International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 11, November 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

Design and Analysis of Solar Based Hybrid Recycling System for Plastic Waste

Nikita Lahoti[1], Mohammed Akbar[1], Ronak Kothari[1] ,
Dr. Ravindra Pathak[1]
1 Mechanical Department, Medi-Caps University, India

ABSTRACT

In the modern day, the threat of plastic waste pollution to our world is greater than ever. Despite relatively poor recovery and recycling ratesonly around fifteen percent of the plastic produced each year is recycledthe world's plastic output is still rising. Despite the fact that recycling rates have steadily risen over the past few decades, the rate at which plastic is produced globally far outpaces recycling rates, which means that a substantial amount of plastic is ending up in landfills, dump sites, and ultimately the environment, where it harms the ecosystem. To support recycling efforts and preclude the significant quantities of plastic waste, better end-of-life options are needed for plastic waste. Plastic pyrolysis is a potential emerging technique to disintegrate polymers. Liquids that resemble hydrocarbons that may be degraded using concentrated solarradiation to yield fuel and other byproducts that can be utilized in other chemical reactions, are among the major outcomes of the pyrolysis reaction, which creates a closed-loop system. The design of a solar hybrid pyrolysis reactor system and its calculations are discussed in this work.

Keywords- *liquid fuel, pyrolysis,threat of plastic waste, solar collector efficiency, solar parabolic reflector,*

1. INTRODUCTION

Synthetic polymers were created in the early 1950s and quickly brought to market, which helped progress a number of fields of human endeavor[1]. Plastics have been used for a wide range of purposes, including the development of computers, lightweight components, building materials, and the bulk of life-saving advancements in modern medicine. Without plastic-based PPE, even the current fight against the COVID 19 pandemic would have been exceedingly challenging[2,3]. Plastics are also commonly utilized in the electrical and electronic sectors because they have high insulating and dielectric properties[4,5]. We have become increasingly reliant on this modern material, the most majority of which are single-use objects, are a result of the increasing popularity of its usage. The production and use of plastic have increased recently. Globally, over 6,300 Mt of plastic trash were generated between 1950 and 2015 from the production of about 8,300 Mt of virgin plastics, of which about 9% were recycled, 12% were burned, and 79% were dumped in landfills[6]. Additionally, post-consumer plastic waste (PCPW) is steadily growing in the environment[7,8].Nowadays, a sizable portion of the total garbage produced in many countries comes from the reckless disposal of used plastics[9,10]. The marine plastic trash, which has been shown to degrade into microplastics and be devoured by aquatic animals[11–14], is much more concerning. According to research, this has a major adverse effect on zooplankton mortality and population, which is a crucial part of the marine ecosystem[13]. The world economy, people, animals, and environment are currently threatened by plastic waste, especially in underdeveloped and underdeveloped countries that lack advanced recycling facilities and have loose regulations on plastic production, consumption, and control[15].Depending on the kind, application, and service conditions of the plastic, any or all of the following additives may be present: plasticizers, fire retardants, antioxidants, thermal stabilizers, light dampers, and lubricants. According to scientific studies, several of these compounds have the ability to mimic, obstruct, or interfere with hormones in the endocrine systems of both humans and animals. They are classified as endocrine disrupting chemicals (EDCs)[16]. Persistent organic pollutants (POPs), sometimes known as "permanent chemicals," have been linked to several of them. They are not easily damaged by chemical, biological, or photolytic environmental activities. The bulk of flame retardants fall under this category, including polychlorinated biphenyls (PCBs), hexachlorobenzene, hexabromocyclododecane (HBCD), polybrominated diphenyl ethers (PBDEs), and hexabromobiphenyl (HBB)[17]. In the development of contemporary technology, plastics have shown to have remarkable qualities and applications. Although the open burning of home and industrial plastics fuels the release of dangerous compounds, inappropriate usage, poor disposal of its waste, and inadequate controls of additions to plastics meant for food packaging might result in their release[18]. Authorities throughout the world have employed phased techniques, such as waste plastic buybacks or partial to full bans on specific types of plastic items, to avoid pollution from used and discarded plastics[19,20]. However, these initiatives have not significantly improved the situation due to negative economic, legal, political, technological, and operational constraints[21,22].A more comprehensive closed-loop approach will be needed than the mechanical recycling methods where used plastics are recycled in order to keep up with the technological advancements brought on by the use of plastics and its sustainable economic growth. Mechanical recycling just extends the amount of time used plastics spend in landfills and the ocean. Thermal treatment, such controlled combustion or pyrolysis, is the only way to permanently remove plastic garbage. Plastic waste is converted into energy in the form of solid, liquid, and gaseous fuels through the closed-loop, holistic process of pyrolysis[23–25].

2. LITERATURE REVIEW AND OBJECTIVES

In many nations, land filling is the standard practice for waste disposal. However, as the global population and associated urbanization rise, land filling space is becoming increasingly scarce. Due to rising environmental and public health concerns, land filling plastic trash is now the least preferred waste management alternative. There is a serious threat to human health from the variety and quantity of harmful substances like leachate that can seep from landfills into underground water [26]. Municipal solid waste (MSW) often contains plastics, and it is a common practice in many communities, especially in less developed or developing nations, to burn this rubbish in open fires. Air pollution is greatly amplified by the incineration of plastic trash in open fields. Plastics account for about 12% of MSW in most cities, and 40% of trash worldwide is incinerated [27]. Pyrolysis is the thermal disintegration of plastic waste at different temperatures (300–900°C). In pyrolysis, feedstocks like waste plastic are burned in an oxygen-free or low-oxygen environment until they decompose into a range of simpler hydrocarbons rather than combust completely. Thermal depolymerization is a simple explanation for how polymers like plastic break down into their building blocks(monomers). Used plastics can be converted back into usable resources including monomers, fuel, and other materials through a process called pyrolysis.

When compared to more traditional methods for dealing with plastic waste, pyrolysis has many benefits. For instance, most plastic trash during recycling is down cycled, meaning that it is utilized to make poorer quality and less useful products. For one reason, plastic tends to lose qualities like clarity, strength, and flexibility the more times it is recycled.

The objectives of this research paper are listed as follows:

1. To design a solar hybrid plastic recycling system to promote sustainable development.
2. To perform calculations for design constraints of compact recycling system.
3. To design the parabolic reflector component of the recycling system.
4. To design the body frame and pyrolysis chamber.
5. To perform calculations of heat generated due to solar parabolic concentrator.
6. To perform a thermal analysis of the system to evaluate its efficiency.

3. METHODOLOGY

3.1 Design Model

A compact model 3Dis prepared as a test model to observe and calculate for its thermal analysis and for its design. The design parameters for container and box are preselected and shown in Fig. 3.3 to accommodate the model as being portable. The portability of the model will aid in its utilization, thus making it adaptable.

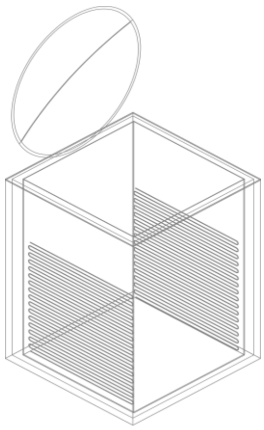

Fig. 3.1: Proposed novel solar hybrid pyrolysis reactor

International Journal of Advance Research in Science and Engineering
Volume No. 11, Issue No. 11, November 2022
www.ijarse.com
IJARSE
ISSN 2319 - 8354

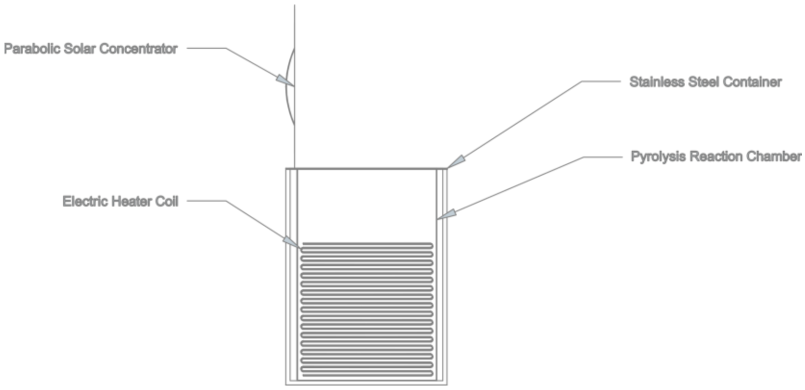

Fig. 3.2: The parts of the solar hybrid pyrolysis reactor.

The solar hybrid pyrolysis reactor system is designed using viable design software such as Catia and AutoCAD. Before proceeding to design the 3D model of the system, a rough sketch of the diagram is made with labeled parts as observed in Fig. 3.2 and with Fig. 3.3 illustrating the dimensions for the selected test design models' consideration for compactness.

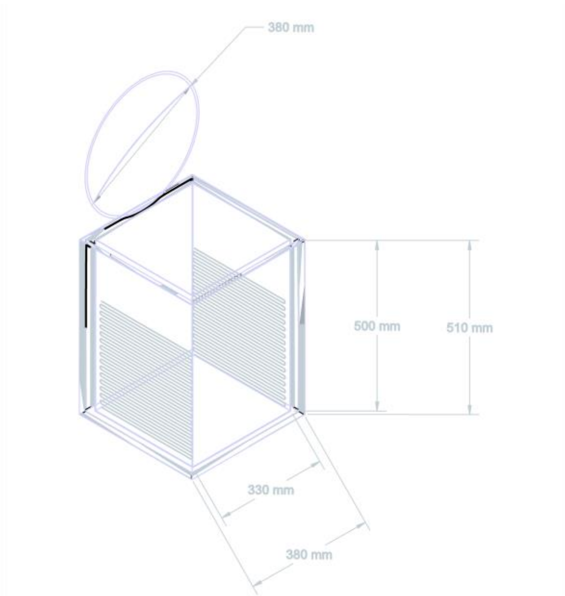

Fig. 3.3: Dimensions of the solar hybrid pyrolysis reactor.

3.2 Parabolic Dish Calculation

"Consider the following equation of parabola as its cross section, so it will result in a paraboloid."

: $$y = ax^2 \#3.1$$

Where a is a constant. And with formula for focal length f,

: $$a = \frac{1}{4f} \#3.2$$

Keeping a depth value of d = 2cm in y in above equation,

: $$y = ax^2 \#3.3$$

: $$2 = a(19^2) \#3.4$$

: $$a = 0.0055401662\ cm^{-1} \#3.5$$

Substitute (3.5) value in (3.2),

: $$0.0055401662 = \frac{1}{4f} \#3.6$$

: $$f = \frac{1}{4(0.0055401662)} \#3.7$$

: $$f = 45.125\ cm \#3.8$$

So height of plastic waste mass at bottom of pyrolysis chamber is given by,

: $$h = 51 - 45.125 \#3.9$$

: $$h = 5.875\ cm\ (approximate) \#3.10$$

Also since r = 19 cm, D or aperture = 38 cm. So exact curved surface area of parabolic reflector

: $$A_D = \pi \left\{ \frac{[(a^2D^2 + 1)]^{\frac{3}{2}} - 1}{6a^2} \right\} \#3.11$$

IJARSE
ISSN 2319 - 8354

:
$$A_D = \pi\left\{\frac{\left[\left((0.0055401662^2)(38^2)+1\right)\right]^{\frac{3}{2}}-1}{6(0.0055401662^2)}\right\} \#3.12$$

:
$$A_D = 1146.590002\ cm^2 \ \#3.13$$

:
$$A_D = 0.114659\ m^2 \ \#3.14$$

Thus in (3.14) the curved surface area of the parabolic reflector is obtained. This is later used in thermal analysis calculations.

3.3 Thermal Calculations

The aperture area of parabolic reflector,

:
$$A_a = \frac{\pi d^2}{4} \ \#3.15$$

:
$$A_a = \frac{\pi(0.38^2)}{4} \ \#3.16$$

:
$$A_a = 0.1134\ m^2 \ \#3.17$$

The heat transfer at focal point of parabolic reflector,

:
$$\dot{Q}_{focal\,point} = I_{bn} A_d E \cos\theta_i\ \rho \emptyset \tau \alpha \ \#3.18$$

:
$$\dot{Q}_{focal\ point} = (275)(0.114659)(0.97)(1)(0.94)(0.8)(1)(1) \ \#3.19$$

:
$$\dot{Q}_{focal\ point} = 23.00014\ W \ \#3.20$$

Now the concentrator efficiency,

:
$$\eta_{concentrator} = E \cos\theta_i\ \rho\emptyset \ \#3.21$$

:
$$\eta_{concentrator} = (0.97)[\cos 0^{\circ}](0.94)(0.8) \ \#3.22$$

$$\eta_{concentrator} = 0.72944 \quad \#3.23$$

$$\eta_{concentrator} = 72.944\ \% \quad \#3.24$$

4. RESULTS

4.1 Design Findings

For the design parameters of solar hybrid recycling system, the following are the findings, provided the dimensions of the steel container are:

$$height\ of\ steel\ container = 510\ mm \quad \#4.1$$

$$side\ of\ steel\ container(square\ base) = 380\ mm \quad \#4.2$$

Then the dimensions of parabolic reflector are found to be:

$$Aperture\ of\ reflector = 380\ mm \quad \#4.3$$

$$Focal\ length = 451.25\ mm \quad \#4.4$$

$$Depth\ parabolic\ reflector = 20\ mm \quad \#4.5$$

$$Surface\ area\ parabolic\ reflector = 0.114659\ m^2 \quad \#4.6$$

4.2 Thermal Findings

From prior calculations as shown in (3.17), (3.20) and (3.24), it is found that:

$$Aperture\ area = 0.1134\ m^2 \quad \#4.7$$

$$Heat\ at\ focus\ point\ of\ reflector = 23\ W \quad \#4.8$$

$$Concentrator\ efficiency = 72.944\ \% \quad \#4.9$$

5. CONCLUSION

1. We have successfully arrived at an optimal design of a solar hybrid recycling system for plastic waste.

2. The final dimensions are :

a. Aperture of parabolic reflector = 38 cm

b. Curved surface area = 1146.59 cm2

c. Height, breadth, thickness of the pyrolysis chamber = 50cm, 33cm, 38cm

3. The dimensions with which the design has been drafted are chosen keeping its prototype in consideration.
4. As per the heat transfer calculations performed we have derived 72.944% efficiency of the solar parabolic concentrator.
5. The designing of a hybrid, closed loop and sustainable recycling system utilizing a renewable source

6. ACKNOWLEDGEMENTS

I would like to express my sincere gratitude towards Medi-Caps University and the entire Mechanical Department for giving us this opportunity to work on this innovative project. I also thank our guide Dr. Ravindra Pathak for providing us the needed insights and guidance to accomplish this research successfully. We also appreciate our teams' efforts and coordination.

REFERENCES

[1] Philippe C (2019) The history of plastics: from the capitol to the Tarpeian Rock. *Field Actions Sci Rep 19*: 6–11.

[2] Livingston E, Desai A, Berkwits M (2020) Sourcing personal protective equipment during the COVID-19 pandemic. *JAMA 323*: 1912–1914.

[3] Czigány T, Ronkay F (2020) The coronavirus and plastics. *Express Polym Lett* 14: 510–511.

[4] Gaiya JD, Eze WU, Ekpenyong SA, et al. (2018) Effect of carbon particles on electrical conductivity of unsaturated polyester resin composite national engineering conference, 142–144.

[5] Gaiya JD, Eze WU, Oyegoke T, et al. (2021) Assessment of the dielectric properties of polyester/metakaolin composite. *Eur J Mater Sci Eng 6*: 19–29.

[6] Babayemi JO, Nnorom IC, Osibanjo O, et al. (2019) Ensuring sustainability in plastics use in Africa: consumption, waste generation, and projections. *Environ Sci Eur 31: 60*.

[7] Li WC, Tse HF, Fok L (2016) Plastic waste in the marine environment: a review of sources, occurrence and effects. *Sci Total Environ* 567: 333–349.

[8] Geyer R, Jambeck JR, Law KL (2017) Production, use, and fate of all plastics ever made. *Sci Adv* 3: 1–5.

[9] Kawai K, Tasaki T (2016) Revisiting estimates of municipal solid waste generation per capita and their reliability. *J Mater Cycles Waste Manage* 18: 1–13.

[10] ESI Africa (2018) S. Africa: 1.144 m tonnes of recyclable plastic dumped in landfills.

[11] Wagner M, Scherer C, Alvarez-Munoz D, et al (2014) Microplastics in freshwater ecosystems: what we know and what we need to know. *Environ Sci Eur* 26: 9.

[12] Wrighta SL, Thompson RC, Galloway TS (2013) The physical impacts of microplastics on marine organisms: a review. *Environ Pollut* 178: 483–492.

[13] Werner S, Budziak A, van Franeker J, et al. (2016) Harm caused by marine litter. MSFD GES TG marine litter—Thematic Report; JRC Technical report; EUR 28317 EN.

[14] Anderson JC, Park BJ, Palace VP (2016) Microplastics in aquatic environments: implications for Canadian ecosystems. *Environ Pollut* 218: 269–280

[15] Srivastava V, Ismail SA, Singh P, et al. (2015) Urban solid waste management in the developing world with emphasis on India: Challenges and opportunities. *Rev Environ Sci Bio-Technol* 14: 317–337.

[16] Schuga TT, Janesickb A, Blumbergb B, et al. (2011) Endocrine disrupting chemicals and disease susceptibility. *J Steroid Biochem Mol Biol* 127: 204–215.

[17] Willner SA, Blumberg B (2019) Encyclopedia of endocrine diseases (second edition).

[18] Verma R, Vinoda KS, Papireddy M, et al. (2016) Toxic pollutants from plastic waste-a review.*Procedia Environ Sci* 35: 701–708.

[19] Conlon K (2021) A social systems approach to sustainable waste management: leverage points for plastic reduction in Colombo, Sri Lanka. *Int J Sustainable Dev World Ecol* 1–19.

[20] Clapp J, Swanston L (2009) Doing away with plastic shopping bags: international patterns of norm emergence and policy implementation. *Environ Polit* 18: 315–332.

[21] Imam A, Mohammed B, Wilson DC, et al. (2008) Solid waste management in Abuja, Nigeria.*Waste Manage* 28: 468–472.

[22] Chida M (2011) Sustainability in retail: The failed debate around plastic shopping bags. *Fashion Pract* 3: 175–196.

[23] Devy K, Nahil MA, Williams PT (2016) Catalytic pyrolysis of waste plastics using staged catalysis for production of gasoline range hydrocarbon oils. *J Anal Appl Pyrolysis* 124: 631–637.

[24] Eze WU, Madufor IC, Onyeagoro GN, et al. (2020) The effect of Kankara zeolite-Y-based catalyst on some physical properties of liquid fuel from mixed waste plastics (MWPs) pyrolysis. *Polym Bull* 77: 1399–1415.

[25] Eze WU, Madufor IC, Onyeagoro GN, et al. (2021) Study on the effect of Kankara zeolite-Y-based catalyst on the chemical properties of liquid fuel from mixed waste plastics (MWPs) pyrolysis. *Polym Bull* 78: 377.

[26] Teuten EL, Saquin JM, Knappe DR, et al. (2009) Transport and release of chemicals from plastics to the environment and to wildlife. *Philos Trans R Soc Lond B Biol Sci* 364: 2027–2045.

[27] Hopewell J, Dvorak R, Kosior E (2009) Plastics recycling: challenges and opportunities. *Philos Trans R Soc B* 364: 2115–2126.