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RECOVERY OF COPPER FROM WASTE CABLES USED IN ELECTRICAL APPLICATIONS

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ABSTRACT

The recycling of copper cables wastes has as main objective the recovery of copper. The effectiveness of this operation is guaranteed by the following factors: infrastructure able to collect, select and sort these wastes; a market capable to capitalize copper recovered from cables wastes to their true value; processors with equipment and technologies to achieve maximum recycling yields without negative effects on the environment. The most effective chains for wastes recycling may be considered those which use the copper recovered in wires and rods production. So is possible the design and operation of specialized flows for production of secondary copper with high purity. Contrary, a less efficient management of these wastes lead to the poor collection and mixed storage mixed with other types of copper scrap. In this case the copper wire can be recycled effectively to obtain copper-based alloys if special measures are applied at the recycling. The paper analyzes the driving forces that motivate the recycling of copper cables wastes. Also are presented the smelting experiments for obtaining high quality secondary copper and secondary brass from feed containing copper recovered from cables wastes into electric crucible furnace. The results are analyzed in terms of recovery yield and chemical composition.

KEYWORDS: secondary copper, recovery, electrical cables, smelting

1. Introduction

Copper is a highly recyclable material. Its potential recovery tends to infinity. The loss of performance can be insignificant for secondary copper processed with most accuracy from scrap. Recycling copper is very efficient way to reintroduce this valuable metal in the economy [1]. The use of secondary copper reduces the impact of primary copper production from ore on the environment. Recycling for metal recovery is also important from the perspective of saving energy. This energy saving leads to the conservation of valuable reserves of oil, gas or coal and reduces the amount of CO_2 released into the atmosphere [2].

The category of scrap copper recycled includes multiple grades of scrap copper and copper content materials. The sources of secondary copper are old scrap (from end of life products) and new scrap (from fabrication residues).

An important source of recyclable copper is wire scrap. It can be efficient recovered after its useful life in electrical applications and also from products reached at the end of their life of cycle.

In this paper is studied the recycling process of electric cables. The recovery of valuable metal copper as the main objective for recycling cable wastes is analysed. The efficiency of melting process in an electric crucible furnace of copper recovered from this typical waste is presented.

2. Driving forces for properly recycling of copper cables wastes

Copper ranks third in the world consumption of metals, after iron and aluminium. The recycling of copper cable wastes has economic and environmental implications. The recycling of copper cables wastes has as main objective the recovery of copper [3-5]. From the economic point of view, the industry for the preparation and utilisation of copper and copper alloys is dependent upon the recycling. About 40% of the total production of copper and its alloys is obtained from waste, for some products the proportion exceeding 90%. According to the report published by International Copper Study Group (ICSG) 41.5% of the copper used in Europe comes from recycling [1]. In the United States copper alloy scrap provides about half of the copper consumed each year [2].

The copper scrap can be recycled relatively simple, with low energy consumption and minimal losses. Costs are significantly reduced if only recycled copper can be recovered only by melting without further refining operations.

Recycling is an important economic activity, with important benefits for the environment. The valorisation of wastes copper leads to saving important natural resources and significant energy economy. The energy requirement for secondary copper production is between 35-85% of primary production. The benchmark energy requirements for the production of cathode copper metal from primary copper ore concentrate by pyrometallurgy, by hydrometallurgy and for secondary cathode copper metal from scrap and secondary sources are shown in Table 1.

Table 1. *Benchmark energy requirements from copper production* [6]

Copper recovery methods	Energy requirement (MJ/kg Cu)	Carbon footprint (t CO_2/t Cu)
Secondary production from scrap	6.3	0.44
Pyrometallurgy from ore concentrate	16.9	1.25
Hydrometallurgy from oxide ores	25.5	1.57
Source: The environmental benefits of recycling. BIR, Brussels. www.bir.org		

At the same time decreases the amount wastes which otherwise would be discharged into the environment.

Valorisation of copper from wastes is dependent on the efficiency of the collection system, a series of technological and economic factors, products design, social values and legislation.

In terms of legislation in the EU the management of waste scrap metal is currently under the waste regulations. The secondary copper production and the associated treatment of scrap metal on site are subject to the IPPC Directive [6]. In the United States since the passage of the Clean Air Act of 1970, numerous laws and regulations relating to improving human health and the environment have been promulgated by Congress and the federal and state agencies that enforce them [7].

Copper can be considered a resource „removable" because it can be recycled without loss of quality (chemical properties and physical). If the conditions of quality are respected can appreciate that the value of recycled copper can reach of ~ 95% from that of primary copper. Although for the use of secondary copper in electrical applications the most severe conditions are imposed on quality, increasing amounts are used in the manufacture of conductors. For this it is essential that the purity of secondary copper to be very high, thus ensuring the required physical properties: high conductivity; the possibility of obtaining the soft annealed wires; copper rods with plastic processing capacity in wires. In the case of using the feed from copper scrap in such applications, it is necessary the electrolytic refining. For non-electric applications, copper can be used in household installations as roofing sheets, heat exchangers and other products that are not so severe conditions imposed on quality. It can also be used for obtaining bronzes and brass.

Starting from quality conditions imposed at copper used to make conductors results that the most important source of high quality copper scrap are the copper cables wastes.

Choice of options for copper recovery from copper cables wastes should be based on: efficient use of energy and material resources; minimizing impacts from emissions and waste; comparative analysis of the economic aspects and ecological.

3. Experimental and discussion

Similar to the other metals, the recycling of copper scrap has three major steps: scrap collecting, dismantling and sorting. For recycling methods of copper wire the basic objective is the separate of metal from the rubber/plastic casing and extract the copper. The recycling stage is followed by secondary copper recovery to manufacture of new copper products.

The recovery of copper from scrap is possible following a technological flow sheet divided into 4 separate steps: scrap pre-treatment, smelting, alloying, and casting. Pre-treatment includes the cleaning and consolidation of scrap in preparation for smelting. Smelting consists of heating and treating the scrap for separation and purification of specific metals. Alloying involves the addition of one or more other metals to copper to obtain desirable qualities characteristic of the combination of metals [8].

The waste electrical cables with different shapes and diameters are used in laboratory experiments. These were in the form of uncoated wire and rod covered with varied insulations (Figure 1).

To melting the copper wire scrap was used an electric tilting crucible furnace (figure 2).

a.

b.

Fig. 1. *Original cables wastes subjected to experiments for copper recovery: a. cables with insulations; b. uncoated copper wires*

Fig. 2. *Electric crucible furnace for copper wire scrap melting*

Fig. 3. *Pouring of copper and copper alloy melted in graphite crucible*

There were two steps of experiments in which the components of feed were different: firstly, the copper wires scrap was melted to obtain copper with high purity; secondly the feed was composed from copper wires scrap and alloy scrap (brass) for obtaining a casting Cu-Zn alloy.

For each experiment the recovery yield was calculated with formula $\eta = \frac{m_i - m_f}{m_i} x100$ [%], when m_i is mass of scrap introduced as feed in crucible of furnace and m_f is the mass of copper or Cu-Zn alloy obtained after smelting.

In the first case the copper wires scrap with constant composition has been used in the feed of furnace. So was easy to obtain secondary copper with good quality. Only was necessary to apply the physical separation method for insulations removing. Also for reducing at melting the interaction of copper with oxygen from atmosphere the cleaned copper wires must be chopped and compressed in briquettes. The use of solid non-metallic flux is recommended for protecting the surface of melt [9]. The charcoal covers were used to add heat to the surface and to prevent the excessive oxidation losses by providing a reducing atmosphere. Also, to produce a refining action a metallic flux is introduced to the melt [9]. In laboratory experiments for deoxidizing was used the phosphor-copper alloy (15% P). The capacity of furnace crucible and the physical condition of de scrap allowed using a charge of 440g. At the end of the first set of experiments from uncoated copper wire was produced premium quality copper. The values of recovery yield were between 94.55 and 98.22%.

In second step the copper cable wastes have been utilized to obtain brass. Brass is usually made from a basic melt of scrap of similar composition adjusted by the addition of virgin copper or zinc [6, 9]. In our experiments brass scrap and copper wire scrap was together melted for obtaining the Cu-Zn alloy.

The chemical composition of brass scrap that was mixed with copper cables wastes is show in table 2.

Table. 2. *Chemical composition of Cu-Zn alloy scrap, (wt.%)*

Si	Al	Zn	Ni	Fe	Cu
0.8	3.51	34.90	0.11	0.18	60.41

Characteristic for melting of feed composed by mixture of untreated copper cables wastes is the burning of insulations from copper wire. Melting without cleaning operations result in higher pollutant emissions consisting of metal oxides and volatile compounds [10]. When brasses scrap is present in the charge, zinc is evaporated and fumed from the furnace. Other elements such as aluminium and silicon are oxidized and they pass into the slag. To minimize the oxidation losses of elements have been required a good control of bath temperature. Also for smelting process was necessary to use a larger amount of fluxes for protecting the surface of melt and for deoxidizing.

The chemical composition of copper alloy obtained is given in Table 3.

Table. 3. *Chemical composition of copper alloy obtained by melting copper wire and Cu-Zn alloy scrap, (wt.%)*

Si	Al	Zn	Ni	Fe	Cu
0.69	0.68	12.77	0.13	0.24	ball.

4. Conclusions

The valorisation of copper cables wastes is justified on the one hand by of profitability copper recovery as valuable metal and on the other hand is determined by conditionings imposed by legislation for environmental protection.

When the copper cables wastes are separately collected and cared stored the removing of insulations by stripping is easy to make. When copper cables wastes are mixed with other copper scrap the treatment operations for cleaning the scrap is clunky or is expensive through environmental measures that must be implemented. Burning of insulation from copper cables wastes generates large amounts of pollutant emissions as particulate matter and partially combusted organic compounds.

A large share of secondary copper or copper alloys is produced in crucible furnaces. In experiments an electric crucible furnace was used for melting clean the copper cables wastes and brass scrap. Non-metallic flux has been efficient used for a protective covering, and alloy flux has been added as a refining agent. By this mean were obtained high recovery yield and high quality for secondary copper or Cu-Zn alloy.

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