Separation of copper from telephone cables by gravity concentration

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Separation of Copper from Telephone Cables by Gravity Concentration

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Abstract

Waste electric and electronic equipment (WEEE) is the fastest growing waste stream compared to other types of waste and thus there is an increasing need for its efficient management. Disposal at landfills is not desired by the fact that this type of waste contains a number of useful materials that can be used again, as well as dangerous substances for which disposal is not desirable. This paper presents the results of laboratory tests of separating copper from telephone (UTP and STP) cables that are an integral part of electronic equipment. Testing was carried out by method of gravity concentration using Wilfley shaking table and Humphreys spiral concentrator. The results showed that these devices can be used successfully to obtain copper concentrate whereby better results were obtained at the shaking table.

Keywords: e-waste, UTP/STP cables, recycling, copper, gravity concentration

Introduction

The significance of Waste electrical and electronic equipment (WEEE) comes from the fact that it consists of different materials and components some of which may be hazardous (asbestos, heavy metals, halogen compounds, etc.). On the other hand, WEEE contains many useful materials, mostly metals (iron, copper, aluminium, etc.) from which recycled secondary raw materials are obtained. Although the mass content of material depends on the type of electric and electronic product, metals and polymers prevail.

The metal content in the WEEE is generally higher than in the primary raw materials and, as a rule, the energy consumption, and therefore the emissions when the metals are obtained from waste, are lower. In addition to these certainly important reasons, this type of waste is also interesting for recycling because its quantity. WEEE has become one of the biggest problem of the modern world (Seo et al. 2004) and one of the fastest growing waste streams in the modern world (Tanskanen, 2013) as a result of the economic and technology development, life standard increase and consequently growth of goods consumption, especially electric and electronic equipment (EEE). In recent years, this general world trend has been changed in Europe. According to Eurostat data (Figure 1), between 2008 and 2009, the amount of EEE put on the marked decreased by 1.1 million tonnes (or 11.1%) i.e. reduced to 9.0 million tonnes due to the recession following the global financial and economic crisis. The newest data is about 9.2 million tonnes EEE in 2014 (Figure 1). By category, large household appliances are the most representative in all EU countries (from 35% in Belgium up to 70% in Bulgaria), while IT and telecommunication equipment (category 3) is the second largest product category in most countries (22 out of the 28 countries) ranging from 5 % in Malta up to 24% in Czech Republic (Eurostat, 2016).

Shielded twisted pair (STP) cables and unshielded twisted pair (UTP) cables are commonly used in IT and telecommunication equipment. Both cable types have the individual wires twisted around one another, creating better conduction. One wire serves as the carrier of the signal itself and another one is grounded and serves as a shock absorber and interference protector. UTP cable is certainly the most popular type of cable around the world. Its popularity stems from the fact that it is easy to work with i.e. easy to install, extend and troubleshoot. There are seven different types of UTP categories determined by data rate (from 1 Mbps in category 1 up to 10 Gbps in categories 6 and 7) and therefore by its applications. Category 1 is typically used as telephone wire and it isn't capable of supporting computer network traffic and is not twisted.

This category is also used for providing ISDN and PSTN services. All other categories (2-7) support computer network and telephone traffic. Category 2 is used mostly for token ring networks (up to 4 Mbps) and categories 3, 4 and 5 are 4 pairs of twisted copper wires which enable higher data rate (up to 10, 16 and 100 Mbps respectively). Category 6 wire was originally designed to support gigabit Ethernet. It is similar to

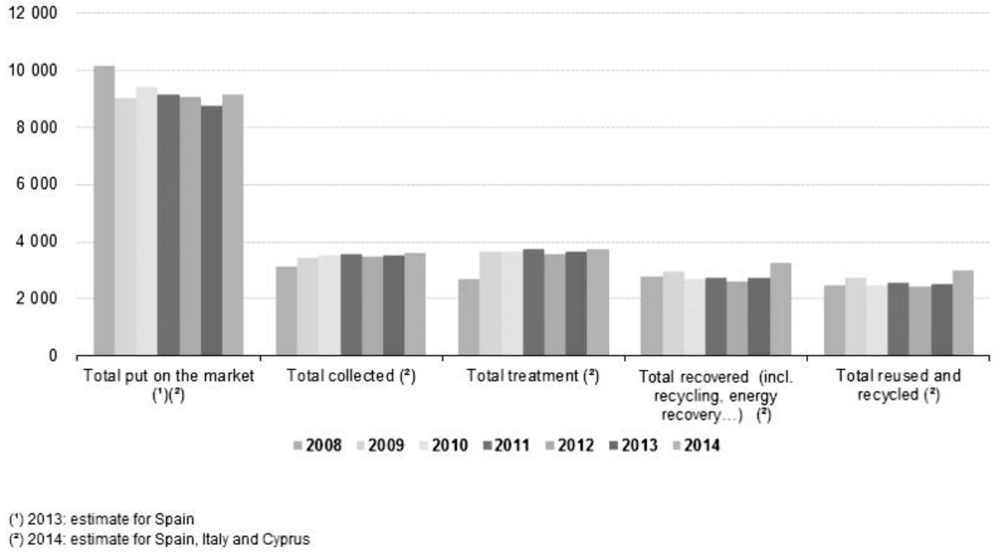

Fig. 1. Electrical and electronic equipment (EEE) put on the market and waste EEE collected and treated, EU, 2008–2014 (in 1 000 tonnes) (Eurostat, 2016)

Rys. 1. Sprzęt elektryczny I elektroniczny (EEE) dostarczony na rynek oraz odpady EEE zebrane i przetworzone, EU, 2008–2014 (w 1 000 ton) (Eurostat, 2016)

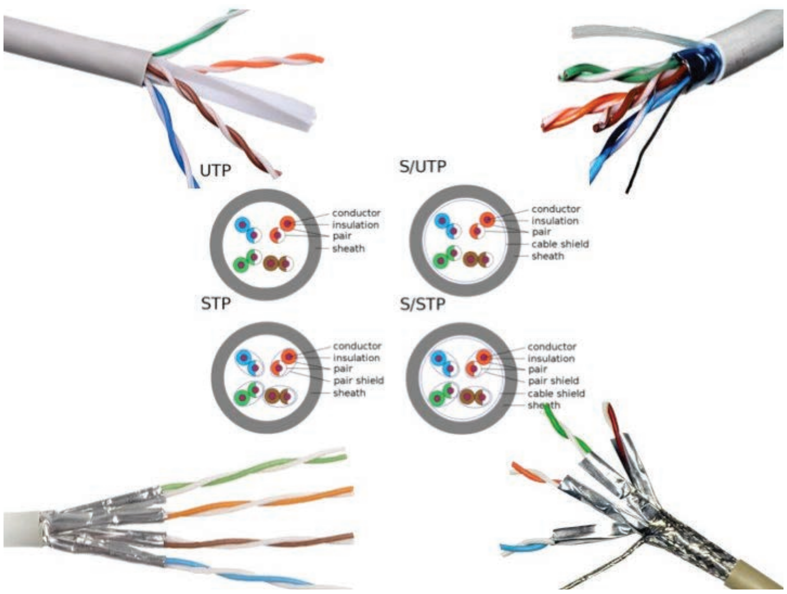

Fig. 2. Structure of UTP and STP cabels (QTP, 2017)

~~Rys. 2. Struktura kabli UTP I STP (QTP, 2017)~~

previous categories but contains physical separator between the four pairs to further reduce electromagnetic interference. Category 7 is a newer copper cable specification designed to support speeds of 10 Gbps and has four individually shielded pair plus an additional cable shield to protect the signals from crosstalk and electromagnetic interference (Firewall.cx, 2017).

STP cable has same concept as UTP but upgraded. In this cable, cable pairs (not individual wires) are shielded by a metallic substance and then all four pairs (assuming an eight-strand cable) are wrapped in yet another metallic protector. The reason is preventing interference via the usage of three techniques known as shielding, cancellation and wire twisting. One problem with STP is harder installation because if it is not installed and grounded properly, the shielding acts as an antenna and receives signals (Electrical Contractor, 2004).

Both cable structures are shown in Figure 2. It has already been mentioned that wires are made of copper and have coloured insulation typically made from polyethylene (PE) or fluorinated ethylene propylene (FEP). Cable shield is made of aluminium and sheath usually of polyvinyl chloride (PVC) or Low Smoke Zero Halogen polymer (LSZH).

Materials and methods

Material used in the tests was UTP and STP cables, normally used as telephone cables. Cables were cut us-

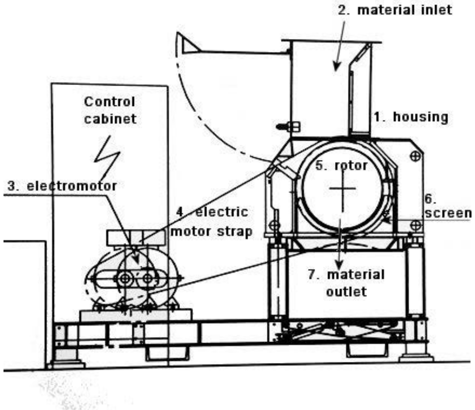

Fig. 3. Granulator UG 600 (Spectra Media, 2015)

Rys. 3. Granulator UG 600 (Spectra Media, 2015)

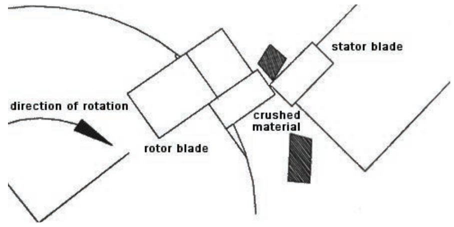

Fig. 4. Detail of cutting (Spectra Media, 2015)

Fig. 4. Szczegóły rozdrabniania (Spectra Media, 2015)

ing granulator UG 600 (Figure 3) at the company Spectra Media. Upon entering the granulator, the cables fall to the rotor with blades. The rotor directs cables to the stator and the cutting takes place between the rotor and stator blades (Figure 4). The gap between the rotors blades and stators blades was set to 0.9 mm. The output size of the comminuted material is determined by the opening size of an exchangeable screen placed at the outlet below the rotor. The tests were done using a screen with opening size of 5 mm in diameter. Cables are retained in cutting area until they are reduced to a size smaller than the screen openings.

The table 1 shows materials present in UTP and STP cables and their densities. The aim of research was to determine whether copper can be separated from the cable waste. As can be seen in Table 1, copper has significantly greater density than other materials present in tested cables. Based on this, it was decided to use gravitation concentration as the most adequate method for separating copper from cable waste in the form of particles ranging in size from 1 to 5 mm. Humphreys spiral concentrator and Wilfley shaking table (Burt, 1984, Wills, 2006) were chosen for that purpose.

Gravity concentration tests were performed in Laboratory for mineral processing and environmental protection at Mining, Geology and Petroleum Faculty, University of Zagreb. The mass fraction of copper (valuable component in tests) in all feed samples was 67.67% and 32.33% of all other materials (PVC, PE, etc.). A standard Humphreys spiral concentrator with six spiral bends and 55 cm in diameter was used. The samples of 4000 g were dosed at a water flow of 4.5–5 l/min. All the openings for heavy fraction were completely open. In order to increase copper content in the concentrate, after first (raw) separation step, two more cleaning steps were also carried out (two stages of concentrate cleaning). A Wilfley shaking table of surface dimension 104 ×38 cm, with strokes of 5 mm and frequency of 270 min-1 was used. The samples of 1000 g and grain size class 5/1 mm were dosed at a water inflow of 3.5 l/min and at table slope of 3°, 6° and 9°. Also, two stage of concentrate cleaning were performed (just as in case of a Humphreys spiral).

After each individual test, obtained products were dried and their composition were determined by hand sorting and weighing. Separation efficiency was estimated by two indicators: recovery (of copper) and grade of concentrate. The recovery represents the percentage of the total copper contained in the feed that is recovered into the concentrate. The recovery R can be expressed by the following equation:

$$R = 100 \cdot \frac{C \cdot c}{F \cdot f} \quad (\%)$$

where R is recovery in percentage, C is mass of concentrate in grams, c is mass content of copper in the concentrate in percentage, F is mass of feed in grams and f is mass content of copper in the feed material in percentage.

Grade of concentrate represents the percentage of the copper contained in the concentrate as a final product and can be expressed by follow equation:

$$G_C = 100 \cdot \frac{m_{Cu}}{m_C} \quad (\%)$$

where GC is grade of concentrate in percentage, mCu is mass of copper in the concentrate in grams and mC is mass of concentrate in grams.

Results and discussion

Figure 5 presents results obtained in Humphreys spiral concentrator. It has been shown that separation in the spiral concentrator only slightly increases copper content in the raw concentrate i.e. by 3.15% (from 67.67% in the feed up to 70.82% in the raw concentrate) at the recovery of 76.73%. Therefore, it was de-

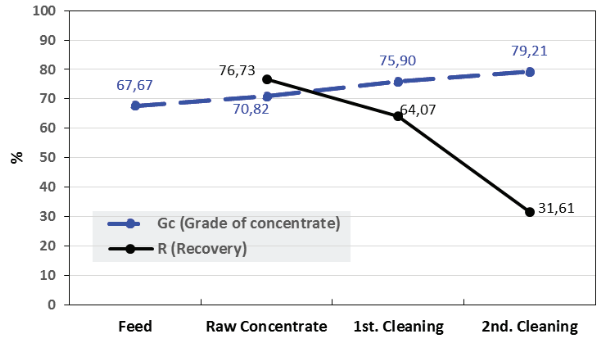

Fig. 5. Result of separation in Humphreys spiral

Fig. 5. Wyniki wzbogacania na spiralach Humphrey'a

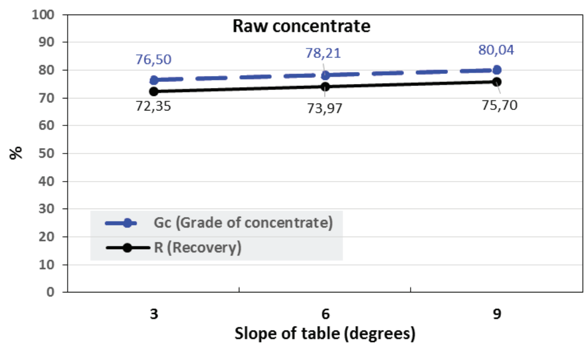

Fig. 6. Result of separation on Wilfley concentration table (Raw concentrate)

Fig. 6. Wyniki separacji na stole Wilfley'a (Surowy materiał)

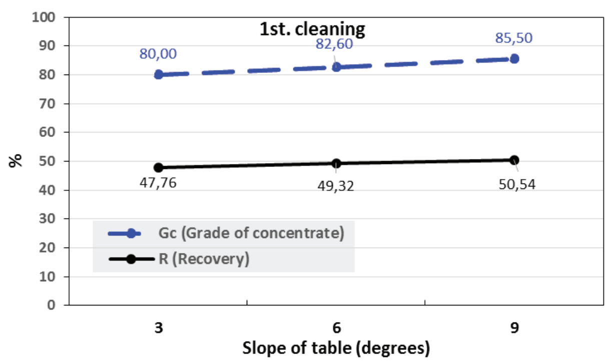

Fig. 7. Result of separation on Wilfley concentration table (1st cleaning)

Fig. 7. Wyniki separacji na stole Wilfley'a (Czyszczenie I)

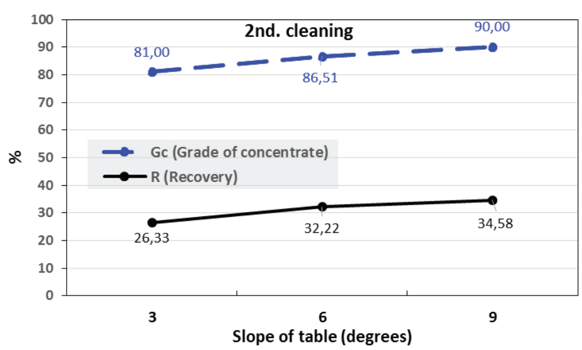

Fig. 8. Result of separation on Wilfley concentration table (2nd cleaning)

Fig. 8. Wyniki separacji na stole Wilfley'a (czyszczenie II)

Tab. 1. Materials present in UTP and STP cables and their densities

Tab. 1. Składniki kabli UTP i STP oraz ich gęstości

Material	Density
	g/cm^3
Cu	8,96
PE	0,91–0,96
FEP	2,15
Al	2,7
PVC (flexible)	1,1–1,35
LSZH	1–1,15

cided to try to increase the copper content by cleaning of concentrate in two more separation steps (cleaning stages). After the first cleaning stage, the copper content increased by an additional 5.08% (total 75.90%) and by another 3.31% after the second cleaning stage (total 79.21%). At the same time, the copper recovery decreased by 12.66% (total 64.07%) after the first cleaning stage and by an additional 32.46% (total 31.61%) after the second cleaning stage.

Such results suggest that Humphreys spiral concentrator is only slightly able to increase concentrate quality (copper content) at the significant reduction in copper recovery. Figures 6 to 8 present results obtained by Wilfley shaking table. As can be seen in these figures, both grade of concentrate and recovery slightly increase with increasing slope of table. As well as in the case of Humphreys spiral, two more cleanings were made to increase copper content in the concentrate (grade of concentrate). After the first cleaning stage, depending on table slope, the copper content increased by an additional amount of up to 5.46% and by another amount of up to 4.50% after the second cleaning stage. At the same time, the copper recovery decreased approximately by 25% at all slopes after the first cleaning stage and by an additional 15.96% up to 21.43% (depending on slope) after second cleaning stage, which is a significant reduction compared to the results obtained in the spiral concentrator. However, by comparing the results of separation achieved in both devices, it can be seen that the shaking table gives better results regarding both concentrate grade (80.04%) and recovery (75.70%) than Humphreys spiral (grade of 70.82% and recovery 76.73%) in raw concentrate, i.e. after only one separation step. In the concentrate cleaning process, the Wilfley table showed slightly better results than Humphreys spiral in terms of grade of concentrate. From the recovery aspect, Wilfley shaking table showed also slightly better results than Humphreys spiral. After two cleaning stages, total recovery decreasing in tests conducted on Wilfley table was about 41% (slopes of 6º and 9º) and 46% (slope of 3º) while, in tests conducted in spiral, it was 45%.

Conclusion

The results of the research have shown that both devices can be used to separate copper from the waste fraction of the telephone (UTP/STP) cables. The Humphreys spiral allows obtaining a concentrate with a copper content of 70.82% which can be increased up to 79.21% by concentrate cleaning. The Wilfley shaking table provides concentrate with a copper content of 80% which can be increased up to 90% by concentrate cleaning. The copper recovery is relatively high (70.82%, obtained by separation in Humphreys spiral and up to 75.70% on Wilfley table) after one separation stage (i.e. in raw concentrate), but in case of concentrate cleaning it is significantly decreased in both devices. By comparing the test results obtained in both devices, the Wilfley shaking table showed better results than Humphreys spiral concentrator.

Acknowledgements

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Separacja miedzi z kabli telefonicznych za pomocą metody wzbogacania grawitacyjnego

Zużyty sprzęt elektryczny i elektroniczny (WEEE) to najszybciej rosnący strumień odpadów w porównaniu do innych rodzajów odpadów, a tym samym powstaje zapotrzebowanie na jego skuteczne zarządzanie. Unieszkodliwianie odpadów na składowiskach odpadów nie jest pożądane z uwagi na to, że ten rodzaj odpadów zawiera wiele użytecznych materiałów, które można wykorzystać ponownie, a także substancje niebezpieczne, których składowanie wymaga spełniania rygorystycznych wymagań.

W artykule przedstawiono wyniki badań laboratoryjnych separacji miedzi z kabli telefonicznych (UTP i STP), które stanowią integralną część sprzętu elektronicznego. Separację przeprowadzono metodą wzbogacania grawitacyjnego na stole wytrząsającego Wilfley i Humphreys oraz separatorze spiralnym. Uzyskane wyniki wykazały, że te urządzenia mogą być z powodzeniem stosowane do uzyskania koncentratu miedzi.

Słowa kluczowe: e-odpady, kable UTP / STP, recykling, miedź, wzbogacanie grawitacyjne