Design of Pyrolysis Reactor for Recycling Polypropylene Plastic to Obtain Free Oil as Energy Source from Waste Mask Amidst Covid-19 Pandemic (MOFUE Machine)

Valerie Anastasia Wijoyo, Nafisa Fatihazzahra, Heidi Tjie, Athaya Amirah Putri Levanska

1. British School Jakarta, West Jakarta, Indonesia (25wijoyov@bsj.sch.id);
2. British School Jakarta, South Jakarta, Indonesia (25wahyudin@bsj.sch.id);
3. Santa Laurensia, South Tangerang, Indonesia (heidi.t@snta-laurensia.sch.id);
4. SMA Negeri 8 Jakarta, South Jakarta, Indonesia (2025-27203@sman8jkt.sch.id).

Abstract

Surgical masks are a vital object for everyone in this pandemic era. This 3-layered mask is made of fabric, polypropylene plastic, wire, and silicone. However, this mask requires a lengthy period to decompose caused of polypropylene plastic. MOFUE machine was designed with the goal to help resolve mask waste which has a greater concern than plastic waste which has been a global issue for decades and helps to maximize the amount of oil supplied in Indonesia. This machine involves three processes, pyrolysis, filtration, and distillation. Stainless steel is the main material used for all surfaces and walls of this invention in addition to an insulator wrapped around the equipment preventing heat loss.

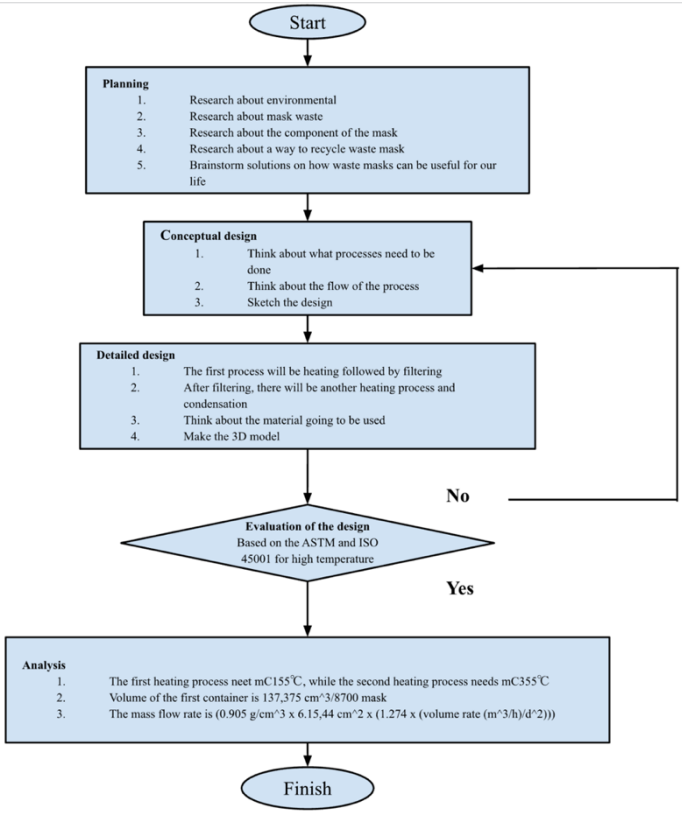
1. Introduction

The ongoing Covid-19 pandemic has significantly infected humans, businesses, jobs, and especially the environment. The Indonesian government still requires us to wear masks when doing outside activities, especially for identified people with Covid-19, following health protocol advice from WHO.[1] Around 6,460,265 people are still positive up until this date, 8 October 2022 even though vaccination processes have been held.[2] Masks are a comprehensive strategy to cut the chain of covid infection, adopting masks as part of our daily lives. Indonesia has the population of 280,309,190, meaning hundreds of tonnes of masks are undisposed each day.[3] A large number of masks are thrown away every day creating greater concern in the world than plastic bags. Surgical masks are recommended by the ministry of health of the Republic of Indonesia.

Disposable masks contain 3 layers of propylene, cotton, and polyester. Polypropylene or PP and polyester used in masks is a thermoplastic polymer produced by non-renewable resources petroleum and natural gases.[4] Polypropylene is known as plastic packaging in the world while polyester is most used as a material for clothing worldwide.[4] Both of these materials are not biodegradable and only 15% of polyester and 1% of polypropylene are recycled of the total polymers used, which means the rest of the materials is headed to the landfill.[5] Homopolymer is a type of polypropylene used in masks where it is stiffer and more robust than copolymer.[6] This leads to a more difficult breakdown of polypropylene. Approximately 20-30 years are needed to fully decompose polypropylene and polyester each and it contributes to emitting carbon dioxide which affects the climate.[7] If these materials are not recycled, micro size plastic fibres will be produced on a great scale, even greater than plastic bags which have been the biggest concern in the world since the 1960s. Micro size fibres contain toxic chemicals that pollute water, harming small water organisms to ingest it.

There have been previous studies on the pyrolysis of mask wastes. Pyrolysis is known to be an environmentally friendly and effective way to convert mask wastes into the oil. Masks contain high hydrogen, carbon content, and heating value. Thus, the pyrolysis method could handle waste and transform it into a valuable product such as oil fuel. [8] Other studies have shown pyrolysis towards face masks occurs at a temperature range of at least 456-466°C, producing carbon and oxygen-deficient oil with a high heating value of 43.5Mj/kg. [9] Furthermore, distillation is a method of separating non-volatile solids and liquids. A study showed distillation aims to separate hydrocarbon from crude oils. [11] However there has been no study that combines both processes to produce oil. As the production of pyrolysis includes carbon made of organic elements like hydrocarbon, we want to combine both processes to convert masks into clean oil directly in one machine.

2. Method and Experimental Details



The machine that we introduce has the function and ability to convert the three-layer mask waste into something more useful such as oil from the plastic pellets. The melting, filtration and shaping processes are all utilized in this machine. Knowing that the outside section of the mask has been infected by the covid-19 virus, it is crucial to sterilize

it before processing the mask with heat to melt it into another substance. It is essential to also employ high-intensity heat to kill both viruses and germs because the inside component also directly contacts the user's mouth and nose. Mask waste is put into the heating room and the heater will melt the three-layer mask waste at a temperature of 456 C. The filter/polypropylene plastic cloth layer of the mask melts so that the melt can travel through the filter and through pipe 1 to lead to pipe 2 for the evaporation process. Wire and other unwanted elements that are not melted will be filtered with mesh that can be manually removed prior to evaporation. The support strap and nose wire segment were left in the mask filter. Following the collection of the filtration results, a ring heater is used in the evaporation step of the process. Following a condensation procedure, the material from the evaporated mask waste will gather in the oil storage where it can later be used for more beneficial purposes.

C. Form	1. Ring Heater  2. Stainless steel chamber 

3. Results and Discussion

3.1. Project Planning Stage

We need a tool or equipment that helps the research faced and challenges include the volume of waste caused by the three layers of masks high due to the high spread of the coronavirus.

Table 1. Morphology

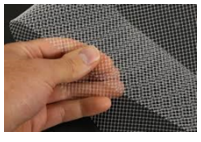
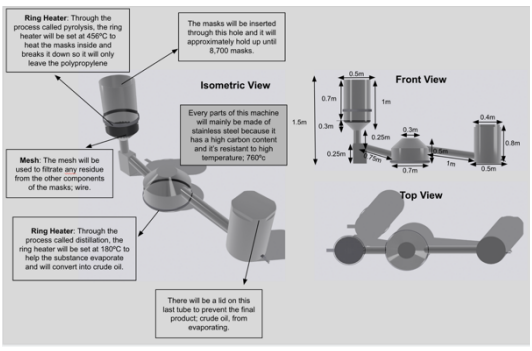
Function	Alternative 1
A. Melt or fuse	1. Ring heater 
B. Separate	1. Mesh 

Table 2. Standard Component

No	Component	Requirement
1	Heating elements: Ring heater 1 Ring heater 2	Power: 1.5 kW Current: 220 V Inside Diameter: 0.5 m Temperature: 456 °C Inside Diameter: 0.7 m Temperature: 360 °C
2	Glass pipes: Glass pipe 1 Glass pipe 2	Dimension: Length: 0.5 m Wall thickness: 4 mm (about 0.16 in) Diameter: 14 cm (about 5.51 in) Length: 0.3 m Wall thickness: 4 mm (about 0.16 in) Diameter: 14 cm (about 5.51 in)
3	Stainless steel chambers	Dimension: Diameter: 0.5 m Height: 0.7 m Wall thickness: 4 mm (about 0.16 in)
4	Stainless steel sheets:	Dimension: Length: 1.8 m x 1.5 m Wall thickness: 4 mm (about 0.16 in) Length: 0.8 m x 0.8 m Wall thickness: 4 mm (about 0.16 in)
5	Stainless steel can	Dimension: Diameter: 0.7 m Height: 0.5 m Wall thickness: 4 mm (about 0.16 in)
6	Wood beam	Dimension: Length: 0.25 m Width: 0.15 m Height: 0.25 m
7	Stainless steel mesh	Dimension: Length: 0.7 m x 0.7 m

3.2 Detailed Design of MOFUE

Used masks will eventually degrade into waste that harms the environment, thus wethat can obliterate them and create something beneficial. The mask itself consists of 3 layers, one of which is made of propylene that can be converted by the pyrolysis method into fuel oil. The masks that have been used will be collected which can fit up to 8,700 masks. Knowing that the outside section of the mask has been infected by the covid-19 virus, it is crucial to sterilize it before processing the mask with heat to melt it into another substance. The three-layer mask trash is placed in the heating area, where it will melt at a temperature of 456 °C to the ring heater. The melted propylene will pass through the filter and pipe 1 for the evaporation process, while the component that is not melted by the heat will be removed manually with the mesh. The substance will then be added to the stainless steel can once it has been heated to 180 °C by the ring heater. The evaporating oil will encounter pipe 2's condensation process and be collected later in the final stainless-steel chamber as an oil fuel.



3.3 Design of Calculation

Q = m c ΔT

- **Heat process 1**

Q = **m c ΔT**

Q = (mass of 8,700 used masks) x (heat density of steel) x (delta temperature)

Q = 52,200 gram x 0.113 kal/gr °c (456.0 °c – 27.0 °c)

= 2,530,499.4 J

1. **Heat Process 2**

Q = **m c ΔT**

Q = (mass of the melted substance) x (heat density of steel) x (delta temperature)

= 38,700 gram x 0.113 kal/gr °c (180.0 °c – 27.0 °c)

= 669,083.3 J

3.4 Economy Aspect

No	Component	Price
1	Heating elements: Ring heater 1 Ring heater 2	 IDR 3,648,000.00 IDR 4,891,000.00
2	Glass pipes	IDR 110,000.00
3	Stainless steel chambers	IDR 1,870,000.00
4	Stainless steel sheets:	IDR 3,406,000.00
5	Stainless steel can	IDR 573,000.00
6	Wood beam	IDR 157,560.00
7	Stainless steel mesh	IDR 240,000.00
Total: IDR 14,895,560.00		

4. Conclusions

From all of the design above; the planning stage, the detailed design of MOFUE, the design of calculation, and the economy aspect, we can conclude that: 1. The main function of this machine is to recycle masks used to prevent more waste in the environment so the product can be reused as fuel. The capacity of the machine planned is 8,700 masks/process. 2. The dimension of the machine will be 1,5 x 3, 25 x 0,7 m. The total estimated cost of this machine will be around IDR 14,895,560.00/2022

5. Acknowledgements

We would like express our special thanks of gratitude to Kak Fayza Yulia for her guidance and support throughout the process of completing this research paper.

6. References:

1. Coronavirus disease (COVID-19): Masks. (2022c, January 5). *Who.Int*. https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-masks
2. WORLD / COUNTRIES / INDONESIA. (n.d.-b). *Worldometers.Info*. Retrieved October 18, 2022, from https://www.worldometers.info/coronavirus/country/indonesia/
3. Factbox: Polypropylene sees demand pull to manufacture specialized masks. (2020, March 27). *Spglobal.Com*. https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/petrochemicals/032720-polypropylene-sees-demand-pull-to-manufacture-specialized-masks
4. What is the Difference Between Polypropylene Types? (2018, October 2). *Machinedesign.Com*. https://www.machinedesign.com/community/article/21837192/whats-the-difference-between-polypropylene-types
5. Is Polypropylene Bad for the Environment? (2021, November 28). *Ourendangeredworld.Com*. https://www.ourendangeredworld.com/eco/is-polypropylene-bad/
6. Polypropylene Uses. (n.d.). *Adrecoplastics.Co.Uk*. https://adrecoplastics.co.uk/polypropylene-uses/#:~:text=Polypropylene%20(PP)%20is%20one%20of,used%20thermoplastics%20in%20the%20world

7. A Simple Guide to Polypropylene Recycling for Businesses. (n.d.). *Www.Aaapolymer.Com*. https://www.aaapolymer.com/a-simple-guide-to-polypropylene-recycling-for-businesses/#:~:text=The%20US%20Environmental%20Protection%20Agency,30%20years%20to%20totally%20breakdown
8. Eddy Y. Zeng, & Christian Sonne. (n.d.). Valorisation of medical waste through pyrolysis for a cleaner environment: Progress and challenges. *Environmental Pollution*, *279*. https://www.sciencedirect.com/science/article/abs/pii/S0269749121005169
9. Converting used face masks into oil for fuel? (n.d.). *Cosmosmagazine.Com*. https://cosmosmagazine.com/science/chemistry/pyrolysis-convert-face-masks-into-oil/
10. Distillation of Pyrolytic Oil Obtained from Fast Pyrolysis of Plastic Wastes. (2017, October). *Energy Procedia*, *138*. https://www.sciencedirect.com/science/article/pii/S1876610217350129