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Development of the Plastic Tile-Making Machine with Isolated Cylinder for Extrusion Process

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***Abstract*: The purpose of this research is to produce a mechanical design approach for an environment-helping machine, a plastic-tile maker. Specifically, the types of plastic used are polyethylene terephthalate and polyethylene. These are used because they are commonly used and disposed in the environment. Engineering computations for the design details of the major components of the proto-type are involved, which is mainly focused on thermodynamics. To develop statements of conclusion, the study conducted a series of testing and evaluation for the isolation system and production. The best size that is made by the prototype is 4" by 4" and 6" by 6". The basis of evaluation of the product is by appearance, notches, and production rate. The study shows all the physical appearance of the rejected and accepted tile. As stated above, the research focuses mainly on the evaluation of the prototype's final product. Since the study is focused mainly on mechanical application whereas it is recommended to apply more electronic enhancement for the prototype.**

***Keywords*: Plastic tile, extrusion process, fume control and polyethylene plastic.**

I. INTRODUCTION

Truly, engineering is the application of scientifically theories to the curiosities and problems of mankind. However, today, it is used to businesses that are focusing too much to the rise of their economy; they neglect the consequences of their action. People forget the responsibility on protecting the nature. Over the past 60 years, plastic production and waste have dramatically increased. Indeed, the vast majority of plastics are not recycled at the end of their useful life, ensuring that this multiplication in production results in multiplication of harmful waste. From raw material extraction through plastic polluting the ocean, plastics represent the failure of a predominantly fossil fuel based, linear economic system. A problem this complex embedded in our societies and economies requires solutions that address the cross-sector nature of the problem and are built upon sustainable and environmentally just frameworks that deliver permanent solutions and the deep changes needed.

Most plastics are based on the carbon atom. Silicones, which are based on the silicon atom, are an exception. The carbon atom can link to other atoms with up to four chemical bonds. When all of the bonds are to other carbon atoms, diamonds or graphite or carbon black soot may result. For plastics the carbon atoms are also connected to the aforementioned hydrogen, oxygen, nitrogen, chlorine, or sulfur. When the connections of atoms result in long chains, like pearls on a string of pearls, the polymer is called a thermoplastic. Thermoplastics are characterized by being meltable. The thermoplastics all have repeat units, the smallest section of the chain that is identical. We call these repeat units' unit cells. The vast majority of plastics, about 92%, are thermoplastics1.

Industrial companies for the production of roofing tiles already exist. The molding and softening process they use to disintegrate the polymer particles is by direct heating of the plastic material. Obviously, this kind of method causes dioxin emissions, which is unhealthy for the environment.

Burning plastics containing organochlorine-based substances like PVC can cause the most dangerous emissions. When such plastics are burned, harmful quantities of dioxins, a group of highly toxic chemicals is emitted. Dioxins are the most toxic to the human organisms. They are carcinogenic and a hormone disruptor and persistent, and they accumulate in our body-fat and thus mothers give it directly to their babies via the placenta. Dioxins also settle on crops and in our waterways where they eventually wind up in our food, accumulate in our bodies and are passed on to our children (WFEC, n.d.).

In this study, the researchers thought of a design and process on lessening or eliminating the toxic fumes produce by burning the plastics. A band heater is used as the softening equipment on the cylinder. For the compression of the softened plastic, a stepper motor with a ball screw and piston head linkage is to be used. The function of this mechanism is to force the softened plastic in the mold.

II. LITERATURE REVIEW

The review of related conceptual literature and studies provides information about plastics, tiles, and the related process of turning a plastic waste into a tile. The study is somehow of a combined alteration and application of current studies. In the comparison of the ceramic tile and plastic tile, the thermal conductivity of the latter is lower than the former, thus, a plastic tile is better when it comes to heat resistance and density.

In the study conducted by Jimoh et.al (2017), it is stated that "any other thermoplastic that is recycled to form any of the specimens above, its properties will be the same since the plastics recycled in this research showed very little or no difference". This conclusion statement provides supporting evidence that there will be a detainment of physical properties of plastic when it is heated with oil. It is also stated in the previous study that "the suitable melting point for all the waste plastics studied in this research was found to be 60" which proves that the temperature needed to soften or melt the plastic can be easily attained by the equipment to be used in this study. However, there is no provision of isolation or controlling the fumes that is exerted from the melting plastic. The tile product in the prototype of the study is generally used for bathroom, and kitchen walls.

In the study conducted by Panganiban et.al (2018), it is stated under on their methodology that cooking oil is one of their additives on making their plastic-sand tile. Although there are common similarities on the method of turning the plastic waste into a useful tile, the previous study used an open chamber for the melting process. This study is also pivoted on the provision of isolation system for the chamber.

III. METHODOLOGY

This study applied the developmental research approach, which includes other engineering researches, engineering principles, standard settings of mechanical systems, and other international and local studies that are related about the study. On the latter part, a testing of evaluation has been conducted to justify the effectiveness of the research. The design of the prototype is a combination of fluid machinery, piping system, and extrusion equipment. To control the fumes from the cylinder, a low voltage air pump has been used. These pumps are used for transferring a fluid from one source to another. For the piping system, standard positioning has used. The fumes will flow through this pipe and will be expanded in the fume tank to reduce pressure also. An extrusion assembly is stage for forcing the plastic waste to turn into a tile. A combination of ball screw and piston head, which is power by a stepper motor, was used to compress the plastic material in the cylinder.

The following materials were the materials used to develop the device:

1. Extrusion Cylinder (Do= 2", Di= 1 15/16", L= 22")
2. Stepper Motor (L=6", W=4", t=2")
3. Stepper Motor Driver (5A) (L=5", W=4", t= 2 ½")
4. Air Pump (L=10", W=6", t= 5½")
5. Mica Band Heater (220V, 700W) (72mm by 60mm)
6. Mica Band Heater (220V, 300W) (36mm by 30mm)
7. Nozzle (Db= 1 ¼", Ds= 3/8", L=3")
8. Power Screw (D= ¾", L= 18")

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9. Power Screw Mount (L=3 ½", W=3 ½", H=18")
10. 6"x6" Tile Molder (L=8", W=8", t=5/8")
11. 4"x4" Tile Molder (L=4 1/8", W=4 1/8",t=5/8")
12. Molder Stand (L=10", W=1 ½", t=1/8")
13. Prototype Stand (L=45", W=19 ½", H= 80", t=2")
14. Control Panel (L= 8", W=6")
15. Flexible Tubes (meter) (D= ½")
16. Thermocouple (K-type) (100mm by 6mm)
17. Temperature Controller (L= 1", W=2")
18. Temperature Controller Arduino (76.2mm by 34.2mm)

a. Project Construction Procedures

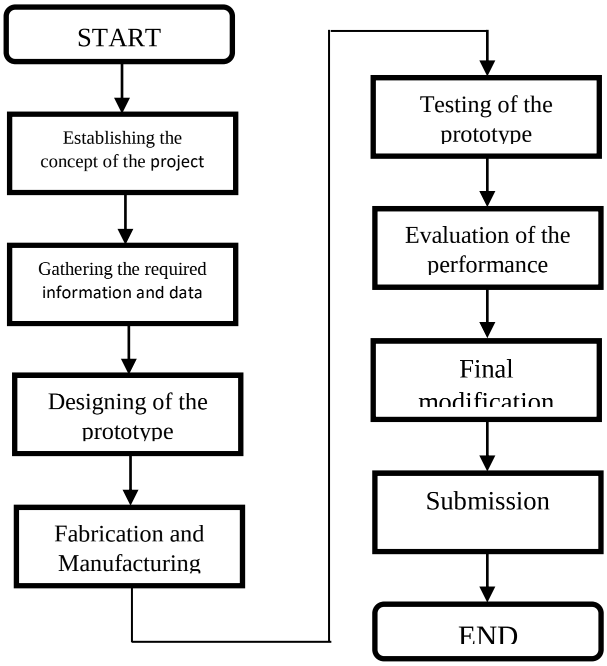

Figure 3.1: Block Diagram of the project

The prototype was started by establishing the main concept of the study, which is the isolation of fumes produced by the melted plastics in the production of plastic tile. Next, the researchers gathered the required information and data from books, researches, and journals that came up to the design of their prototype "Development of Plastic Tile-Making Machine with Isolated Cylinder for Extrusion Process'. The prototype was then fabricated and manufactured. Lastly, it was tested and evaluated by the researchers and modified it for the final touches of the study.

b. Schematic Diagram

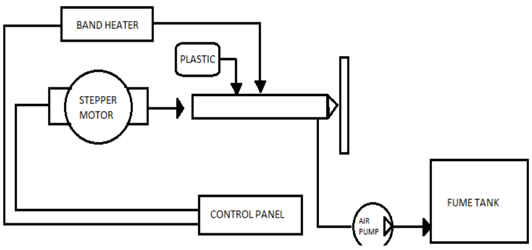

Figure 3.2: Schematic Diagram of the Prototype

Processes:

1. *Gathering of Used Plastics*

The used plastics will be gathered from residence areas, public places, buildings, garbage lands and in any other places where used plastics are seen.

2. *Segregation of Plastics depending on its type*

Two types of plastics will be only used in the study which is Polyethylene (PE) and Polyethylene Terephthalate (PET). Polyethylene (PE) Plastics is the most abundant and most produced type of plastics. Example of PE are plastics bags, packaging plastics, fabrics and etc., while Polyethylene Terephthalate (PTE) is used in fibers for clothing, containers for liquids and foods or any other type of commercial plastics that are harder than polyethylene plastics. The two types will be separated and will be used in different batches where it is heated and formed in the different temperature and length of time.

3. *Shredding of Plastics*

The segregated plastics will be shredded by batch and will be formed into the prefer size of plastic resins. The average area of a piece of shredded plastic ranges from $1cm^2$ up to $1.5cm^2$.

4. *Mixing and Weighing of Plastics*

The shredded plastic will be mixed evenly and will be weighed according to the desired weight needed to insert it inside the cylinder.

5. *Inserting of Shredded Plastics in the Extrusion Cylinder*

The mixed and weighed plastics will be put in the extrusion cylinder by using double lock system to avoid the diffusion of fumes.

6. *Softening*

The extrusion temperature is set to the proper softening point of the used plastic.

7. *Extruding*

The stepper motor is used to compress the softened plastic in the extrusion cylinder. With this equipment, the piston head in the cylinder will force the plastic to pass through the through the die.

8. *Shaping of the Melted Plastics in the Mold*

The shape of the melted plastic will conform on the inner space size of the mold.

9. *Suction of the fumes Using Vacuum Air Pumps*

The fumes produced by the soften plastic will be drawn in in the fume tank using vacuum air pumps. In this method, fumes produced by the plastic will be reduced.

10. *Cooling*

In this process, the produced plastic tile together with its mold will be cooled in a water container so that the plastic which is molded into a tile will not be hard to remove.

IV. RESULTS AND DISCUSSION

This chapter presents the development and results of the experiment conducted by the prototype where it includes the evaluation of the product rate, and the evaluation of the fume control mechanism. The experiment is conducted by providing a series of trial to gain the frequent or average data to be used as a conclusion to the study and its prototype.

Testing Preparation

For the testing preparation, materials are gathered accordingly. The raw plastic material used is weighted until it is between 80g to 310g. The shredded plastics are used so that it would not consume air space in the extrusion cylinder.

The proper melting time of the different plastic used is being tested in series. Since the melting temperature is standard, only the time of operation is variable. Melting temperatures of different plastics ranges from 200°C to 400°C (sometimes above 400°C). Since the band heater can handle temperatures for up 500°C, the manipulation of temperature is safe. Before feeding raw materials to the cylinder, a preheating must be done on the cylinder. The preheating temperature should slightly below or above the operating temperature of each kind of plastics.

A. Determining the Mass of Raw Plastics to be Put in the Hopper

Below are the list of tables according to the mass of raw plastics needed to be put in the hopper of the prototype. The only acceptable plastic waste is PE plastic wastes with 100g to 110g for 4"x4" molder size and 200g-250g for 6"x6" molder size.

Table I: Mass of Raw Plastic to be put in the Hopper

Type	Mass	Remark
PET (4"x4")	100g-175g	Unacceptable
PE (4"x4")	100g-110g	Acceptable
Nylon (4"x4")	80g-110g	Unacceptable
PET (6"x6")	100g-350g	Unacceptable
PE (6"x6")	200g-250g	Acceptable
Nylon (6"x6")	100g-250g	Unacceptable

B. Determining the Heating Temperature

Several trials were made to determine appropriate heating temperature to where raw plastics will be melted before the molding process to obtain the best quality of the tiles. In the preliminary testing, the PET plastic melted where the temperature of the cylinder reached 225°C up to 250°C. While on PE Plastic Wastes, the recommended temperature is 230°C and unacceptable on Nylon Wastes at 250-350°C.

Table II: Heating Temperature

Type	Temperature Ranges(°C)	Remarks
PET	225-250	Acceptable
PE	150-260	Acceptable
Nylon	200-350	Unacceptable

C. Determining the Melting Time

Melting time of the plastic waste is very big factor in considering the best and suitable material that will be used in the prototype. For PET plastics waste, the result is unacceptable for 10-25 minutes of recommended melting time while acceptable for both PE and Nylon plastic waste at 15-20minutes and 15 minutes.

Table III: Melting Time

Types	Melting Time	Remark
PET	10-25 minutes	Unacceptable
PE	15-20 minutes	Acceptable
Nylon	15 minutes	Acceptable

D. Molding Time

Same as the melting time of the plastic waste, the molding time was also evaluated. By the testing and merging both of the times, the best tile was evaluated. The researched suggested that the best total time for molding and cooling the tile is 11 to 13 minutes for 4"x4" plastic tile and 18-21 minutes for 6"x6" plastic tile.

Table IV: Molding Time

Trial	Molding Time	Cooling Time	Total Time	Remark
4”x4”	8 -10 minutes	3 minutes	11-13 minutes	Acceptable
6”x6”	15-18 minutes	3 minutes	18-21 minutes	Acceptable

E. Determining the Motor Speed

In determining the best motor speed for the prototype, several trials are made at different speed. The speed was adjusted while the time of pushing was recorded. Only trial 3 with 6 rpm motor speed is acceptable.

Table V: Motor Speed

Trial	Speed (RPM)	Pushing Efficiency	Pushing Time	Remarks
1	50	Not Pushed well	-	Unacceptable
2	20	Not Pushed Well	-	Unacceptable
3	6	Good	12 min	Acceptable
4	2.5	Too slow	26 min	Unacceptable

F. Determining the Fumes in terms of Appearance and Odor at a Given Temperature

Series of tests was made in determining the appearance and odor of the fumes produced by the different kind of melted plastic wastes. The fumes were described in appearance and rated in terms of the fumes’ color (whitish, grayish, blackish) and in terms of the fumes’ odor (tolerable and not tolerable). The acceptable melting temperature for PET is 180-200°C, PE is 125-00°C and Nylon is 200-300°C.

Table VI: Fumes in terms of Appearance and Odor at a Given Temperature

Type	Melting Temperature	Appearance	Odor	Remark
PET	180-200°C	The fume exerted by the melting plastics is invisible.	Tolerable	Acceptable
PE	125-300°C	The fumes exerted by the melted plastics is invisible than the previous type of plastics.	Tolerable	Acceptable
Nylon	200-300°C	The fumes exerted by the melting plastics is also invisible.	Tolerable	Acceptable

G. Determining of the Product Rate

According to the testing data, the shortest acceptable time to pull out the mold from the cylinder is at 15 minutes. Since there are 2 mold sizes (4in by 4in, and 6in by 6in), the rate is evaluated at each size of molds.

Product Rate $_{4”x4”\ tile}$ =

$$\frac{number\ of\ product number\ of\ product}{Average\ unit\ time\ \ Average\ unit\ time} = \frac{1\ piece\ (4in\ by\ 4in\ tile)}{9\ minutes} =$$

0.1111 tiles/min or 6.67 tiles/hour

Product Rate $_{6”x6”\ tile}$ =

$$\frac{number\ of\ product number\ of\ product}{Average\ unit\ time\ \ Average\ unit\ time} = \frac{1\ piece\ (6in\ by\ 6in\ tile) 1\ piece\ (6in\ by\ 6in\ tile)}{16.5\ minutes\ \ \ \ 16.5\ minutes} =$$

0.0606 tiles/mins or 3.63637 tiles/hour

V. CONCLUSION

This chapter presents the conclusion resulted from the conducted study. It shows the overall outcomes from the testing of the different plastic wastes in plastic tile-making machine. The conclusions were justified based on the data, remarks, and results from the testing and evaluation. The main conclusion of the study is justified by the actual testing of the prototype. The researchers came up that if the discharging of melted plastics from the cylinder comes too late, the plastic will be burned and will cause a blockage on the nozzle, thus, refraining it to conform into a tile. Secondly, it is important to set a preheating time first before conducting a full machine operation. Based on a series of testing, 15 minutes is the most appropriate time for the prototype's preparation heating time. The preheating temperature must not exceed the set melting temperature too far. Lastly, the discharging of melted plastics from the cylinder is too early, the piston would not be able to force the plastic to flow through the nozzle and the mass will not be uniform across the face of the tile.

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BIOGRAPHY

Caleb C. Dioso was born on October 2, 1998 in Dasmariñas, Cavite. He went to Lyceum of the Philippines University – Cavite Campus to take Bachelor of Science in Mechanical Engineering from 2015 to 2020. He attended several conventions and seminars to further enhance his knowledge and skills, including the PSME National Student's Conference and the 22nd Region 13 Regional Conference that was held in Kuala Lumpur, Malaysia and other seminars and conferences. He was the 5th year representaive of association of the Philippine Society of Mechanical Engineering – Student Unit in LPU-C and was an offcier of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers – Student Unit in LPU-C

Earl Christian O. Ignacio was born on April 10, 1998 in Bacoor, Cavite. He went to Lyceum of the Philippines University – Cavite Campus to take Bachelor of Science in Mechanical Engineering from 2015 to 2020. He attended several conventions and seminars to further enhance his knowledge and skills, including the PSME National Student's Conference and the 22nd Region 13 Regional Conference that was held in Kuala Lumpur, Malaysia and other seminars and conferences. He was the treasurer of association of the Philippine Society of Mechanical Engineering – Student Unit in LPU-C and was the Vice President – External of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers – Student Unit in LPU-C.

Krissia Mae G. Palanog was born at Trece Martires City, Cavite on May 04, 1999. He took up Bachelor of Science in Mechanical Engineering at Lyceum of the Philippines University – Cavite Campus from year 2015-2020. She was the former President of Philippine Society of Mechanical Engineers – LPU- Cavite – Student Council (A.Y.2018-2019), former Vice President-Internal (A.Y. 2017-2018) and Board Member (A.Y. 2016-2017) of Philippine Society of Mechanical Engineers – Cavite Chapter, former Vice President – External of American Society of Heating, Refrigerating and Air-conditioning Engineers (2018-2019). She also participated in various international and local seminars related to her field, such as the 22nd Region 13 Regional Conference held in Kuala Lumpur, Malaysia, 2020 And Beyond: Envisioning A Greener Philippines held at Architectural Center Club, Inc., Makati City, Metro Manila, Philippines, IMPULSE 2018"Mechanical Engineers: Building a Smart and Green City" held at University Auditorium, Lyceum of the Philippines University Cavite, 2017 General Membership Meeting (GMM) [1] NFPA 20 Fire Protection Pumping System, 2. RA 8495] held at FCIE Locator's Hall, Dasmarinas City, Cavite, 3rd Luzon Regional PSME Student Conference held at Development Academy of the Philippines, Tagaytay City, Cavite and others.