International Scientific Conference
UNITECH`2024

AUTOMATIC WASTE SORTING: DEVICE FOR SORTING ALUMINIUM CANS AND PLASSTIC BOTTLES

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Abstract

The large production of plastic and aluminium, as well as their use in people's daily lives, led to the need for more efficient disposal of this waste and later recycling. Sorting waste is one of the most important steps in recycling. This paper describes how plastic bottles and aluminium cans can be sorted, so they help in the recycling process and thus protect the environment. Specifically, a device was designed that automatically sorts plastic bottles and aluminium cans using sensors. Also, the impact of plastic and aluminium on the environment, their production and recycling is described.

Keywords: waste, plastic, aluminium, sorting, arduino.

INTRODUCTION

Plastics and their byproducts are polluting our cities, oceans, and waterways, and contributing to health problems in humans and animals. Since plastics have become significant in our economic and social activities, it is urgent and essential to make progress in plastic waste reduction [7].

There is also material that is light, durable and functional: these are the qualities that make aluminium one of the key engineering materials of our time. We can find aluminium in the homes we live in, in the automobiles we drive, in the trains and airplanes that take us across long distances...

Aluminium, like all metals, is composed of atoms bonded together and formed in a crystal structure. This makes aluminium easy to melt and reform into a solid state without changing its fundamental properties. Therefore, aluminium can be recycled repeatedly and back into use with no limitation. Aluminium cans are the most recycled beverage container. Aluminium can be recycled over and over again without any loss of quality.

In contrast, plastics are a polymer, a synthetic substance composed of very large molecules, which break down when recycled.

Aluminium is one of the most recycled materials on earth. Almost 75 per cent of the 1.5 billion tonnes of aluminium ever produced is still in use today. The situation is different with plastic. Around 500 billion plastic bottles are used worldwide yearly, with 35 billion empty water bottles discarded in the US alone. Only 12% of these bottles are recycled, and 91% of the world's plastic bottles are not recycled.

Because of this, it is crucial that each person individually takes care of disposing of waste, which would later be recycled. One of the key steps in recycling is sorting. The device for sorting plastic bottles and aluminum cans, which is described in this paper, can contribute to better organization of waste and later recycling.

ALUMINIUM

Aluminium is a silvery, soft, and light metal. It is an element with the atomic number 13 and the symbol Al that belongs

"UNITECH – SELECTED PAPERS" Vol. 2024
Published by Technical University of Gabrovo
ISSN 2603-378X

doi: www.doi.org/10.70456/.........................

to the boron group in the periodic table of elements. Aluminium is the most frequent metal and the element with the greatest abundance in the earth's crust, followed by silicon and oxygen. It makes about 8% of the solid surface of the Earth's weight. Hans Christian Ørsted, a Danish scientist and physicist, created the metal for the first time in 1825. After iron, aluminium is the most used metal worldwide, with 31.9 million tons produced in 2005. Aluminium can be used in a variety of applications, like as packaging, building, street lighting poles, photography equipment, cooking utensils, and sailing ship masts.

Since aluminium is a highly reactive metal, pure forms of it are not found in nature.

Aluminium is present in more than 270 minerals in Earth's crust, the most prevalent of which is bauxite ore. Aluminium that is metallic is almost exclusively produced by mining bauxite ore.

Deforestation, erosion, contaminated water supplies, and a threat to animal life are all results of mining. The majority of the ore mined today comes from Ghana, Indonesia, Jamaica, Russia, and Surinam, however there are significant bauxite resources in Australia, Brazil, Guinea, and Jamaica himself [3].

MANUFACTURING PROCESS (OF ALUMINIUM)

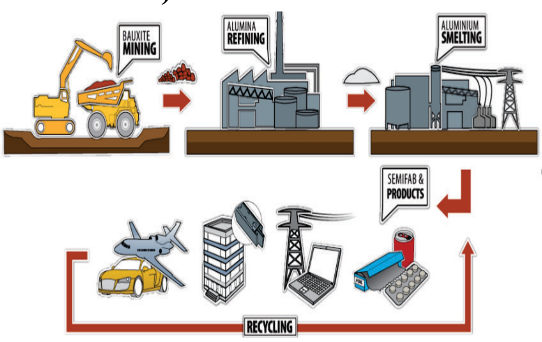

***Fig. 1.** Manufacturing process*

1. Mining of Bauxite

Bauxite is used as the main raw material in the manufacture of aluminium. The bauxite is often mined from only a few metres below the ground level. About 4-5 tonnes of bauxites are required for 1 tonne of aluminium.

2. Grinding of bauxite

The bauxite mineral is transported to refineries where the clay is washed off and the bauxite passes through a grinder to produce a more consistent material.

3. Crushing and digesting bauxite to make sodium aluminate

A caustic soda or sodium hydroxide solution is pumped with the ground mineral into sizable pressure tanks, and steam heat is then supplied. A sodium aluminate solution is created when the aluminium compounds in the bauxite material react with the caustic soda. Iron, silicon, and titanium-containing undesirable leftovers, sometimes referred to as red mud, eventually sink to the bottom of the tank and are removed.

4. Settling

The sodium aluminate solution is then passed through into lower pressure settling tanks. The solution at the top of the tanks is directed downwards through a series of filers to remove excess red mud. The remaining alumina is then passed through huge "leaves" or cloth filters to remove any solids in the solution.

5. Precipitation

The sodium aluminate solution is then cooled and pumped into large precipitators (sometimes as tall as a 6-story building). Aluminium hydroxide seed crystals added to the solution to start the precipitation process. At this point, large aluminium crystals are formed.

6. Calcination

The crystals are then heated in rotary kilns to temperatures over 960°C. This extracts the last impurities and creates a white powder, known as alumina or aluminium oxide. The refined alumina is transformed into aluminium through the smelting or Hall–Héroult process.

7. The Smelting Procedure

The alumina is poured into a reduction cell with 950°C molten cryolite. 400kA electrical currents are passed through the mixture to break the bond between the aluminium and oxygen. The result is 99.8% pure aluminium [4].

ALUMINIUM CANS

Aluminium cans are containers primarily used for packaging beverages such as soda, beer, energy drinks, and various other beverages. Aluminium cans are recyclable, lightweight, convenient, and protective. Because of these characteristics, they are among the most widely used materials for beverage packaging globally [1].

RECYCLING ALUMINIUM

Cans made of aluminium are produced in vast quantities and then discarded. Cans made of aluminium are the main source of aluminium in the trash flow, according to the EPA.

Roughly 1.9 million tons of metal are used annually in the US for packaging and containers like aluminium cans. There are several advantages to recycling these sturdy, lightweight containers in terms of energy consumption, expenses, and environmental effects. Recycling aluminium cans has a lot of benefits and not too many drawbacks.

An vast quantity of electricity is used in this procedure. In contrast, since an aluminium can is already composed of refined metal, melting and processing it to create another can is not too difficult.

One ton of raw aluminium requires the equivalent of 1,740 gasoline gallons, which releases a significant amount of greenhouse gases into the atmosphere. In comparison, just roughly 90 gallons of gasoline or the equivalent in fossil fuels are needed to recycle a ton of aluminium cans.

Therefore, recycling aluminium cans benefits the environment overall. The best part is that aluminium is infinitely recyclable, so you can recycle a can and use it to manufacture new ones endlessly [2].

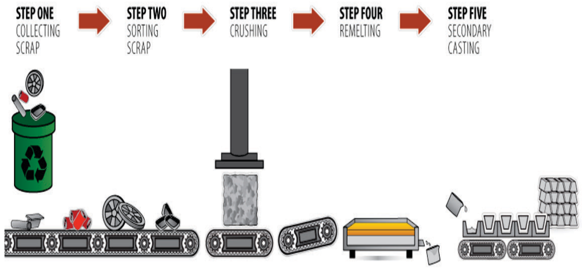

***Fig. 2.** Recycling aluminium*

Recycling aluminium has five steps:

1. Collecting Scrap

Material that has been utilized by a customer and then thrown away is known as old scrap. Old scrap includes things like car cylinder heads, window frames, electrical wiring, and used beverage cans. This old scrap cannot be accepted safely by aluminium smelters since its composition is usually unknown and it may be polluted.

2. Sorting Scrap

Next, the scrap is separated, with all coated (painted or lacquered) aluminium being grouped with bare aluminium.

3. Crushing

After the aluminium has been sorted, it is crushed into bales. By compacting the aluminium scrap, handling, storage, and transportation expenses are decreased.

4. Melting again

Scrap that has not been coated is fed straight into a remelter, a huge furnace that melts material at high temperatures.

In the event that the scrap aluminium is coated, the coating is removed by processing it in a gas-fired rotary furnace before it is sent to the remelter.

5. Casting

To create ingots, molten aluminium is cast at a temperature just above 700°C [5].

PLASTIC

Plastics, like all other substances, consist of molecules, the small particles that make up matter. There are both large and small molecules. Plastics always consist of large molecules called polymers. Polymers, in turn, consist of many identical small particles monomers, which are strung together like a chain. It is the length of these chains and the patterns in which they are arrayed that make polymers strong, lightweight, and flexible.

These properties make synthetic polymers exceptionally useful, and since we learned how to create and manipulate them, polymers have become an essential part of our lives. Especially over the last 50 years, plastics have saturated our world and changed the way that we live.

The Polymer Age is also called the Age of Plastics. "Plastic" (from the Greek "plastikos," meaning moldable) is the popular term for a variety of synthetic, or man-made, polymers.

In 1870, the American inventor John Wesley Hyatt used chemically modified cellulose to produce an astonishing new product called Celluloid. By 1890, Count Hilaire de Chardonnet was marketing the first synthetic textile, Chardonnet silk, made by spinning strands of cellulose nitrate into artificial fiber.

These and other early plastics were made from existing materials. The next step, the creation of completely synthetic plastic, was still to come.

In 1907 Leo Baekeland invented Bakelite, the first fully synthetic plastic, meaning it contained no molecules found in nature. Baekeland had been searching for a synthetic substitute for shellac, a natural electrical insulator, to meet the needs of the rapidly electrifying United States. Bakelite was not only a good insulator; it was also durable, heat resistant, and, unlike celluloid, ideally suited for mechanical mass production. Marketed as “the material of a thousand uses,” Bakelite could be shaped or molded into almost anything, providing endless possibilities.

Hyatt’s and Baekeland’s successes led major chemical companies to invest in the research and development of new polymers, and new plastics soon joined celluloid and Bakelite. While Hyatt and Baekeland had been searching for materials with specific properties, the new research programs sought new plastics for their own sake and worried about finding uses for them later.

World War II necessitated a great expansion of the plastics industry in the United States. The surge in plastic production continued after the war ended.

Today, synthetic plastics are everywhere. They are as familiar to us as wood or metal. Familiar products made in part or in whole with plastic: toys, computers, clothing, sports equipment, carpets, appliances, building materials, signs, office supplies, packaging, phones and fashion accessories [8].

Dr. Baekeland's new material opened the door to the Age of Plastics and seeded the growth of a worldwide industry that today employs more than 60 million people. As the future unfolds, plastics and other synthetic polymers will play increasingly versatile roles in medicine, electronics, aerospace and advanced structural composites [6].

PLASTIC BOTTLES

A plastic bottle is a container constructed of plastic. Plastic bottles are typically used to store liquids such as water, soft drinks, cooking oil, medicine, shampoo, milk, etc.

The most-common plastic bottle you see nowadays is the soda bottle. It is made from polyethylene terephthalate, also known as PET. PET is used for 14 percent of all plastic containers and 43 percent of soda bottles. It was developed in 1941, but it wasn't used for soda bottles until the 1970s.

Before a plastic bottle can be manufactured, the PET must be made. PET is a polymer that is made from petroleum hydrocarbons. The process to make PET is called polymerization [9].

PET BOTTLE MANUFACTURING PROCESS

Blow molding is a very popular manufacturing process. It starts from the 1930s, although till now this technology has already had a wide range of applications. It is used to create hollow plastic parts by inflating a heated plastic tube until it fills a mold and forms the desired shape. The raw material used in this process is thermoplastic in the form of small pellets or granules, which are first melted and formed into a hollow tube, called the parison.

There are various methods of forming the parison. The parison is then clamped between two mold halves and inflated by pressurized air until it conforms to the inner shape of the mold cavity. Lastly, when the plastic product has be cooled, the blowing mold will be separated and the products are ejected [10].

The process consists of six steps:

1. Heated plastic is extruded into a hollow tube (parison).
2. Mould closes parison is gripped in place.
3. Compressed air blown into the parison, which inflates.
4. Parison fills the mould.
5. Product is trimmed and removed from blowing mould.
6. Finished product ready for next production stage.

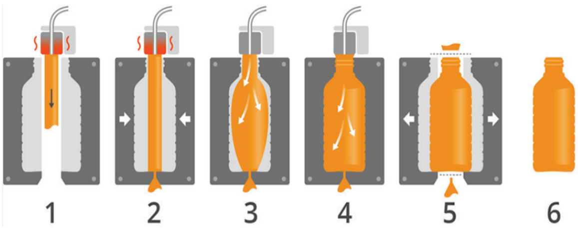

Fig. 3. *Pet bottle manufacturing process*

PLASTIC RECYCLING

Plastic is made from materials such as petrochemicals that can pollute and harm the environment and humans. If you do not manage plastic correctly, you will have tons of reusable waste materials.

To reduce the harmful effects of excessive plastic, recycling is necessary. Before any plastic waste is recycled, it needs to go through 7 different stages so that it can be further used for making various types of products.

7 steps of the plastic recycling process:

1. Collection

Collecting the plastic to be recycled depends on how businesses, restaurants, and the public dispose of their plastic waste. If plastic wastelands up in normal trash bins, it cannot be recycled. Therefore, it is important to separate common waste and plastic waste.

2. Sorting

The collected plastic waste is then taken to a recycling facility for sorting. The machines sort the plastic into different areas depending upon its properties, and what final product is being produced. Plastics are sorted based on the type, color, or how it was made. Sorting is important because each type of plastic has to be processed differently, and most recycling facilities are only capable of recycling one type of plastic.

Washing

The sorted plastic is then washed to remove impurities, such as labels and adhesives. This enhances the quality of the finished product. If the non-plastic waste is not removed, it can result in a final product that has poor structural integrity.

3. Shredding or Resizing

The plastic waste is loaded into different conveyor belts that run the waste through the different shredders. These shredders tear up the plastic into small pellets, thus increasing its surface area. Smaller pellets of plastic make it easier to process, reshape, and transport them if needed. Metal detectors or magnets are used to remove any leftover metal in the mixture.

4. Melting

Dried flakes are melted and molded into the desired shape or are further processed into granules. The flakes are melted with the help of regulated temperatures with specialized equipment to ensure that they are not destroyed.

5. Identification and Classification

In this step, the small plastic particles are tested to determine their quality and class. The first test is to check the density. The particles are put in a large tank of water. Denser particles sink and less dense float.

The next test is air classification, which determines how thin or thick the particle is. The particles are dropped into a small wind tunnel. The bigger ones remain low, and the smaller ones fly higher up. Additionally, the sample particles from each batch are collected and analyzed to test their melting point and color.

6. Compounding or Extruding

In this step, the shredded plastic is melted and extruded into pellets, which are used for future plastic product production.

Reducing plastic-produced waste is heavily beneficial for the environment [11].

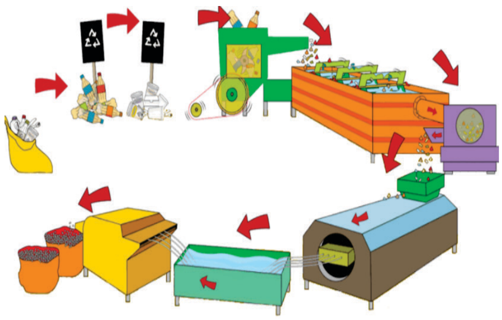

Fig. 4. *Plastic recycling*

Device for Sorting Plastic Bottles and Aluminum Cans

Waste sorting is the process of separating different types of waste that are then recycled. Waste selection is one of the most important things when it comes to recycling. Waste selection, in addition to improving the efficiency of recycling, affects the reduction of waste in landfills and the creation of illegal landfills, environmental protection and saving energy and natural resources, as well as efficient waste management.

There are two types of waste selection:
1. Primary selection - Primary waste selection is the sorting of waste at the place of its origin.
2. Secondary selection - Secondary waste selection is the sorting of waste in recycling centers. When various wastes are transported to recycling centers or landfills and then sorted, impurities are separated and wastes are sorted that continue their way in recycling.

The device for sorting plastic bottles and aluminium cans facilitates waste separation. Sorting in this way represents the primary separation of waste. In addition to facilitating waste disposal, it also enables more efficient recycling. One of the goals of this system is to raise people's awareness, because one of the most important goals today is environmental protection. Technology enters all spheres of human life, and this kind of project represents a kind of smart waste sorting bin.

The components used for the realization of this project are:

- Arduino Nano
- Servo motor
- Inductive sensor
- Photoresistor
- LED diode

The microcontroller used for this project is an Arduino Nano. Arduino Nano is a small, compatible, flexible and microcontroller board, developed by Arduino.cc in Italy, based on the ATmega328p. There is one limitation to using the Arduino Nano, and that is that it does not come with a DC power connector.

This board does not use standard USB to connect to the computer, but comes with Mini USB support. The Arduino Nano has numerous options for communicating with a computer, another Arduino, or another microcontroller. The SoftwareSerial library enables serial communication on any of the Nano's digital pins. The ATmega328 also supports I2C (TVI) and SPI communication. The Arduino Software includes the Wire library to simplify the use of the I2C bus.

It is programmed using the Arduino Integrated Development Environment (IDE) software[12].

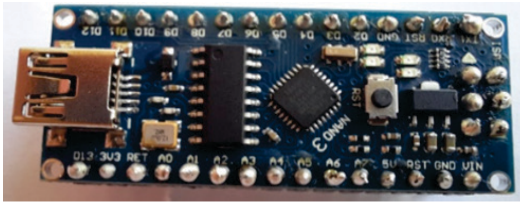

Fig. 5. *Arduino Nano*

MG996R servo motor was chosen for this project. The high torque MG996R servo motor has metal gears resulting in an extremely high 10kg of stopping torque in a small package. The high-torque MG996R servo motor can rotate approximately 120 degrees (60 in each direction). Any servo motor library can be used.

For this project, we used an inductive sensor marked "lj12a3-4-z/bx". Inductive sensors belong to the category of passive sensors. They were created as a replacement for Reed sensors that have a relatively short lifespan. The work of inductive sensors is based on the dependence of the inductive coil on the change in the resistance of the electromagnetic circuit or on electromagnetic induction. Inductive sensors react mainly to metals, and possibly to some other materials such as graphite. They are produced as non-contact parts of the equipment, which enables a number of benefits.

A photoresistor is a resistor whose resistance changes under the influence of light falling on it. Due to this feature, it is used as an electronic sensor. The photoresistor is made of semiconductor material. If the incident photons of light are of high enough frequency (enough energy), they will give the bound electrons enough energy to become free electrons in the semiconductor. This reduces the resistance of the photoresistor under the influence of light.

A white LED was used for the project. The diode is placed in parallel with the photoresistor and its role is to illuminate the photoresistor.

The scheme of the whole system is shown in Fig. 6.

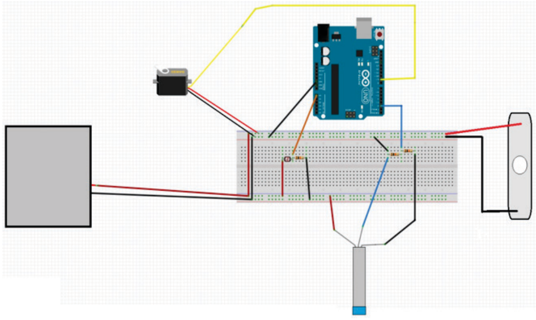

Fig. 6. *Scheme of the system*

A tube is attached to the servo motor. The diode is placed parallel to the photoresistor and its role is to illuminate the photoresistor. The photoresistor detects when a plastic bottle or aluminium can enters the device, and the signal goes to the Arduino Nano.

The Arduino Nano uses the information to determine the material by the amount of light. According to the amount of light, the operation of the servo motor, which moves at a certain angle, is determined. If metal is detected, the servo motor will turn the aluminium can into the appropriate metal box. If a plastic bottle is detected, the servo motor will turn the plastic bottle into the corresponding plastic box.

The implemented scheme is shown in Fig. 7.

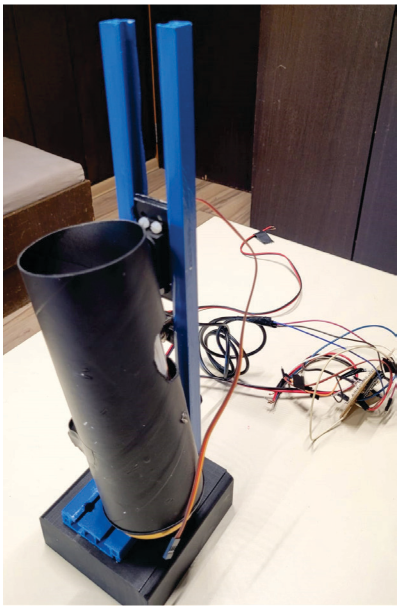

Fig. 7. *Implemented scheme*

CONCLUSION

This paper describes a device for sorting waste. The device sorts aluminium cans and plastic bottles, and represents the primary selection of waste.

The device can be used in everyday life, both in homes and in different places where there is a large concentration of people. In this way, they also help with waste recycling. In this way, there is an opportunity to reduce the waste that damages our environment every day. Also, it can help people who collect and recycle waste.

The paper describes the components used, namely: Arduino Nano, phototransistor, LED diode, servo motor, inductive sensor.

The device is a type of smart bin for primary sorting of waste. This project represents a prototype that will be further refined.

Acknowledgments:
This study was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia, and these results are parts of the Grant No. 451-03-66 / 2024-03 / 200132 with University of Kragujevac - Faculty of Technical Sciences Čačak.

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