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Production of PVC electrical cable apparatus for thermal cracking and dichlorination

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ABSTRACT

Copper wires account for over 70% of copper ore conversion. All electrical devices need copper. Landfills receive a significant quantity of PVC (polyvinyl chloride) waste, which is often used to insulate power wires. It takes a long time for plastic to break down in dirt. This will lead to environmental contamination on land. This plastic may be converted into bioenergy using the thermal cracking process. Here, we can keep recycling free of mechanical drawbacks and environmental contamination. Additionally, make crude oils as a byproduct via the thermal cracking process. The use of incineration and mechanical procedures is not without its own set of drawbacks. The purpose of this study is to investigate whether or not thermal cracking can be used to recycle electrical cables. Additionally, in order to determine its efficacy. The overarching goal of this study is to develop a one-step procedure for dechlorinating and breaking PVC-insulated electrical wires in order to generate low chlorinated oil. Slaked lime was chosen as the chlorine adsorbent after evaluating other possible solids. To prevent the material from burning during decomposition, oxygen was not present. After solids were heated to extract oil, the oil was concentrated and tested for chlorine levels.

1. INTRODUCTION

Proper waste management is one of the major environmental concerns of public institutions. Waste management systems cover all actions that seek to recover and recycle materials, looking at waste as a resource, in order to prevent health and environmental problems and to conserve natural resources, reducing the cost of production of many products, such as metals, plastics, glass and paper.

Copper is the most valuable component of the cable. Some most popular techniques are used nowadays. They are Incineration process, Mechanical process.

Nowadays our daily needs are depended upon electrical devices. Most electrical devices contain electrical wires. But after some useful life it becomes waste contamination of lands. The pyrolysis process shows excellent results to recycling electrical wires as compared with other processes. But pyrolysis of electrical cables can produce chlorine compounds during process. Here we introduce dechlorination technic to enhance pyrolysis process for recycling of pvc electrical cables. By these technics we can produce high quality oil and it reduces environmentaleffects.

2.LITERATURE REVIEW

The rate of generation of plastic waste is increasing exponentially. This is primarily because of the increased production of plastics and the low recycling rate around the globe. For instance, the production of plastics has increased from 250 million metric tons in 2008 to 745 million metric tons in 2023.[1] However, only less than 10% of the total plastic waste generated is recycled, while the rest is found in landfills or oceans.[2]

The most commonly used areas of plastic in our daily lives are packaging, building and construction plastic, automotive, electrical and electronic, agriculture, and sports.[3] The usage of plastic in these areas has been inevitable due to low price, the durability of plastic, prevention of food waste and contamination, and reduced weight of the packaging. On the downside, the non-degradable nature of plastic waste unbalances the ecosystem. About 5–13 million tons of plastic end up in the ocean every year.[2] The municipal solid waste (MSW), which comprises 10–12% of plastic, is also burned, releasing toxic gases such as dioxins, furans, mercury, and polychlorinated biphenyls.[4]

Recycling plays a key role in ensuring these plastics do not reach the ocean or the landfill. Recycling is broadly classified into physical and chemical recycling.[5] Physical recycling involves sorting, washing, cleaning, and shredding plastic waste to re-extrude plastic. The plastic waste undergoes oxidation, radiation, and heating in mechanical recycling, degrading the polymer quality.[6] Additionally, it is challenging to treat mixed plastic waste through mechanical recycling due to the difference in melting point and processing temperature.

Pyrolysis carried out in a wide range of temperatures from 300 to 900 °C. The process yields three products (1) liquid oils, (2) non-condensable gases, and (3) char (solid). Studies have shown oil recovery of up to 80% with gaseous and char byproducts.[7] The gaseous byproduct with a high calorific value is used as a secondary heat source to reduce the overall energy requirement of the system.[8] The application of liquid oil includes usage in boilers for combustion, engines, turbines, and chemical feedstock.[9]

The conventional pyrolysis systems are temperature-dependent, and the liquid fuel recovered from the process might contain residues and impurities.[10] The low selectivity nature of the pyrolysis process often leads to uncontrolled product distribution.[11] Additionally, the conduct of polyolefin-based plastics such as high-density polyethylene (HDPE), low-density polyethylene (LDPE), and polypropylene (PP) is difficult in temperature-dependent processes in the absence of catalysts due to the crossed chain hydrocarbon structures. Thus, it is of critical importance to use a catalyst to generate products in the range of commercial-grade fuels such as gasoline to ensure economic viability for pyrolysis plants.[12–15]

The usage of catalysts to improve product distribution and selectivity has been studied over the past two decades. A range of catalysts has been tested, such as commercial and domestic activated carbon, modified natural calcium carbonet (NZ) catalyst,[16] two-stage catalysis using mesoporous MCM-41 followed by microporous ZSM-5,[17] Ni/Al_2O_3 catalyst,[18] HZSM-5 calcium carbonet, ZnO, silica, calcium carbide, alumina, magnesium oxide, zinc oxide and homogeneous mixture of silica and alumina,[19] ZSM-5 calcium carbonet and Red Mud.[20] The usage of these catalysts improves the product distribution, reduces the temperature required for the process, and thus significantly reduces the energy consumption and ensures faster reaction time.[21] Additionally, the high selectivity

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Volume 9 Issue 03 2021

in catalytic pyrolysis holds a key advantage against the thermal degradation process by simulating isomerization.[22]

The objective is to absorb the thermal cracking process with and without catalyst and to eliminate mechanical disadvantages and pollution.

1. METHODOLOGY

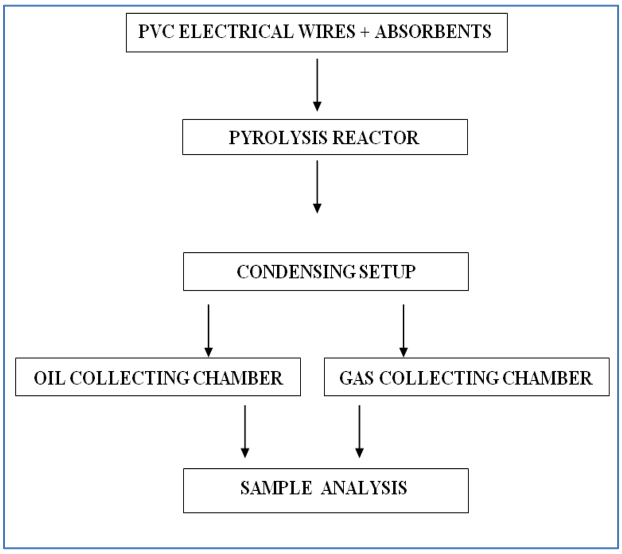

Figure.1 Methodology

WORKING PRINCIPLE:

Thermal cracking is a common technique used to convert plastic waste into energy, in the formof solid, liquid and gaseous fuels. Thermal cracking is the thermal degradation of plastic waste at different temperatures (300 - 900°C), in the absence of oxygen, to produced liquid oil. The thermal cracking process transforms plastic waste into oil, gases, charcoal, by thermal decomposition in the absence of oxygen.

Here the primary output is pyrolysis oil along with less chlorine content. Here the primary output of the electrical waste thermal cracking process is copper with purity of 99.9%, while gases,oil, charcoal are byproducts.

2. DESIGN AND FABRICATION

BLOCK DIAGRAM:

ISSN NO: 9726-001X

Volume 9 Issue 03 2021

JOURNAL OF CURRENT SCIENCE

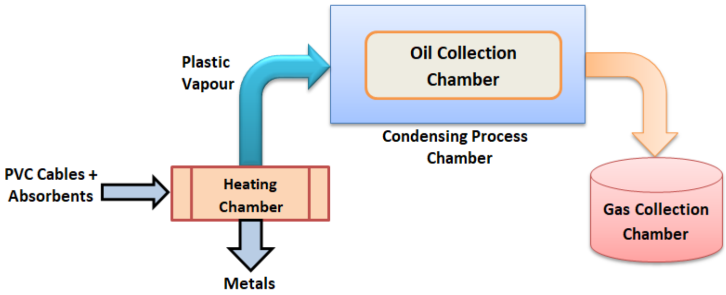

Figure.2 Block Diagram:

3. EXPERIMENTAL SETUP:

- Arrange the setup as per required connections. Feed the raw materials into vertical tube. Makethe vertical tube air tithed.
- Switch on the thermal cracking setup. Alter the voltage according to process requirement. Place thetemperature sensor and switch on the temperature setup. Set the set point limit in controller.

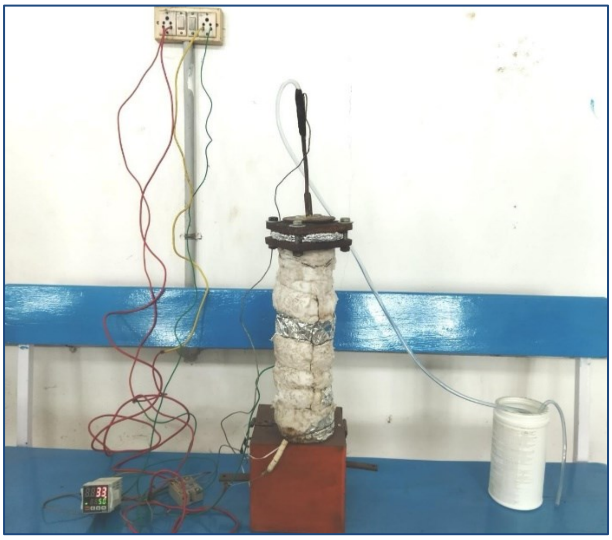

Figure.2.2 THERMAL CRACKING EQUIPMENT

VERTICAL TUBE:

Vertical tube is the tube made by mild steel and it is used to carry raw materials like electrical wires at inside. It facilitates the process as anaerobic process. It eliminates oxidation during processing. It is placed vertically on floor. It was surrounded by heating element and ceramic wool. By providing anaerobic process we can achive pure form of copper. And other byproducts like fuel gas, Fuel oil, and other solids. These are utilized to generate energy.

NICHROME WIRE:

Nichrome wire is heating element in this process. In this process it was used to heat upto 450°c.It is commonly used as resistance wire, heating elements in devices like toasters, electrical kettles and space heaters, in some dental restorations (fillings) and in a few other applications.

CERAMIC WOOL:

These are made from long refractory fibers, needled mat without binder. These refractory blankets are available in roll form in a wide variety of densities and thicknesses. They have excellent strength before and after heating with excellent insulation performance. All blankets have good chemical resistance unaffected by all chemicals except hydrofluoric acids and strong alkali. As these blankets have excellent thermal stability and low heat storage, they have good demand in high thermal range insulation purpose. Blankets are zirconoca stabilized and are suitable up to 1260°C and 1425°C.

CONDENSING SETUP: Condensation setup is used for converting exhaust gas into liquid form. It consists two containers and pipelines.

1. **PIPELINES:** Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances which can flow—liquids and gases (fluids), slurries, powders and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members. Here these are used for carrying gas from vertical tube to condensing container. These are directly contacted with coolants to condense the gas.

2. **CONTAINERS:** Plastic containers are containers made exclusively or partially of plastic. Plastic containers are ubiquitous either as single-use or reusable/durable plastic cups, plastic bottles, plastic bags, foam food containers, Tupperware, plastic tubes, clamshells, cosmetic containers, up to intermediate bulk containers and various types of containers made of corrugated plastic. Thermal cracking consists two containers. One is for collection of crude oil and another one for directing gas. These are directly contacted with coolants to condense the gas.

3. **TEMPERATURE CONTROLLER:**

A temperature controller is an device that is used to control temperature. It does this by first measuring the temperature (process variable), it then compares it to the desired value (set value). The difference between these values is known as the error (Deviation).

The role of the temperature controller is to measure the temperature on the thermocouple, compare it to the set point and to calculate the amount of time the heater should remain switched on tomaintain a constant temperature.

Many factors change the amount of time that the heater needs to on, to maintain the process temperature. For example the size of the heater, the size of the oven, the amount of insulation surrounding the oven and the ambient temperature will all change the rate at which the oven will heat up or cool down. The important point, is that the temperature controller has one input, one outputand one set point.

4. TEMPERATURE SENSOR:

A Type K thermocouple refers to any temperature sensor containing Chromel and Alumel conductors, that meets the output requirements as stated in ANSI/ASTM E230 or IEC 60584 for Type K thermocouples. This may be an immersion sensor, a surface sensor, wire or another style of sensor or cable.

Type K thermocouples have a general temperature range of -200 to 1260°C (-326 to 2300°F).

If used for temperatures below 0°C special material is needed in order to meet the specified accuracies. Also, Special Limits of Error are not specified for temperatures below 0°C.

The ultimate suggested upper temperature limits for Type K are based on the size of the conductor used.Thermocouples are not manufactured to a specific resistance, they measure temperature based on the output voltage they provide. Resistances will vary with conductor size and somewhat with the lot of conductor used.

5. VOLTAGE REGULATOR:

The power supply unit of an electronic device converts incoming power into the desired type (AC-DC or DC-AC) and desired voltage/current characteristics. A voltage regulator is a component ofthe power supply unit that ensures a steady constant voltage supply through all operational conditions. It regulates voltage during power fluctuations and variations in loads. It can regulate AC as well as DC voltages.

A voltage regulator usually takes in higher input voltage and emits a lower, more stable output voltage. Their secondary use is also to protect the circuit against voltage spikes that can potentially damage/fry them.

Here voltage regulator is used to regulate voltage according to process time and temperature rating.

6. COPPER CORED ELECTRICAL WIRES:

Wires are pieces of metal that transport electricity. They are usually flexible which makes them easier to use. These electrical conductors are key to all electrical devices.At end-of-life electrical wires become contamination in lands. This will create pollution in environment.

Because of improper technologies to recycle copper, makes demand of copper in market is high. We can reduce this effect by utilizing thermal cracking process. Here we can achieve pure form of copper and also some useful energy sources. Here wires are recycled under thermal cracking process. Thermal cracking of electrical wires will meet the demand of metals (copper) in market, it reduces emissions, and producing fuels as byproduct

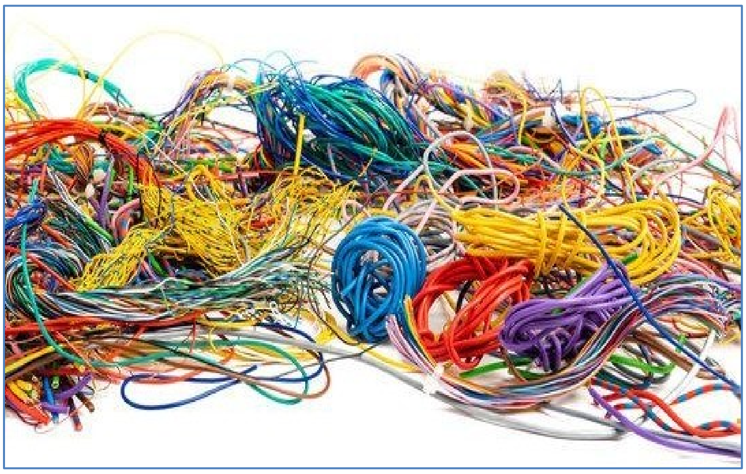

Figure 11: Electrical Wires

7. RED MUD:

Red mud, now more frequently termed bauxite residue, is an industrial waste generated during the processing of bauxite into alumina using the Bayer process. It is composed of
various oxide compounds, including the iron oxides which give its red color. Over 95% of the aluminaproduced globally is through the Bayer process; for every tonne of alumina produced, approximately 1 to 1.5 tonnes of red mud are also produced. Annual production of alumina in 2020 was over 133 million tonnes resulting in the generation of over 175 million tonnes of red mud.

Here it is used to neutralizing the HCl compound emissions.

Chemical reaction: $2\,HCl + FeO \rightarrow FeCl_2 + H_2O$

8. CALCIUM CARBONATE:

Calcium carbonate is one of the most popular chemicals which is first encountered in school classrooms, where the use of chalk (a form of CaCO3) is found. It is found in the earth's crust. It is also found in many forms such as marble, limestone, etc. Although they are available in various forms they are chemically similar and only differ physically. They are also referred to as calcite.

Here it is used to neutralizing the HCl compound emissions.

Chemical reaction:

$$CaCO_3 + 2HCl \longrightarrow CaCl_2 + CO + H_2O$$

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Volume 9 Issue 03 2021

OUTPUTS OF THERMAL CRACKING

1. **COPPER WITH 99.9% PURITY:**

The copper obtained from thermal cracking is in 99.9 % pure form. Because it doesn't interact with any oxides. thermal cracking maintenance copper quality same as before and after processing. with thermal cracking the processing time and maintenance cost becomes less. Other process makes interaction with surface of metals. This makes quality less products. By means off thermal cracking these problems can avoid.

2. **CRUDEOIL:** Thermal cracking oil, sometimes also known as bio-crude or bio-oil, is a synthetic fuel underinvestigation as substitute for petroleum. It is obtained by heating dried biomass without oxygen in a reactor at a temperature of about 500 °C (900 °F) with subsequent cooling.Crude is Obtained during condensing of gas which is came from vertical tube. This crude oil is used for furnace oil in various industries.

3. **GAS**:

Gases from thermal cracking typically contain significant quantities of methane, hydrogen, carbon monoxide, and dioxide, as well as higher hydrocarbons that build their calorific value and make them important fuel for the chemical and energy industries.During condensation process some gas is condensed into liquid form and remaining is in form of gas. This gas is also used as fuel in gasfurnace.

4. **CHARCOAL**:

In general, thermal cracking of organic substances produces volatile products and leaves char, a carbon-rich solid residue. Extreme thermal cracking, which leaves mostly carbon as the residue, is called carbonization. Thermal cracking is considered the first step in the processes of gasification or combustion. Here charcoal is Obtained inside of vertical tube. This is also used for fuelin various applications.

1. **MECHANICAL PROCESS:**

Mechanic process consists shudders, conveyers, vibrators, air separators, liquid separators, etc. The productivity of plant is less comparing to thermal cracking. Because it consists major friction losses. It requires heavy manpower and consumes heavy electricity. It has less effective in separation.

ISSN NO: 9726-001X

Volume 9 Issue 03 2021

2. INCINERATION:

In the process of incineration, copper wire is directly contacted with air and oxidizes, resulting in large loss and low quality of copper. However, when incinerated, a large amount of greenhouse gas (carbon dioxide) is emitted, and most incinerators are incinerated in the form of trash, so in this case, air pollution caused by exhaust gases. after combustion reaction post-treatment equipment is necessary because of the material, and about 30% of residues are generated due to incomplete combustion, and these residues are reclaimed in the landfill. There is a problem that occurs secondary pollution.

Figure 6.2: Incineration of Wires

RESULTS AND ANALYSIS

CHLORINE CONTENT AFTER ADDITION OF CATALYIST

Table: 3

Sample	Chlorine (mg/L)	Chlorine (mg)	Chlorine Distribution (%)
OIL	1.69	0.17	0.01
Char	17450.68	1745.07	77.86
Gas	389.53	62.32	3.47

Addition of Catalyst

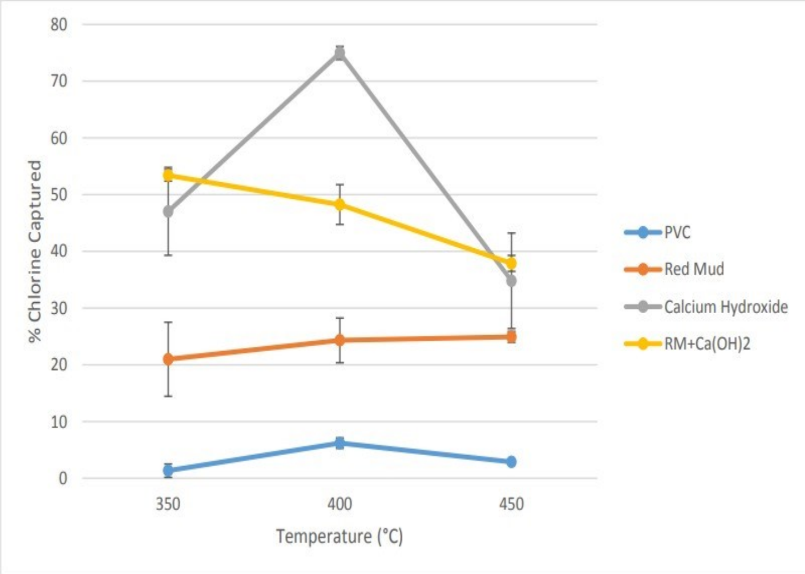
CHLORINE CONTENT BEFORE ADDITION OF CATALYIST

Table: 7.4

Sample	Chlorine (mg/L)	Chlorine (mg)	Chlorine Distribution (%)
OIL	n/a	n/a	n/a
Char	77.9	7.8	0.34
Gas	9036.96	1807.39	78.80

Without Addition of Catalysis

Graph between Temperature and % chlorine Captured



Temperature dependence on chlorine Absorption.
The error bars are the standard deviation

Before the addition of catalyst the gas contains 78.8% of chlorine. After addition of catalyst the gas contains 3.47% of chlorine. Here chlorine content is observed by solid char coal. Hence environment pollution is prevented by adding catalyst. Emission of chlorine gasses are reduced. Emission of chlorine gasses are reduced.

CONCLUSIONS

We draw the conclusion that including additional catalysts into the thermal cracking process enhances this technology. The procedure is being enhanced and the efficiency is being raised by the catalyst. We can obtain a highly purified copper form while maintaining its quality. Chlorine gas emissions are decreased.

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