. M. Lemieux, C. C. Lutes, and D. A. Santoianni, "Emissions of organic air toxics from open burning: a comprehensive review," *Progress in Energy and Combustion Science,* vol. 30, pp. 1-32, // 2004.

[17] A. Singh, S. N. Spak, E. A. Stone, J. Downard, R. L. Bullard, M. Pooley, *et al.*, "Uncontrolled combustion of shredded tires in a landfill – Part 2: Population exposure, public health response, and an air quality index for urban fires," *Atmospheric Environment,* vol. 104, pp. 273-283, 3// 2015.

[18] R. LeBlanc. (2015). *The Importance of Tire Recycling*. Available: http://recycling.about.com/od/TireRecycling/a/The-Importance-Of-Tire-Recycling.htm

[19] Environmental Law Alliance Worldwide (ELAW). (2012, 19 April 2015). *Health Impacts of Open Burning of Used (Scrap) Tires and Potential Solutions (Science Memo)*. Available: https://www.elaw.org/node/2764

[20] P. C. a. P. J. Michelle Allsopp, "State of Knowledge of the Impacts of Waste Incinerators on Human Health (Executive Summary) *," *Greenpeace Research Laboratories,* 2001.

[21] B. S, "Assessment of Small-Scale Incinerators for Health Care Waste," *Ann Arbor: University of Michigan,* 2004.

[22] A. Patki, "Study and design of a small portable incinerator for medical hazardous waste by using natural convection flow," 1511637 M.E.S., Lamar University - Beaumont, Ann Arbor, 2012.

APPENDICES

Appendix 1 (Laboratory Work for Incinerator Fabrication)

Appendix 2 (Experimental Work)