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Problems and methodology of metal scrap management

Key words

Metal scraps — types and sources, methods of scrap collecting, technologies of scrap beneficiation

Abstract

Metal scrap may represent an enormous source of raw materials for manufacturing metals and their alloys. Proper preparation of the scrap is of essential importance for quality and economics of production processes. Therefore, growing demand for metal scrap should be followed by development of technologies directed at making the scrap usable.

The paper deals with the problems of metal scrap management in Poland. The author classifies sources and types of scrap metals and discusses the methods of scrap collecting. She also presents technologies of making metal scrap usable: they include all processes that prepare scrap from the point of view of its chemical and physical properties to use it as a charge for remelting in metallurgical plants. Various techniques of metal scrap beneficiation are shown as well as examples of flowsheets used in separation of scrap metals. Extending the hitherto existing methods of scrap collecting and recycling into "deep" scrap beneficiation may result not only in obtaining better selected secondary raw materials for smelters, but also in better protecting of the environment.

Introduction

In the last ten years Poland has recorded strong economic growth, followed by improving life standard of the Poles. Increasing consumption, particularly visible in the branch of dispensable products, results in growing volume of generated wastes. Also modernization of

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industry generates wastes, but if combined with introduction of modern technologies and complied with environmental standards, such modernization will decrease the overall volume of wastes and even may make some of them usable as secondary raw materials. For this reason, waste management not only has become a major problem in environmental protection, but also contributed to the development of a special branch of industry dealing with waste recovery. As a result, waste management is more often controlled not only by legal regulations but also by the market laws of supply and demand: secondary raw materials as valuable substances represent many a time a major subject of economic activities providing income.

Scrap metal collecting is currently a hot issue in Poland. The scrap of both, non-ferrous and ferrous metals, is a valuable source of raw materials for metal manufacturing, the utilization of which does not require cost-consuming technologies. For instance, the cost of producing non-ferrous metals from secondary raw materials (i.e. scrap) reaches 1/3 of costs incurred when the metal is produced from primary ores. These low costs in the case of scrap utilization result first of all from low consumption of energy carriers. For example, consumption of electric energy when scrap is utilized equals about 5% for aluminium, about 15% for copper and about 40% for zinc and lead in comparison with the respective, average amounts of energy consumed when the ores of these metals are used. Secondary raw materials, including scrap metals, are utilized not only for economic reasons, but also considering demands of environment protection. From the point of view of preservation of natural reserves it is worthy noticing that 1 Mg of copper scrap replaces 70 Mg of copper ore containing about 1.5% Cu, while 1 Mg of zinc scrap about 1.85 Mg of the 54% Zn concentrate. Recycling of secondary raw materials also decreases emission of deleterious gases into the atmosphere, lowers water consumption and the volume of effluents, and reduces amount of wastes disposed of on dumps (Żygadło 2001; NIK 1998).

In the last quarter of the 20^{th} century the volume of scrap collected oscillated in Poland in rather wide limits, but in the last years the demand for scrap has considerably prevailed over its salvage. Such a situation may largely result from quite a huge export of scrap.

1. Types of scrap and sources of its origin

Metal scrap is defined as discards originating in manufacturing of various metal products and also as no longer usable metal products, both suitable for remelting in metallurgical furnaces. They become secondary raw materials when their purchase can be effected, and this depends upon the type of scrap, its origin, form and chemical composition.

Sources of metal scrap

The scrap that originates as a result of manufacturing of metals as well as during further mechanical or plastic working of the metals and production of machinery and equipment represents wastes that are classified as production-generated scrap. Into this category belong both the scrap of ferrous metals and their alloys as well as the scrap of non-ferrous metals and respective alloys. Such metal scraps can usually be selectively separated and returned directly into remelting in metallurgical furnaces.

Looking at the origin of scrap, there is another type of waste metals that can be called post-amortization scrap and understood as all possible types of no longer serviceable metal products and semi-products. They include worn out or damaged machines or their metal parts, spare parts from dismantling or repairs, and such final products and semi-products that were manufactured some time earlier but currently cannot be put into use.

Into this group basically also belong wastes generated in our households, such as: non-serviceable appliances (refrigerators, washing machines), old pots and pans, stoves, stove grates and similar discards, empty tins after preserved food and drinks, tubes after pastes and ointments, crown caps and other small items of everyday use, as well as metal scrap left behind after demolition of various buildings. Considering a substantial material variability of these wastes and the fact that they contain many non-ferrous metals, all of them can be described as the scrap of consumption goods.

A particular attention should be paid to worn-out and abandoned vehicles. Their amount was continuously growing in the last decade, and since the accession of Poland into the European Union the growth has been avalanche-like.

Post-amortization scrap and in particular scrap of non-serviceable consumer goods is troublesome considering its collecting and then utilization. In Poland these problems are socially important as a substantial number of people make their living out of scrap collecting.

From the point of view of metal scrap utilization, i.e. its use in metallurgical processes, the following scrap traits are the most important: form (its sizes), purity and usability for remelting, a degree of refining or chemical composition. Accordingly, all types of metal scrap can be classified as follows:

- wastes and non-chargeable scrap that prior to any use must be manually or mechanically treated because of their chemical composition, form, sizes, weight or contaminants. This processing aims at obtaining suitable size and mass, removing explodable and hazardous materials, metallic and non-metallic contaminants, and in the case of alloy scrap at sorting and even preliminary metallurgical treating,
- wastes and chargeable scrap whose chemical composition, degree of purity, forms, sizes and mass may be economically and safely, directly used in manufacturing steel, cast and pig iron, ferro-alloys as well as non-ferrous metals and their alloys, eventually in chemical processing (Bimczok i in. 1973).

Depending on the chemical composition and the direction of further use, secondary metal raw materials can be divided into materials for production of steel, cast iron as well as non-ferrous metals and their alloys.

2. Recovering of metal scrap

Steelworks obtain metal scrap either directly from producers of metal equipment or from scrap-purchasing centres. The latter may buy metals from:

- — producers of metal equipment or plants applying metals in production,
- — companies involved in any kind of economic activity,
- — communes (the smallest administrative units in Poland) that selectively collect communal waste and separate from them metal scrap,
- — individual scrap collectors.

Irrespective of the sources of metal scrap obtained, each metal scrap must be classified according to the requirements contained in relevant norms, such as PN-85/H-15000 Steel scrap, PN-62/H-15100 Cast iron scrap, or PN-76/H-15715 Secondary raw materials of non-ferrous metals.

Collecting, trade and processing of secondary materials in the form of metal scrap is being carried out by many economic subjects that may be divided into three groups:

- — **group A** — minor metal scrap collectors that recover it from landfills and deliver it to small scrap purchasing centres. Into this group also belong the economic subjects that get rid of subordinate amounts of scrap,
- — **group B** — middle-sized and large scrap collecting firms, possessing specialized equipment for scrap treating and employing a larger staff. These firms buy relatively large volumes of scrap and are involved in its basing preparation. Next, they either sell secondary metal to large scrap processing centres and metallurgical plants in Poland or export scrap,
- — **group C** — metallurgical plants that process secondary metals into new metal goods or remelt scrap into alloys. Their products may be further utilized in Poland or sold outside the country. This very group of plants obtains the scrap collected by economic subjects belonging to the groups A and B (NIK 1998).

Scrap collecting should be selective from the moment of scrap formation to its final utilization. The selective collecting makes possible providing scrap for direct remelting in the form of furnace charge in required proportions, without costly and time-consuming separation of mixed scraps at a later stage. Also the Law of Waste (Ustawa o odpadach... 2001) legally regulates selective collecting and storing of scrap. The said regulations and legal requirements refer to all natural persons and legal subjects, but in practice they can only be enforced by law in the case of subjects involved in economic activity.

A considerable interest in metal scrap collecting shown by natural persons in Poland is a result of high prices of the metals recovered, a substantial unemployment and a growing number of impoverished people. These reasons have caused a stealing spree of easily available, unprotected metal elements such as covers of sewage wells, railway rails, construction fragments of railway and tramway traction, telecommunication devices, construction elements of buildings and even small bridges (!). Such activities lead to human health risk and represent life hazard to scrap collectors themselves and other people, and on the other hand are a source of financial losses to specific plants and the whole society. To control illegal scrap salvage, the Law of Waste has been amended with two new chapters introduced. The first stipulates that every private person selling metal scrap should supply documentary evidence of its legal possessing. The other requires the staff of each scrap-purchasing centre to keep record of not only the scrap bought, but also particulars of its owner (Gov. Gazette No. 116, item 1208, 2004).

3. Technologies of making metal scrap usable

Making scrap usable involves preparing scrap metals and their alloys in such a way that from the point of view of their chemical and physical properties they can be directly used as a furnace charge. The processes include sorting, fragmenting, balling or compacting, and — the most important — removing all metallic and non-metallic contaminants (beneficiation of the selected metal). The metal contaminants removed in the process may represent themselves a class of new, selected raw materials.

Scrap sorting may be manual or mechanical and depends mainly upon the form of scrap (size of elements). The process is based on identification of types of metals and alloys that must be classified and separated according to the norms referred to in the former chapter. Manual sorting includes the following actions:

- identification of the metal with naked eye,
- manual removing of metallic and non-metallic contaminants with simple tools (hammer, chisel, shears, torch),
- magnetic separation of iron scrap,
- shaping of the scrap into the form (size) proper for furnace charging,
- balling or compacting of smaller scrap fragments,

while mechanical sorting involves:

- screening using vibrating or rotating screens,
- electromagnetic separation,
- cutting (mechanical shears and saws, laser knives, plasma torches),
- balling or compacting.

Manual and mechanical sorting may alternate, depending mainly upon the type of scrap and the aim of sorting, i.e. whether we want separate all usable materials or only selected contaminants.

Post-amortization metal wastes are so variegated that represent mostly non-chargeable scrap. Separation of individual kinds of these metals is combined with improving the quality of scrap as far as the kind of a major metal is concerned and includes scrap processing technologies (Kuczyńska 1998), i.e. beneficiation of the metals, applying the following methods:

- magnetic,
- gravity separation,

— electrodynamic,
— magnetogravimetric,
— optical,
— others.

Each of these methods requires prior fragmentation of scrap, executed to liberate individual types of metals and non-metallic contaminants. Fragmenting equipment includes crushers/breakers (e.g. hammer and impact shredders), compactors-shears and, in the case of softer scrap, knife crushers. The size of the reduced scrap fragments should not exceed single or fifteen or so centimetres depending upon a further method of beneficiation.

Magnetic beneficiation

Magnetic beneficiation applied directly after scrap comminution is aimed at separation of magnetic fragments (iron, steel) from the remaining scrap fragments (non-ferrous metals, non-magnetic steel, non-metals). It is usually carried out with permanent magnets.

Gravity separation

Beneficiation of non-magnetic fractions may be carried out (depending on the degree of comminution) in jigs and dense liquids (suspension liquids) or in elutriators. Differences in specific gravity of individual metals and alloys are presented in table 1 and figure 1.

A **jig** separates scrap fragments with sizes of up to about 10 mm. The segregating medium is water, pulsating in the jig in the vertical direction and forming the bed in which the lighter material concentrates in its upper part and the heavier close to the bottom. Horizontal water

TABLE 1

Specific gravity of selected metals and their alloys

TABELA 1

Ciężary właściwe wybranych metali i ich stopów

Metal or alloy	Specific gravity	
	[G/cm^3]	[N/m^3]
Magnesium (Mg)	1.74	$17.07 \cdot 10^3$
Aluminium (Al)	2.70	$26.49 \cdot 10^3$
Zinc (Zn)	7.13	$69.94 \cdot 10^3$
Bronze	av. 8.20	$80.44 \cdot 10^3$
Brass	av. 8.60	$84.37 \cdot 10^3$
Cadmium (Cd)	8.60	$84.37 \cdot 10^3$
Copper (Cu)	8.96	$87.90 \cdot 10^3$
Lead (Pb)	11.35	$111.34 \cdot 10^3$
Iron (Fe)	7.87	$77.20 \cdot 10^3$

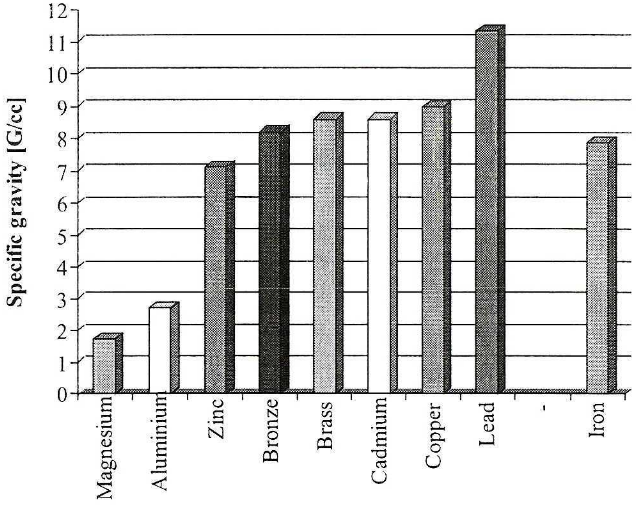

Fig. 1. Specific gravity of selected metals and their alloys

Rys. 1. Ciężary właściwe wybranych metali i ich stopów

movement is enforced by inclination of the jig at about 3—5° to the level. A barrier at the end of the jig separates the bed formed into two fractions, heavy and light. The light fraction represents a metallurgical raw material after further removal of non-metals in electro= magnetic separators (Kuczyńska 1998).

Beneficiation in dense suspensions is carried out in drum separators. The process is usually carried out in two stages and produces aluminium and its alloys with specific gravity in the range 2.6—2.9 G/cm^3. Initially, a suspension with density about 2 g/cm^3 is used, in which light metals (e.g. magnesium with specific gravity 1.74 G/cm^3) and possible non-metal contaminants (paper, wood, plastics) form a floating fraction. Cleaning is followed with a suspension of density about 3 g/cm^3, in which heavy metals (e.g. zinc — 7.13 G/cm^3, iron — 7.87 G/cm^3, copper 8.96 G/cm^3) sink and are concentrated in the underflow, while a floating fraction represents aluminium, either pure or contaminated with non-metals (silica, glass). Final cleaning of the aluminium concentrates is effected using electromagnetic methods (Kuczyńska 1998).

Another possibility of removing a non-magnetic fraction is offered by a **hydraulic separator, so-called elutriator**, in which gravity separation takes place in a water stream, flowing upward in a column with a suitable diameter. The flow velocity is chosen in a way providing effects similar to those obtained in heavy liquids. The volume of water and the way of collecting the overflow (the light and intermediate products) control the morphological composition of the products and their yield. The underflow (heavy, non-magnetic fraction) is a mixture of metals that must by further cleaned, e.g. in electromagnetic or electric separators (Mączka 2004).

Electromagnetic beneficiation

Non-magnetic metal scrap contaminated with non-metals, for instance with aluminium, can be cleaned in electromagnetic separators, using induced current (Kuczyńska, Niedziałek 1995). Electromagnetic field in the metals induces secondary electromagnetic field that repulses them. The stream of metals is finally separated from non-metals in a catch-box by a properly arranged separating plate. The metal fraction cleaned is a metallurgical raw material for direct remelting or casting specific alloys.

Other separation methods

Apart of typical methods of ore-processing described above and applicable — although not too often — also in Poland, some unique technologies are worthy mentioning. The magneto-gravity method MGM (Brożek, Nowakowski 1985a, 1985b) can be used for non-ferrous metals, and also non-metals, for instance glass. The process involves separation of fragmented scrap in the liquid medium subjected to non-uniform magnetic field. The liquids used are ferromagnetic colloids (Brożek, Nowakowski 1985a), composed of:

— dispersed phase, i.e. metal or metal alloy particles with strong magnetic properties;
— dispersing medium, i.e. unsaturated fatty acids, special organic polymers, etc.;
— carrier liquid — most often various hydrocarbon and fluorocarbon compounds, esters, waxes, organic polymers, etc.

The material prepared for magneto-gravity treatment (Brożek, Nowakowski 1985b; Khalafalla 1981) must be properly fragmented (6—50 mm) and cleaned of magnetic particles.

The feed, containing mainly zinc, aluminium, copper and, e.g., glass and various plastics enters a separator with a paraffin-based ferrocolloid containing Fe_3O_4. Separation may be single- or two-stage, depending on variability of the feed and the required accuracy of separation. In the two-stage process, the light (floating) fraction (aluminium + plastics) and the heavy (sinking) fraction (zinc + copper) are separated first and the process is followed by separation of zinc from copper in the second stage.

Optical beneficiation

Scrap metals differing in colours may be separated optically but it requires:

— surface cleanness of scrap fragments,
— proper size of scrap fragments.

Surface cleanness may be obtained by washing with water or etching with, e.g., sodium hydro-oxide, as both process reveal a distinct, characteristic colour of the metal treated. Optic sensors may distinguish even several colours and this means that a physical mixture of several scrap fragments can be separated.

The size of scrap fragments is a requisite of separation efficiency, but the fragments separated should be not smaller than some millimetres. Also advisable is beneficiation of narrow grain-size classes, because it limits wrong readings of the sensors.

A novel method involves sorting with a laser-equipped system. The stream of scrap fragments, which have been etched to remove paint or oxide covers, passes under a sensor. When a scrap fragment is detected, the sensor switches on a laser beam that excites a secondary spectrum. The spectrum is analysed by a proper spectrometer and compared with a set of standards. The method allows recognizing some 6,000 various alloys (Mączka 2004).

Air beneficiation

The methods is suitable for separation in the air column (so-called air ellutriator) of metals from non-metals in the case of scrap fragments with sizes up to 15 mm into the light (plastics, paper, textiles) and the heavy (metals) fractions. This process can be effected in drum or chamber separators.

The scrap processing technologies presented above may be combined in various configurations. The flowsheet proposed depends on the purity of the final charge scrap, required by an end-user (metallurgical plant). Three various flowsheets are presented in figures 2—4. Each of the flowsheets shown can be customized.

Figure 2 presents the scrap processing circuit involving mainly manual segregation. The metals segregated are identified due to their colours or weight of elements. Figure 3 shows an advanced circuit treating mixed scrap, in which various types of metals are present as well as nn-metal contaminants. The methods proposed include magnetic and air separation, combined with the use of heavy liquids and electromagnets. The feed into this circuit must be

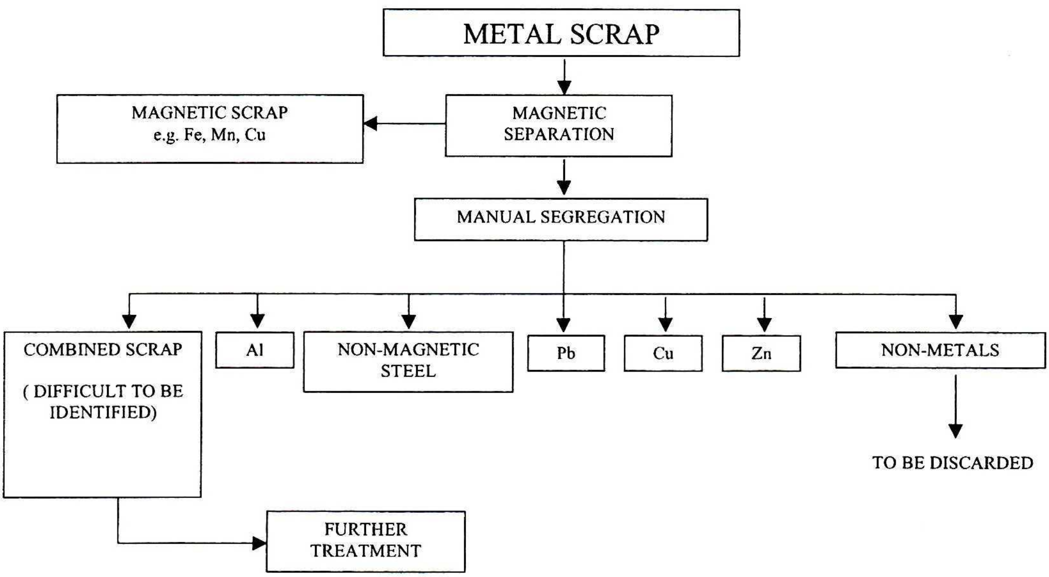

Fig. 2. Flowsheet of manual scrap segregation

Rys. 2. Proces ręcznej segregacji złomów

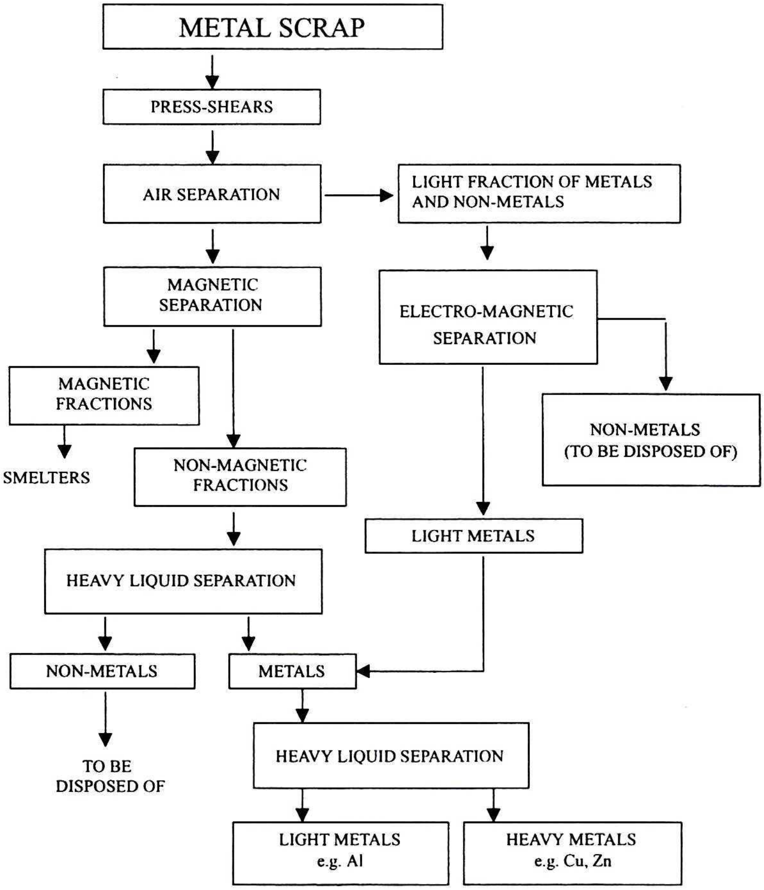

Fig. 3. Scrap treatment — flowsheet No. 1

Rys. 3. Schemat uprzydatniania złomów. Przykład nr 1

properly fragmented. The circuit characterized in Figure 4 represents scrap processing that starts with its comminution and sizing. Grain-size fractions produced are next subject to air separation, beneficiation in jigs and final electromagnetic separation.

4. Final remarks

Scrap metals may represent an enormous source of raw materials for manufacturing metals and their alloys. Proper preparation of these materials essentially affects quality and economics of metal production processes. Therefore, growing demand for scrap metals should be followed by development of technologies directed at making the scrap usable.

The author has presented not only various technologies of making scrap usable, but also examples of separation flowsheets for metal scrap. Their implementation should not present

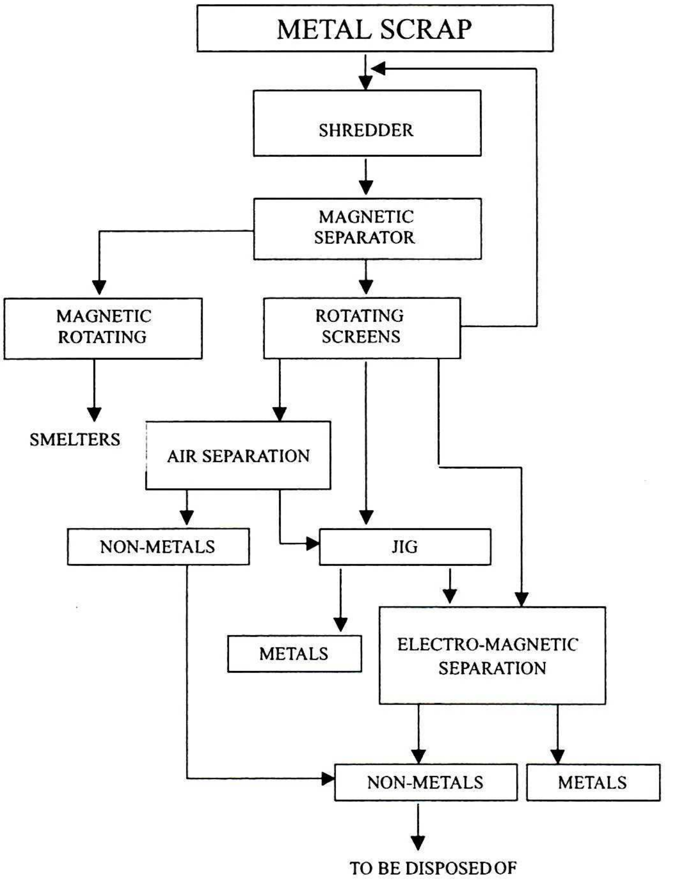

Fig. 4. Scrap treatment — flowsheet No. 2

Rys. 4. Schemat uprzydatniania złomów. Przykład nr 2

any problem from the technical point of view, as most of the equipment needed is available if not in Poland then in other European countries. Traditional collecting of metal scrap should be extended by "deep" treatment of the scrap and result not only in better selected metals for smelters, but also in improving environmental standards (reduction of the area occupied by landfills, preservation of natural resources, protection of the air).

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PROBLEMATYKA I METODYKA GOSPODARKI ZŁOMAMI

Słowa kluczowe

Złomy metali — ich rodzaje i źródła, metody zbiórki złomów, technologie wzbogacania złomów

Streszczenie

Złomy metali mogą stanowić znaczące źródło surowców do produkcji metali i ich stopów. Odpowiednie przygotowanie tych surowców ma zasadniczy wpływ na jakość produkcji i jej ekonomikę. Zatem w ślad za większym popytem na złom powinien nastąpić rozwój stosowania technologii uprzydatniania złomu.

W artykule przedstawiono problemy związane z gospodarką złomem metali w Polsce. Uporządkowano źródła i rodzaje złomów oraz wskazano sposoby zbierania złomów metali. Przedstawiono także technologie uprzydatniania złomów metali, obejmujące wszystkie czynności zmierzające do przygotowania złomów pod względem cech chemicznych i fizycznych, z punktu widzenia ich wykorzystania, jako złomów wsadowych, nadających się do przetopu w hutach. Dokonano prezentacji różnych technologii ich wzbogacania oraz zaproponowano przykładowe rozwiązania schematów rozdziału złomów. Rozszerzenie dotychczasowej zbiórki i recyklingu złomów metali o „głębokie" ich wzbogacanie może przyczynić się nie tylko do pozyskiwania lepiej wyselekcjonowanych surowców wtórnych dla hut, ale również do ochrony środowiska.