# SORTING ELECTRICAL WASTE GRIT AND PROCESSING THE METALLIC COMPONENT

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**Abstract**

The main object of this article is to present methods of electrical waste sorting and the subsequent processing of its metallic component. Electrical waste grit is formed by the crushing of electric current cable conductors and consists of pieces of copper wires and plastic granulate. The original sample was characterized by fundamental mechanical-physical properties, which are the angle of internal friction, density and morphology (shape and size distribution). Methods of electrical waste sorting were assessed on the basis of the obtained amount of pure copper component. This metal part of the sample was subsequently pelletized to facilitate re-use in the metallurgical industry. The first results showed that the vibrating sieve method is, in comparison with the pneumatic means, more efficient for this purpose. The produced copper pellets showed good mechanical resistance and hardness. The advantage of the densified metal component in the form of pellets appears to be the easier falling into the melting furnace, without unnecessary losses, in contrast to the lighter, untreated copper wires with a high specific surface.

**Keywords:** Electrical waste, sorting, copper, pelletization

## 1. INTRODUCTION

The protection and restoration of the environment, which continues to deteriorate as a result of the behaviour of the human population, is a global concern. One of the main factors which have a negative effect on the environment is the treatment of waste of various origins. Decommissioned electrical equipment and electrical appliances represent a huge amount of electrical waste which needs to be recycled. Electrical equipment and electrical appliances are made of many kinds of materials such as plastics, ferrous as well as non-ferrous metals, paper, glass, rubber, wood, etc. It is very important to seek and develop new ways oftreating these waste types and subsequently to search for new possibilities of their use and application[1, 2, 3]. A frequent case of the aforesaid waste is electrical waste grit, composed of plastic granulate and fine copper wires. This compound is formed by the crushing of electric current cable conductors. The electrical waste grit compound contains two different kinds of material, which are plastics and copper. Plastics and copper have very dissimilar physical properties which are advantageously used to sort the individual components [4]. Literature describes several technological procedures for separating a compound consisting of fine copper wires and plastic particles. However, each method has its advantages and disadvantages, and it is usually selected based on the identified mechanical-physical properties of the given compound. One of them is for instance a gravity separator which utilizes different densities of the individual compound components on a vibrating plate, resulting in the gradual separation of fine copper wires from plastics. This sorting technology is relatively demanding in terms of manufacture and adjustment of the gravity separator [5].Another option of sorting electrical waste grit is pneumatic separation. Pneumatic separators are composed of an air source with the required flow rate and pipingended by a cyclone which separates solid particles from the air. This sorting method utilizes different densities of the individual components, too. The electrical waste grit compound is fed into the piping through which the air volume flows. Lower density plastic particles are wafted by air into the cyclone area, where their consequent separation takes place. Heavier fine copper wires cannot be borne by the air volume, and therefore remain lying on a fluidized bed. Thus, the study aims at discovering a suitable separation technique for sorting electrical waste grit with characteristic mechanical-physical properties, and subsequently at finding a possibility of processing the metal component with a view to its easy and trouble-free recycling.

## 2. EXPERIMENTS AND METHODS

### 2.1. Material

The electrical waste grit is composed of two material components, which are plastic granulate and fine copper wires. This compound is formed by the crushing of electric current cable conductors which are not intended for their primary use anymore. The conducting element for electric current consists of copper bundles, comprising several dozens of fine copper wires of a cross-sectional diameter of less than 500 µm. The individual copper bundles are covered with a thin plastic layer which serves as an insulator protecting the surroundings from electric current. **Figure 1** shows a sample of cable conductors together with a detailed view of the electrical waste grit where plastic granulate particles of various colours, sizes and irregular shapes are visible, whereas pure fine copper wires obtained by sieve sorting are also shown here. The fine copper wires have a uniform cross-sectional dimension, various lengths and are irregularly bent and twisted.

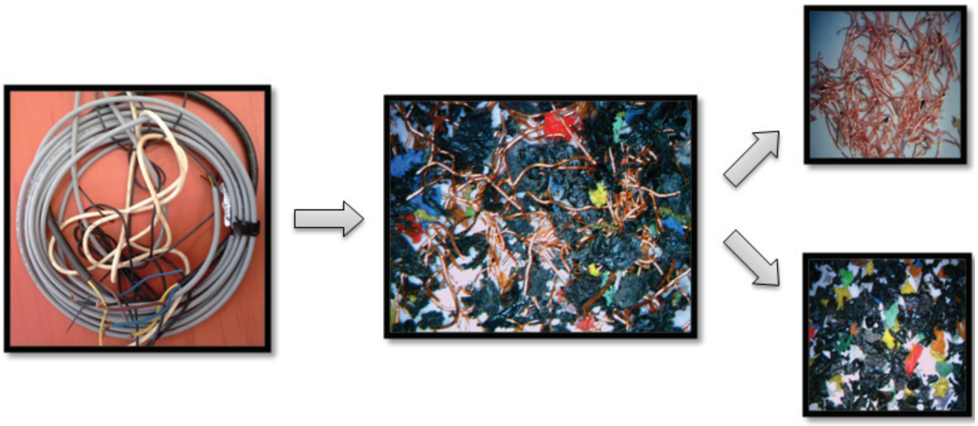


**Figure 1** Schematic representation of electrical waste grit formation and its separated components

### 2.2. Mechanical-physical properties of electrical waste grit

Measurement of the angle of internal friction was performed on the Schulze ring shear tester. The principle of measurement of the angle of internal friction consists in measuring the time dependence of the shear force which is required for the transformation of the bulk solid in as hear chamber through the shear zone under the influence of normal load, for a specific density of the bulk material. The density for the given measurement is achieved through consolidation (compaction) at a defined strength load. Shear force is applied by the rotating chamber of the apparatus and the torque is transmitted by two rods which are fixed onto the shear lid during the rotational measurement test.

For the sample, bulk density was measured using the classical method. The electrical waste grit was loosely filled into a measuring cylinder. Then the volume of the sample was read and its weight was determined. The measurement was repeated 10x.

### 2.3. Sorting process

To sort the electrical waste grit, the sieve sorting method was chosen. For sorting, a FRITSCH ANALYSETTE 3S vibrating sieve separator was deployed. The vibrating sieve separator was comprised of a series of sieves of different mesh size as follows: sieve0 = bowl, sieve1 = 500 µm, sieve2 =710 µm, sieve3= 900 µm, sieve4= 1000 µm, sieve5= 1400 µm, sieve6= 2000 µm, sieve7= 2500 µm, sieve8= 3350 µm, sieve9= 5000 µm.

### 2.4. Pelletization

For the preparation of copper pellets, a JGE 120 Green Energy pelleting press of the firm Pest Control Corporation Vlčnov was deployed. It is a laboratory pelleting press with a flat double-sided matrix of an output of up to 100 kg·h$^{-1}$. To achieve a sufficient quality of pellets, the manufacturer recommends multiple pelletizing which was also used in this case.

### 2.5. Mechanical Properties of Pellets

**Durability**

Durability was measured on a Holmen NHP 100 tester and expressed in terms of the Pellet Durability Index (PDI). In the test, a 100g pellet sample circulates pneumatically in a chamber with perforated walls for 60 seconds. When the test is over, the sample is sieved on a sieve with a 3.15 mm mesh. The PDI is calculated as the percent weight fraction of the pellets remaining on the sieve relative to the initial sample weight (1):

$$PDI = \frac{m_2}{m_1} \times 100\ [\%], \tag{1}$$

where $m_1$ and $m_2$ are the initial and final pellet sample weights, respectively [6]. This procedure is performed in five replicate tests.

**Hardness**

The hardness of the pellets was expressed in terms of the weight load, in kg, that the pellet withstands without breaking or crushing. A KAHL ak-14 tester was used to determine the hardness. In the test, the pellet is placed between a steady plane and a flat tip which is progressively compressed by a spring simulating the weight load. The flat tip is pressed down until the pellet is broken or crushed. The load is then read on a scale. Ten replicate tests are performed.

**Density**

The density of the pelletized material is a measure of densification. A Mettler Toledo JEW-DNY-43 density tester was used to determine the density of the pellets. The procedure was repeated ten times.

**Water resistance**

Water resistance is expressed by the wettability index (WI). The test consists in submerging the pellet into distilled water for 30 seconds and measuring the difference between the pellet weights before the test, $m_1$, and after the test, $m_2$ (2). The wettability index is the percent weight increment relative to the initial pellet weight, which is the relative absorbed amount of water [7]:

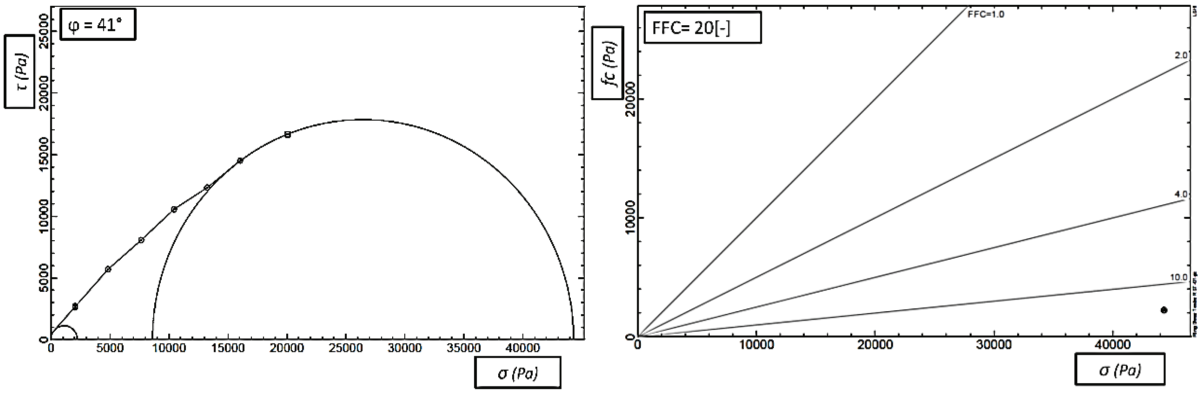
$$\mathrm{WI} = \frac{\mathrm{m_2} - \mathrm{m_1}}{\mathrm{m_1}} \times 100\ [\%] \tag{2}$$

The test is repeated ten times and the mean value is used to calculate the wettability index.

## 3. RESULTS AND DISCUSSION

### 3.1. Characterisation of material

The original sample of the electrical waste grit was characterized by an angle of internal friction. This parameter determining the degree of internal loss work during the material flow is affected by the sample composition in terms of the representation of the individual fractions, the shape of particles and their bonds. The value of the angle of internal friction of the electrical waste grit is shown in **Figure 2a)**, where the result is expressed by Mohr's circle. The numeric value of the angle of internal friction of the electrical waste grit is $\varphi = 41°$. This value indicates the overcoming of a relatively higher level of energy during the movement of the material. Flowability was evaluated by the FFC (flow function) whose value is 19.81(-). Therefore, the material was classified as falling into the free flowing material group, which follows from **Figure 2b)**.




a) b)

**Figure 2** Results a) angle of internal friction φ , b) flowability FFC

Bulk density was determined as an indicator of the degree of densification of the material under study. It is an important parameter especially for the pelletization process. A value of 1.606 g·cm$^{-3}$ was identified, which corresponds to the arithmetic average of the ten measurements.

Fine copper wires (**Figure 3**) taken from the compound sample have a uniform cross-sectional dimension, various lengths and are irregularly bent and twisted.

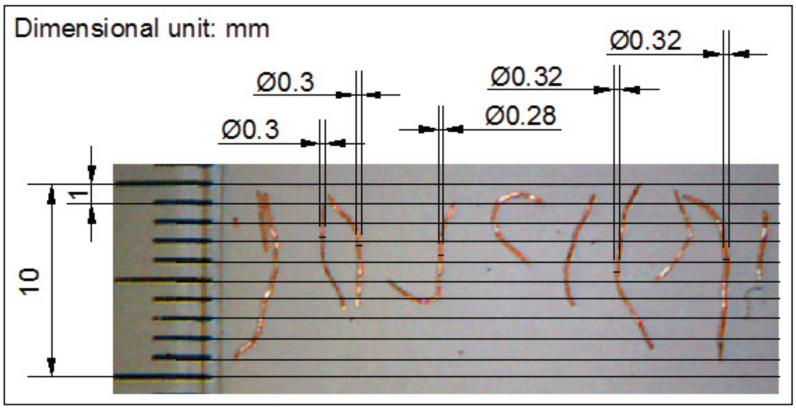



**Figure 3** Dimensional detail of fine copper wires on a scale of 2.5:1

### 3.2. Sorting processes

For the sorting process, the pneumatic method was first chosen, using an air flow of 400 l·min$^{-1}$in a pipe with a 50 mm diameter. A compound of fine copper wires and a relatively high amount of larger particles of plastic granulate was obtained. With the increased air flow, the fine copper wires were also wafted together with the plastic granulate, which was undesirable for our purpose. Therefore, the effectiveness of this sorting method for the given electrical waste grit compound was characterized as unsatisfactory.

Another examined method of separating fine Cu-wires from plastic granulate was the sieve sorting method, chosen with regard to the basic properties of the compound described in subchapter 3.1. The smallest mesh size of the sieve series was set at 500 µm based on the morphology of the individual fine wires. In the image detail of the fine copper wires (**Figure 3**), it is visible that the maximum particle diameter is 0.32 mm, which is smaller than the dimension of the lower sieve1 with a mesh size of 0.500 mm. The fine copper wires have different lengths and are variously curved. Due to vibrations, the individual fine copper wires move chaotically over the sieve bed, whereas they are occasionally found in a vertical position. The placement of a fine copper wire in a vertical position allows free fall through sieve1 to sieve0 (bowl) where the desired pure fine copper wires (**Figure 4**) are collected. The electrical waste grit of a weight of 100 g was placed into the vibrating sieve separator. One sorting cycle was set for a period of 5 minutes. From one sorting cycle, we obtained 53.7 g of pure fine copper wires. The sorting cycles were repeated several times. **Figure 4** shows the result of the electrical waste grit sorting. On the individual sieves sieve1 - sieve9, plastic granulate particles of different sizes can be seen. In the bowl, the plastic granulate was not visually noticeable. Theresults of the sorting process are also summarized in a neatly arranged chart, forming a part of **Figure 4**.

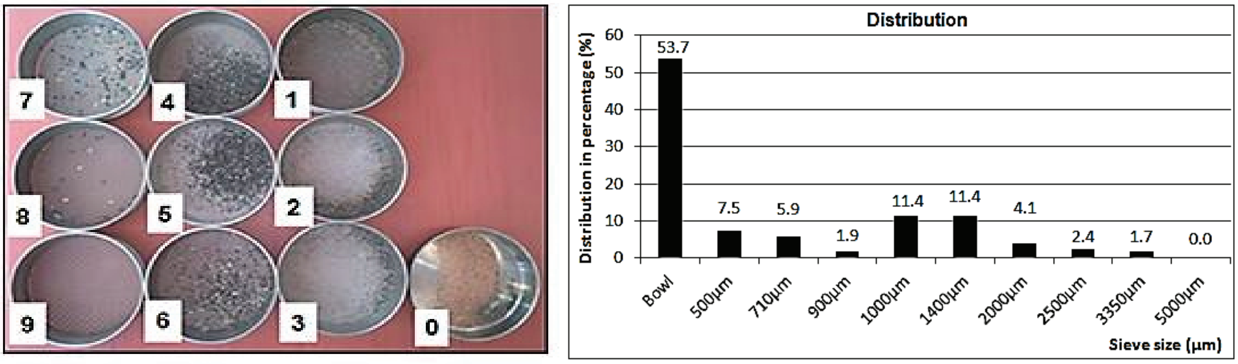



**Figure 4** Representation of the sieve sorting result

The largest percentage share is, as already mentioned, in sieve0 = bowl, where the desired pure fine copper wires are found, representing 53.7% of the total amount. The other sieves captured particles of the plastic granulate and fine copper wires which did not fall through sieve1.

### 3.3. Processing the metal part of the waste - copper pelletization

Metal fraction obtained by the sorting of the electrical waste grit was processed into pellets with a view to facilitated handling in further possible processing (**Figure 5**).


**Figure 5** Appearance of fine copper wires for the production of pellets (left) and produced pellets (right). A-pellets with added water, B - pellets without added water

The copper component of the electrical waste grit was first pelleted without the addition of any wetting agent. Pellets with a diameter of 6 mm did not exhibit a good quality, which was also confirmed by the qualitative tests of mechanical properties of the pellets. In the next step, the mixture was wetted by water before the actual pelletization process to a value of 8.5%. Pellets with the addition of water already exhibited a higher strength, density and in connection therewith, also a longer lifespan. A decrease in values of abrasion of the pellets (from 23% to 10%) and of mutual friction were reduced.

**Table 1** Mechanical properties of pellets

| **Sample** | **PDI** (%) | **Hardness** (kg) | **WI** ( %) | **Density** ($g \cdot cm^{-3}$) |
|---|---|---|---|---|
| **Pellets without water** | 76.56 | 5 | 0.49 | 3.670 |
| **Pellets with water** | 90.24 | 16 | 0.37 | 3.947 |

The values of wettability index are important especially for the transport of pellets and their storage. Due to moisture absorption, their deformation, embrittlement and decomposition may occur. In metal pellets, this parameter is negligible, which applies to both cases. A copper pellet will certainly be more utilizable for re-use than fine copper wires as such. For instance, when charged into a melting furnace, pellets fall through and melt more easily. As compared with pellets, fine metal wires are lighter, while having a larger specific surface area. Therefore, before they can melt, their burning takes place. For material recycling, this presents further losses.

## 4. CONCLUSION

The article describes a method of electrical waste grit processing with a view to obtaining pure fine copper wires for the manufacture of metal pellets. Electrical waste grit was subjected to the measurement of fundamental mechanical-physical properties. Its morphology (shape and size distribution) was determined, showing that the electrical waste grit compound consists of plastic granulate particles of different colours, sizes and irregular shapes, whereas pure fine copper wires obtained by sieve sorting were also visible there. The fine copper wires have a uniform cross-sectional dimension, various lengths and are irregularly bent and twisted. Furthermore, the angle of internal friction $\varphi$ = 41° and bulk density $\rho_s$ = 1.606 g·cm$^{-3}$ was measured. Pure fine copper wires were obtained by sieve sorting of the electrical waste grit. Sieve sorting proved to be a more efficient method of sorting. The almost uniform diameter of the individual fine wires, having a diameter of up to 320 µm, was utilized, and under the influence of vibration, this dimension fell easily through a square sieve with dimensions of 500 x 500 µm. By means of sorting, we obtained 53.7 g of pure fine copper wires from 100 g of the electrical waste grit compound. The separated copper component of the electrical waste grit was densified into the form of pellets. It was shown that it is possible to produce copper pellets without the use of additives such as starch or lignosulphonate. The pellets exhibited good mechanical strength quantified by the PDI (Pellet Durability Index). The hardness values of the pellets were not very high, but sufficient for re-use of the separated component and its handling.

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## REFERENCES

[1] WANG, R., XU, Z. Recycling of non-metallic fractions from waste electrical and electronic equipment (WEEE): A review. Waste Management, 2014, vol. 34, pp. 1455-1469.

[2] CHANCERED, P., ROTTER, S. Recycling-oriented characterization of small waste electrical and electronic equipment. Waste Management, 2009, vol. 29, pp. 2336-2352.

[3] CUI, J.,FORSSBERG, E. Mechanical recycling of waste electric and electronic equipment: a review. Hazardous materials, 2003, vol. B99, pp. 243-263.

[4] BEIGBEDER, J., PERRIN, D., MASCARO, J. F., LOPEZ-CUESTA, J. M. Study of the physico-chemical properties of recycled polymers from waste electrical and electronic equipment (WEEE) sorted by high resolution near infrared devices. Resources, Conservation and Recycling, 2013, vol. 78, pp. 105-114.

[5] KOYANAKA, S., ENDOH, S., OHYA, H., IWATA, H. Particle shape of copper milled by swing-hammer-type impact mill. Powder Technology, 1997, vol. 90, pp.135-140.

[6] KALIYAN, N., MOREY, R.V. Natural binders and solid bridge type binding mechanisms in briquettes and pellets made from corn stover and switch grass. Bioresource Technology, 2010, vol. 101, no. 3, pp. 1082-1090.

[7] LINDLEY, J.A., VOSSOUGHI, M. Physical properties of biomass briquets. American Society of Agricultural Engineers, 2008, vol. 32, pp. 2-5.