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Recycling of various electrical and electronic cables to get valuable metals and materials

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ABSTRACT

Huge amounts of scrap cables are being generated from the end-of-life electrical and electronic equipments. These scrap cables containing significant amount of copper (Cu), aluminium (Al), iron (Fe), etc., require proper management in view of environmental protection and resource recycling. Present work is focused on different recycling techniques used to get valuable metals and materials from various scrap electrical and electronic cables/wires. In order to convert these scrap into valuables, pyro-hydro- and electrometallurgical processes are used depending upon the content of metals present in each scrap. Based on various research work carried out, pyrolysis followed by leaching and advance separation techniques is selected to be the best way to treat these cables. Wires are initially pyrolysed in a closed chamber and generated fumes are condensed back as low density oil (LD oil). From the pyrolysed materials, metallic and non-metallic part is separated using physical beneficiation methods. The non-metallic part termed as activated carbon is a salable product. The metallic fraction is put to pyro- or hydrometallurgical process of leaching to get the metals as ingot or as ions in solution. Further, solvent extraction (SX)/ ion exchange (IX) is used to get pure solution of individual metals. After this, precipitation, evaporation or electro-winning is used to get respective metal salts or sheets. Thus, instead of collecting metal values in improper manner, these techniques will be useful from environmental and economical viewpoint.

Keywords*:* Cables; Copper (Cu); Pyrolysis; Leaching; Solvent Extraction; Precipitation;

INTRODUCTION

The increase of electro-electronic goods has grown largely in the last decades. The current market launched new products as the demand increases day by day and as a result there is rapid increase in waste cables. Therefore, the collection and recycling of waste of electric and electronic equipment(WEEE) cable and wire is a current need, not only for conserving natural resources, but also to protect the environment and also to reduce the negative impact on environment. Cables comes in varieties and can be divided into five major categories, including magnetic wire, uninsulated wire, electrical wires and cables, power cable and communication cable as per their structure, manufacturing, functionality and application characteristics (Conesa et al., 2013). The commonly used electrical power cable is that which are suspended between poles or towers. The cables include a number of wires twisted together in concentric ring basically these

wires are copper or aluminium. Copper/aluminium selected for good electrical conductivity while stranding gives the wire flexibility. Power cables operate at low frequency alternating current whereas communication cable operates at high frequencies. In the last 10 years, the recycling of electro-electronics scrap studies (Cui and Forssberg, 2003; Lee et al., 1999; Zhang and Forssberg, 1999) has enhanced, although many aspects still need to be developed. The European Community Waste Electrical and Electronic Equipment Directive (Directive 2002) have promoted even more advance investigation in this area. In this factors, this work focus on effective donatives to wire and cable recycling, suppose that in the development of recycling processes, the waste wires and cables, also the batteries, should be segregated.

A general description of waste cable recycling and treatment technologies

The aim is waste cable that uses high-purity copper (Cu), Iron (Fe), and aluminium (Al). These waste cables are divided into the three types: type I is waste cable with a full diameter, constant composition and uniform specifications; type II is waste cable with different compositions of insulating layers, intermediate diameters and mixed types; and last type III is copper, Aluminium and iron containing waste cable with small diameters and mixed types. Waste cable recycling process use semi-mechanized or mechanized treatment techniques to separate the copper, iron and aluminium from the insulating layer. The most common techniques include mechanical treatment technology, the freezing process, ultrasonic separation recycling, high-pressure water jet technology, a heat-recovery process, and chemical treatment (Xiao et al., 2015).

Physical recycling techniques

Mechanical treatment

Mechanical treatment technology is a physical treatment technology which is widely used in various waste cable recycling industries (Koyanaka et al., 1997; Li et al., 2010; Yokoyama et al., 2011; Zhang and Forssberg 1998). In the early stage of mechanical treatment technology, it requires manual rough sorting of type I, II and III waste cables. Next, separation equipment is used to separate the conductive Cu, Al, Fe core and plastic sheath of the waste cables. Finally, the separated copper core along with the others metals and plastic sheath are separately recycled. The mostly used mechanical treatment technologies include wire stripping and crushing, and the instrument used includes wire stripper and copper rice machines.

Stripping method

For the disposal of large diameter uniformed waste cables this is an appropriate method. Automatic mechanical strippers operated with PLC as the core control system (Liu et al., 2008), the components can be simply fitted for the guarantee of comprehensive application. Stripping is mainly driven by a stepping motor and wheel clamped cable and wire movement. A state in which cutting and stripping, the specified processes are Wire and cable through the right-wheel drive stepper motor movement, stepper motor control through the cutter, tool relative displacement, so that peeling and cutting. And at the same time the left-wheel drive motor caught between the copper-contained discarded cables to move; the twisted cable wheel stepping motor driven, bottom roller back and forth in the opposite path, to achieve twisting. Such type of stripping equipment well-atomised, but the scale of application is deeply confined, only applies to the stripping of a particularly scrap cables of different diameters.

Crushing method

This method includes the steps of crushing and sorting. The particular sizes of waste cables are crushed into particles after passing the crushers. After that, they are separated into a plastic sheath and a copper core along with the other metals with the sorting equipment. The equipment which is complete with crushing and sorting units is commonly known as the “copper rice machine”; it’s working mechanism. The scraped wires are put to the primary crusher (triangle blade crusher) through the feeder. After magnetically craning, the primary crushed materials are sieved from which the large particles are put to copper rice crusher. The treated materials from the rice crusher are then put to the oscillating screen by screw conveyor and segregated into four components (copper rice, plastic, insufficiently crushed copper wire and mixture of copper rice and plastic); copper rice and plastic are separately collected, and the insufficiently

crushed particles and the mixture of copper rice and plastic are separately returned to the compatibly step for repeated crushing and separation. This process optimizes the working conditions; a cloth dust bag is used during the steps that produce a great deal of dust. The copper rice machine is suited for waste cables with a single wire. However, the cables come in many types in addition to important mixing and tangling, which are show as a conglomeration. Can also experience operational failure if the direct result is that the crushing equipment is easily worm. For this reason, crushing often requires initial manual cutting, leading to severe human resource waste and extremely low efficiency. This has become one problem in the waste cable treatment industry, seriously impacting both efficiency and working conditions so, the development of high efficiency and low consumption waste cable cutting and sorting technology and equipment is very significant for improving this industry's efficiency and working conditions.

High-pressure water jet method

In this the main process was to swathe waste cables of certain specifications onto reels. The parameters of high-pressure water jet (normally greater than 55 MPa) and the feed rates of the feed gear were set based on the specification or size of the waste cables to be treated. The high-pressure water jet was used at a similar speed to tear the plastic sheath. Finally, simple ancillary separation equipment was used to separate the copper, aluminium and other metals core and plastic sheath from the waste cables. Although this technology is very easy to operate, it has less degree of automation than it should. Therefore, workers need to monitor the operation process in real time. In addition, the majority of the trajectory of the wet jet is absent from cables; in other words, the real effect is only from the instant that the jet impacts the cable, resulting in the waste of a substantial portion of energy.

Ultrasonic separation

Ultrasonic separation technologies have been generally used to recycling electronic waste in recent years. It is widely used because of the magnificent environmental benefit and the fact that ultrasonic waves do not alter the physical and chemical properties of the treated materials; ultrasonic technology has been successfully applied by the waste cable recycling industry. The ultrasound cavitations effect refers to the growth and collapse of thermodynamic processes of the oscillated microscopic bubbles in a liquid under ultrasound when the ultrasonic pressure reaches a certain value (Fan et al.), applied this effect to the recycling of waste cables in which the ultrasound cavitations effect causes waste cables immersed in water to sway and vibrate to perform the separation of the plastic sheath and copper core. By analyzing the effect of water temperature, the length of the cut cables and the liquid-to-solid ratio on the separation efficiency of single- and multiple-core cables, the authors believed that under the dual effect of thermal expansion and contraction and the ultrasound cavitations effect, separation efficiency is optimal when the ultrasonic frequency is 20 kHz, the treatment time is 5 min and the water temperature is 60 °C. The cable length is almost inversely proportional to the separation efficiency. In the meantime, the solid-liquid ratio also has certain effects on separation efficiency.

Heat recovery process

Incineration

Incineration is a conventional method and is used for waste treatment process that includes the combustion of organics contained in the waste material. It is also known as "heat treatment''. Incineration of wastes converts the waste material into ash, flue gas and heat. It is simple method to recycle copper and the other metals through burning the waste cable along with the sheath directly in an incinerator. The waste cable contains plastic sheath which are thermoplastic including PVC, PE and flame retardants (Lee et al., 2012; Yang et al., 2007). The smoke and gases produced from the incineration process contain toxic gases which detriot the environment as well as human health, so it is prohibited in many countries (Sijstermans 1997). Therefore, environmentally friendly incineration uses bath smelting technology in which the waste cables directly enter the high-temperature zone (above 850 °C) for incineration. In this process, organics are rapidly decomposed to avoid generating dioxin (heating temperature between 260 °C −430 °) (Hense et al., 2015; Lai et al., 2007).

Chemical recycling techniques

Waste cable types II and III are the most difficult to treat among all waste cables because of the disorderly arrangement and non-uniform cable diameter. Therefore, these types of waste cables are difficult to recycle. Accordingly, chemical treatment techniques have been proposed. The traditional chemical treatment technique is a method in which the solid materials are immersed in a series of leaching solutions to obtain the metal-ion containing leaching solutions; the target metal products are then obtained through the displacement, crystallization, extraction, or electrolysis of the leaching solution. Typical leaching systems include ammonium salt systems chloride systems, nitric acid systems and bio-leaching systems. However, such chemical treatment techniques are unsuitable for the treatment of waste cables. Therefore, if chemical techniques are to treat waste cables, the use of salt solution or organic solvents that do not react with the copper cores but dissolve the plastic sheath are required, thereby achieving the separation of the metal core and plastic sheath.

Chemical treatment techniques can efficiently treat disorderly and non-uniform sized type II and III waste cables that are difficult for existing strippers to treat. However, their adaptability is low for chemical methods; the required chemical regents depend on the composition of the plastic sheath in waste cables; additionally, the treatment process consumes a large quantity of solvents and thus can easily lead to secondary pollution. Because of these concerns, further improvements are imperative for the industrialization of chemical methods.

Recovery of valuable metals and materials from waste electrical and electronic cable/wire at CSIR-NML Jamshedpur.

Present work is focused on different recycling techniques used to get valuable metals and materials from various electrical and electronic cables/wires. In order to convert these scrap into valuables products, by pyro-hydro- and electrometallurgical processes are used depending upon the content of metals present in each scrap. Based on various research work carried out, pyrolysis followed by leaching and advance separation techniques is selected to be the best way to treat these cables. Wires are initially pyrolysed in a closed chamber and generated fumes are condensed back as low density oil (LD oil). From the pyrolysed materials, metallic and non-metallic part is separated using physical beneficiation methods. The non-metallic part termed as activated carbon is a salable product. The metallic fraction is put to pyro- or hydrometallurgical process of leaching to get the metals as ingot or as ions in solution. Further, solvent extraction (SX)/ ion exchange (IX) is used to get pure solution of individual metals. After this, precipitation, evaporation or electro-winning is used to get respective metal salts or sheets. Thus, instead of collecting metal values in improper manner, these techniques will be useful from environmental and economical point of view.

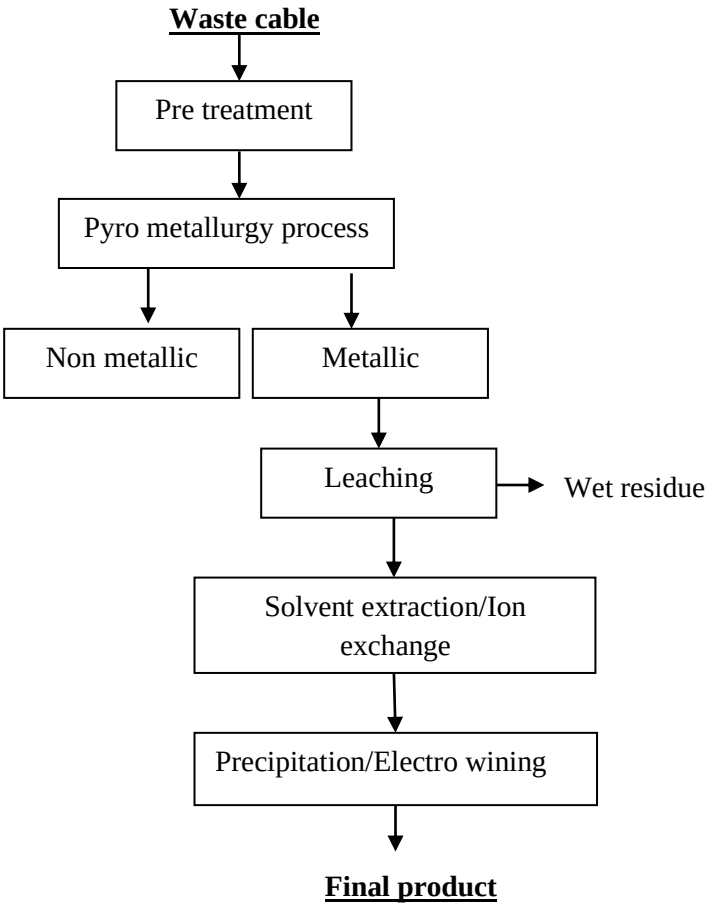

Fig: Process flow sheet for recovery of copper and others metals from waste cable.

Conclusion

The comparative analysis shown that there are number of ways to recycle waste cable or wire, each technique has their own advantages and disadvantages but the ultimate goal is somehow same that is to economically and environment friendly extract the metals along with the other value products. The key to

recycling technology for waste cables is, efficient separation of the conductive copper rod and the other metals including the plastic sheath. Mechanical recycling technology is the most common techniques used in recycling of valuable metals from waste cables/wires, which primarily involves cable stripping and crushing. Although mechanical recycling has strong adaptability, there are several challenges in the treatment process, such as loss of metals, high energy consumption, a tendency to generate dust, and noise pollution. Workers in the cables recycling industry and researchers should focus more on improving this technology for future studies. In addition to developing large-scale, automated equipment for industrialization, we should develop proper equipment for recycling that allows the easy separation of metals and the plastic sheath.

The re-use of recovery of copper from the recycling of scrap wires and cables should depend on its quality. The object of this study is waste cables with highly pure Cu, Al & Fe. Because the purity of reclaimed Cu, Al & Fe obtained from separation is about 90%, the quality of copper is high quality red impure copper. The most cost effective process for obtaining this type of reclaimed copper as rod is direct fire refining. This method observed to the development of Chinese industries because of its used low energy consumption, low-priced and low pollution creates. Even the fire refining process to directly produce copper rods, the processes lag far beyond those of developed countries. Therefore, China should accelerate its pace of upgrading technology and equipment, advancing science and upgrading industrial processes and technology. We should adhere to the path of independent innovation and the proper importation of advanced technology and equipment from abroad so that the quality of metals produced from reclaimed wastes through fire refining technology can meet advanced global levels.

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