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Plastic Waste Management - A Novel Plastic Recycling and Vending Machine

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Abstract – Plastic is profusely used in a variety of forms like Polyethylene Terephthalate, Polyvinyl Chloride, Polypropylene, etc. The chemical bonds that hold monomers of plastic together are very strong hence decomposition becomes very difficult, rendering one of the biggest concerns in front of the humans of this age, which is plastic waste management. Extensive research has been done around the globe to solve the problem of plastic waste and the solution can be broadly divided into two categories- decomposition and recycling. While decomposition has not yet proven to be the best and most efficient technique to get rid of the waste plastic, recycling has shown a lot of potential. Hence, a novel solution is proposed in this article to manage plastic waste based on recycling principles. Automation, recycling time and cost are the three major parameters analyzed in this process. The machine is expected to completely automate the recycling process after the feed is provided. Although recycling time and cost are also analyzed, they are treated secondary since the machine is in prototype phase. Two different kinds of thermoplastics are recycled, and the desired shape is achieved.

Keywords — plastic, pyrolysis, recycling, vending machine,

I. INTRODUCTION

Plastics are inexpensive, lightweight and durable materials, which can readily be moulded into a variety of products that find use in a wide range of applications. Consequently, the production of plastics has increased markedly over the last 60 years. However, current levels of their usage and disposal generate several environmental problems [1]. A major portion of plastic produced each year is used to make disposable items of packaging or other short-lived products that are discarded within a year of manufacture. These two observations alone indicate that our current use of plastics is not sustainable. In addition, because of the durability of the polymers involved, substantial quantities of discarded end-of-life plastics are accumulating as debris in landfills and in natural habitats worldwide.

Several solutions are proposed to solve the problem of plastic waste management, one of which focuses on converting the plastic waste into fuel [2]-[7]. Fossil fuels like coal, petroleum and natural gas is a limited source which will be exhausted in few more decades and hence the possibility of using waste plastic to produce fuel was studied. In [2], the method of converting plastic into fuel is called 'Pyrolysis'. Further research [9] proves that pyrolysis plant for self-sustaining energy from waste is thermodynamically unproven, practically implausible, and environmentally unsound. This limits the use of pyrolysis for plastic waste management.

Furthermore, an extensive research on plastic recycling [10] shows that recycling is one of the best ways to manage the problem of plastic waste. Recycling is a waste-management strategy. It provides opportunities to reduce oil usage, carbon dioxide emissions and the quantities of waste requiring disposal. The method proposed in this article uses recycling technique to convert plastic waste directly into a desired shape by application of heat.

Some literature survey about types of plastics used are discussed first in this paper followed by the theory and working of the proposed method. Results are discussed at the end.

II. LITERATURE SURVEY

Various types of plastics are found in the environment. These plastics are categorized into various types. The Society of the Plastics Industry (SPI) introduced a code system in 1988 that helps with recycling plastic by numbers. There are six common types of plastic and one miscellaneous category. Fig. 1 shows these different kinds of plastics and their properties.

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Code & Symbol	Name	Properties
1 PET	Polyethylene Terephthalate	Toughness, resistance to heat.
2 HDPE	High Density Polyethylene	Toughness, resistance to chemicals and moisture permeability to gas.
3 PVC	Polyvinyl Chloride	Versatility, ease of bending.
4 LDPE	Low Density Polyethylene	Ease of processing, flexibility.
5 PP	Polypropylene	Resistance to heat, barrier to moisture.
6 PS	Polystyrene	Versatility, Insulation.
7 OTHER	Others	Nylon (PA) Acrylonitrile butadiene styrene (ABS) Polycarbonate (PC) Layered or multi-material mixed polymers

Fig. (1): Various types of plastics and their SPI Codes

Plastics are manufactured in two categories: Thermoset and Thermoplastics. Once hardened, thermoset plastic remains in their solid state, whereas thermoplastics can be re-melted. This machine is developed to recycle the thermoplastics as it can be recycled multiple times.

III. THEORY AND WORKING

The block diagram of the vending machine is shown in Fig (2).

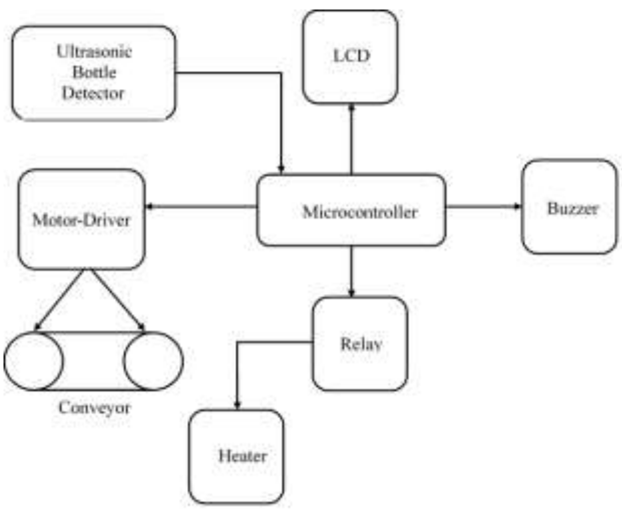

Fig. (2): Block Diagram of Plastic Recycling and Vending Machine

The main components of the machine are microcontroller, conveyer belt, motor, ultrasonic bottle detector and heater. Microcontroller forms the brain of the machine and coordinates the process between different peripherals. The container where the feed is provided has an ultrasonic detector to sense the plastic feed and to alarm if any material other than plastic is present inside the container. The conveyer belt is rolled on two drums directly connected to the main shaft of the electric motors. This is done to increase the efficiency over the conventional chain drive method. A relay switches the heater ON/OFF and is controlled by the microcontroller.

The plastic bottles are loaded in the container on the conveyer belt. The ultrasonic senor senses the bottle for a defined period and then gives a signal to the microcontroller. The microcontroller gives command to the motor driver which turns ON the conveyer belt and the feed is then taken to the heater. Once the conveyer is unloaded it gives another command to the microcontroller. The microcontroller then turns ON the heater through the relay. The heating process starts which melts the plastic. The melted plastic is then poured into a mold which gives the plastic it's final profile shape e.g. a mold of a toy. The final product is normally cooled by passing through a water bath since plastics are very good thermal insulators and are therefore difficult to cool quickly through natural air. The plastics were cooled naturally in this study due to unavailability of the hardware required for the water bath.

The microcontroller used in the system is ATMEGA328. This microcontroller controls the three major functions: LCD display, conveyor motor and the heater. 12 V servo motors are used for driving the conveyer belt. A 16x2 character LCD display is used to track the process. A 1000 W coil heater is used to melt the plastic and reshape it as desired. Fig. 3 below shows a photo of the recycling machine.

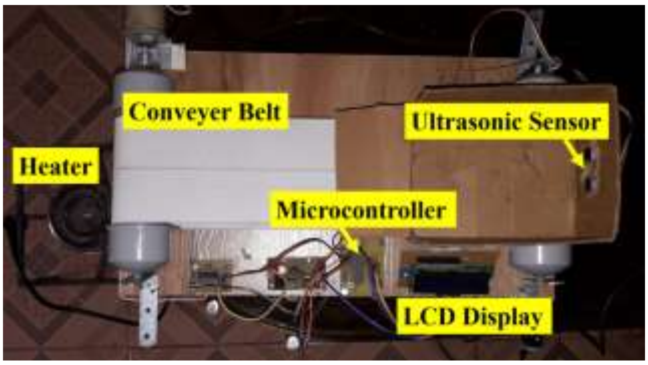

Fig. (3): Photo of the Recycling Machine

The machine was tested with two types of thermoplastics-PET and HDPE. These thermoplastics were chosen because of their low densities and their popularity for being used as containers for soft-drinks and food. Waste plastic was fed to

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the container and the process was monitored. The mold was shaped like a cuboid.

IV. Results and Discussions

The recycling of both the thermoplastics i.e. PET and HDPE was done successfully by the machine with minimal to no human intervention. Both the categories of plastics were successfully molded into the cuboid shape and the complete recycling time with this prototype machine was less than one hour each. The final molded product was 98.71 % accurate and the accuracy was measured by calculating the weighted average of the difference between the dimensions (length, width & height) of the expected cuboid and the molded cuboid.

The one-hour recycling time mentioned earlier includes the time required for the final product to cool down and take the shape of the mold. This process can be expedited by passing the final product under a water bath which will save the recycling time. In the existing design, conventional heat is applied to melt the plastic using heating coils. Significant recycling time can be further saved by using infrared radiation for melting the waste plastic [11].

The machine is simple to operate and hence not too much technical skill is needed to use it. It is compact, less complex and requires no special expertise. The maintenance cost is also lower compared to many other existing imported systems.

The machine at the prototype phase comes with disadvantages referring to the heterogeneity of the solid waste and the deterioration of product's properties in each cycle which occurs due to the low molecular weight of the recycled resin. Another limitation is the recycling time, but it can be overcome by modifications in the machine as discussed earlier in this section.

V. Conclusion

A successful design of a completely automated plastic recycling machine is presented in this article. The machine performed as expected and proved efficient to an acceptable degree with respect to the parameters concerned i.e. automation, recycling time and cost. The final molded product was 98.71 % accurate in size and shape.

The machine is expected to perform satisfactorily with all thermoplastics. The performance of thermoplastics other than PET and HDPE requires further analysis and is one of the future scopes of this study. It is efficient, cheap, easy to operate and cheap to maintain. These features make it particularly suitable for the informal sector where there is little or no technical knowledge. It eliminates the restrictions posed to recycling by the high cost of existing machinery, consequently increasing recycling activities.

This project has set out the vision of making a clean environment free of littered plastic. The existing system has no detection technologies, but this can be included for further upgrades. It will be soon beating the market which mainly can be introduced at public places such as shopping malls, airports, railway stations etc. At this moment the prototype machine takes longer time than expected for the complete process, but this can be improved by implementing the proposed solution in section IV. Furthermore, this machine can also be upgraded to recycle not only plastic bottles, but also Metal and Glass Bottles.

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