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DEVELOPMENT OF A FLOWCHART TO OBTAIN AND RESEARCH THE STRUCTURE AND PROPERTIES OF COMPOSITE WIRE SORTABLE SCRAP METAL WASTE FROM COPPER AND ITS ALLOYS

Master's Program Metal and Alloys Forming under Pressure

The abstract of the Master's Thesis

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INTRODUCTION

Topicality of the work. Currently, in the conditions of market economy for many branches of engineering and metallurgy there remains a major problem, which at the same time is a challenge, the creation of competitive steel products. In this case, a prominent role in ensuring a high level of physical and mechanical properties and an acceptable cost of the metal technology plays the production technology. Due to modern development trends that are associated with saving earth's resources, there is a need to use and integrate existing sources of raw materials more complete, and find new, non-traditional ways based on their low-waste production.

Melting redistribution has been the main method used to treat the production of raw material waste (shaving scraps) that is generated during the operation of various kinds of cutting equipment.

Due to the low efficiency of its implementation, particularly in relation to the granular chips fines, there is an urgent need to solve this problem by developing new ways that would completely rule out the waste of metal from the melting redistribution, minimize energy used and the associated redistribution of gas and dust emissions, which is one of the main sources of air pollution.

The subject of the research is sortable scrap metal copper and its alloys which are raw material used for hot rod - wire products for specific purposes manufacturing.

Objectives of the research:

1. To clarify the opportunities of production of metal rods and wires from shaving scrap waste produced from copper and its alloys bypassing the traditional method of re-melting;
2. To explore the question of production based on their composite metallic materials with specific structures and properties.

To achieve the objectives the following tasks should be solved:

- to choose from a wide variety of copper-based materials (which chips will be used for experimental studies) that will be used to produce hot- rods and cold deformation (drawn) round wire;

- having developed a common single universal flowchart for rods and wire production , to select for each of the materials studied the numerical values of the basic components parameters of its operations by instantiating their names and sequence for each of the cases considered in this work;

- to design and manufacture tooling components for the basic operations performance, having prior chosen the equipment on which the operations will be performed;

- according to the flowcharts developed, to conduct in the laboratory a series of experiments designed to produce prototypes of rod - wire products from the experimental compounds of scrap metal that would be sufficient for further metallographic analysis and mechanical testing;

- to analyze the nature of the structure of the semi-finished product at each stage of processing on the basis of metallographic studies, and to establish a correlation in the material structural changes with technological parameters;

- according to the results from the experimented wire rods (using standard techniques of various kinds of tests and wire rods from different scrap metal materials groups) to assess their level of strength and ductility, as well as to provide information of the chemical composition and physical properties;

- to develop general guidelines for the intended practical use of the results obtained in the products manufacturing process.

Scientific novelty of this work:

1. A mechanism of particle interaction in the process of compacting metal scrap, consisting of granular or chip from copper alone or its alloys or the makeup of other metal scrap compositions has been analyzed.

2. Character analysis of structure and the evaluation of the level of strength and ductility obtained from rod - wire products, accompanied by relevant photographs and diagrams has been conducted.

Practical significance of this work:

1. A basic flow diagram of semi-finished products manufacturing, providing increased efficiency of processing scrap metal waste has been developed. A revision is made in relation to the manufacturing of rod- wire products that meet their properties and a certain level of mechanical performance characteristics of the products according to the required standards.

2. Tooling components required for basic operations as well as the material selection for their implementation were designed and manufactured. The prototypes of rod - wire products from the investigated compounds of the scrap metal materials were obtained.

3. Metallographic results obtained from semi-finished products in the application of each of the planned processing steps were submitted.

4. Mechanical tests in tension, as well as the measurement of hardness and micro hardness of the rods and wires from different groups of the scrap metal material were carried out.

Personal contribution of the author:

The author was directly involved in conducting each step in the experimental study: the selection and preparation of the initial scrap metal components , hot briquetting formed from the metal scraps compositions, the author obtained briquettes from hot extrusion and subsequent cold drawing rods; assessed the level of mechanical and physical properties of the samples made.

Place of performance of the thesis: Department «Metal Forming Under Pressure» of the Institute of Nonferrous Metals and Materials of Federal State Autonomous Educational Institution of Higher Professional Education «Siberian Federal University».

Place of internships. INTAMT (Dusseldorf, Germany).

Work approbation: Key provisions of the thesis were presented at the annual International Congress «Non-Ferrous Metals» (Krasnoyarsk, 2013), as well as the annual All-Russian Scientific and Technical Conference of Siberian Federal University with international participation «Youth and Science» (Krasnoyarsk, 2013)

Publications: Results of the thesis are reflected in 5 printed works, two of which were published in journals that are included in the list of publications recommended by the WAC.

Volume and structure of the thesis: The thesis consists of an introduction, three chapters and a conclusion. It contains 94 typewritten pages, 40 drawings, 13 tables and bibliography of 35 positions.

CONTENTS OF WORK

***Introduction*.** The urgency of the topic and the purpose of the work are stated, noting its novelty and practical significance.

The first chapter describes the classification of scrap metal waste depending on the sources of their formation; identifies major shortcomings of the traditional processing method of scrap metal waste and offers ways to address the scrap waste by powder metallurgy; proposes a flowchart which states requirements for the initial raw materials undergoing conversion; addresses the basic features of proposed compositions and production technology of alloyed copper alloys.

The analysis of scientific, technical and patent literature led to the following conclusions:

1. The present technology for processing nonferrous scrap metal and alloys do not always satisfy the requirements of the economy and efficiency of secondary metals and alloys - due to the increased waste of metal , which is 2-3 times higher than the same metals being processed in the form of lump scrap metal ; performance decreases by 10-15% when metallurgical equipment processes batches of scrap metal waste instead of lump scrap; metal loss due to corrosion of the scrap metal shavings exceeds the loss of corrosion of the lump scrap metal.

2. Shortcomings of the conventional technology can be minimized by recycling metal scrap shavings by powder metallurgy techniques using conventional processes and pressure treatment. In this case, the process cycle of " chip-to - compact semi-finished product ", including the steps of briquetting , sintering , additional hot and cold plastic deformation is significantly shorter than the conventional smelting cycle , less energy intensive , is automated easily, and , if necessary , is integrated organically in the modern production process.

3. Copper and its alloys due to many unique physical - chemical, mechanical and technological properties are still widely used in various industries of non-ferrous metals, so the issues of minimize losses and implementation of the most effective ways of involving in production turnover generated return wastes pose to this group of materials undoubted practical interest.

Based on the findings the objectives of the thesis are formulated.

The second chapter presents the main methods used (in some cases the necessary universal standards are mentioned), related to the mechanical testing of bars and wire tensile , hardness measurement, analysis of the chemical composition, electrical properties of the study, needed to assess the level strength and plastic characteristics, and some physical properties.

The third chapter is devoted to solving the problem of manufacturing semi-finished products of shavings meads and its alloys , as shown in Figure using the

adaptation composed flowchart , with respect to brass L63 , a mixture of copper and brass double, as well as mixtures of copper with various types of bronzes . Thus the inclusion in the general diagram of a particular process step is the nature of variability, due to appearance and characteristics of the processed material, the size and configuration of the obtained products, and the level of achievable mechanical properties and other factors.

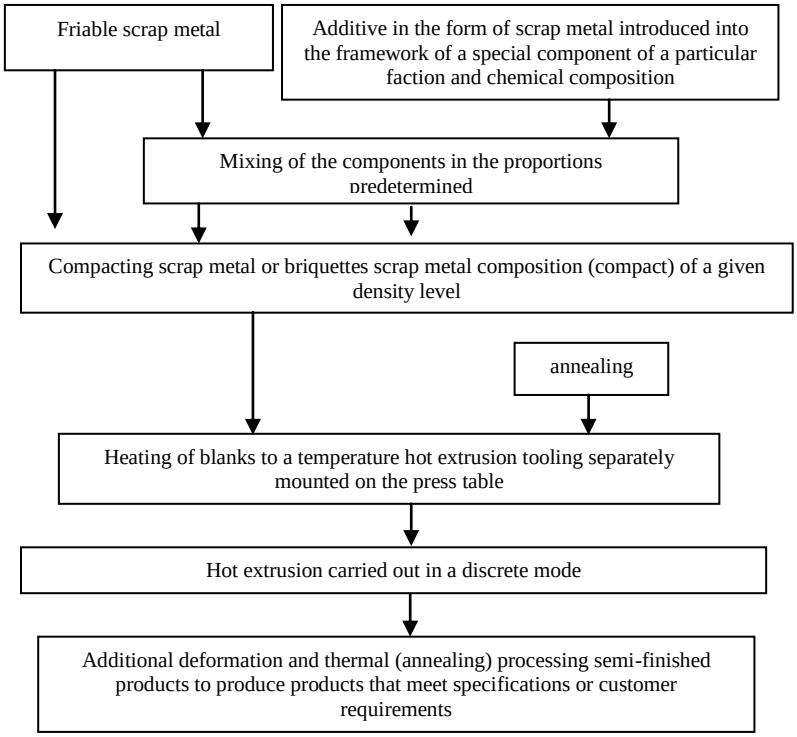

Figure - General process flow diagram for production of scrap metal based on the processing of non-ferrous metals and alloys.

In the first phase several questions had been resolved related to the compaction of the granular features of pure copper scrap metal produced when extruded rods were cut on the band saw. In particular, experiments were conducted to establish the effect of the temperature heating press - forms and the compacting pressure on the density of briquettes and their mechanical characteristics, as these indicators are crucial in the general outline for the next stage of processing that is hot extrusion.

Varying temperature - deformation modes of compaction revealed that for briquettes manufacturing with a relative density of 95 - 97% with a satisfactory combination of strength and plastic properties it is required that the scrap metal heating temperature press – forms should be 450 - 500 °C and the compaction pressure should be not less than 160 - 180 MPs. Whereas pre-annealing scrap metal has a minimum influence on the formation of the briquettes properties, therefore, as a rule, there is no need to produce it.

However, it’s observed that despite the fairly dense packing scrap metal fragments are only mechanically clutched with each other, the physical connection between the particles of the scrap metal is virtually absent. To get and develop the foci setting the compacts obtained must be subjected to further large deformation under the action of compressive stresses. One of the basic operations, realizing the given scheme is extrusion.

For the extrusion process simulation, in the laboratory there was designed and manufactured some special tooling to be mounted on a vertical hydraulic press table 1 MN, with the help of which rods of 8 mm diameter (reduction ratio μ with approximately equal 32) and 6 mm (μ=56) were obtained.

The heating temperature of briquettes before extrusion was equal to 900-950 °C, which corresponds to the «upper» boundary of the temperature range of hot copper processing. The obtained moldings were cut into a few pieces of equal length, some of which were used for the subsequent drawing, others were cut in proportional length and were selected for studying the microstructure platen and the rest of the samples were machined for mechanical tensile tests. As a result, it was found, that the microstructure and properties taken from various locations along the length of the rod samples were not fundamentally changed, and corresponded to the GOST standard 1535-2006 intermediate between soft and semi-solid material of copper rod.

Subsequently, rods obtained by hot extrusion were subjected to single drawn on the chain drawing machine. Experiments showed that when extruded rods of copper scrap metal were pulled through various dies, the breaking drawing compression unit for the transfer should not exceed 30%. Thus it is necessary to make allowance for the fact that drawing takes place in conditions that are far from optimal. When using fiber with optimum geometry, a good quality surface finish deformation zone, applying effective lubrication and optimum speed mode the drawing value, apparently, can be improved and brought to the same values as in the compact drawing copper rods.

The next stage was related to the study of the influence of particle morphology of graded scrap metal waste on the properties of rods and wires, different types of brass scrap metal L63 were used for that purpose. As a result, it was found that the difference in particle morphology has no significant effect on the process of hot pressing and hot extrusion. With further drawing of the hot-rods that are obtained from different types of scrap metal, the difference between the values of tensile strength in the wire $\sigma_в$ is traceable. For example, if the total relative reduction ε_Σ = 34 % the difference between the values in $\sigma_в$ wire made up of large and medium scrap metal is 20-25 % of medium and small scrap metal is 10-15 %. This combination of cold working with large degrees of deformation and intermediate annealing allows to level this difference, bringing the value of the mechanical characteristics of the wire to the scrap metal waste properties of the wire, obtained by traditional technology, using billet.

Further studies were devoted to the analysis of the nature of the material structure formation in the implementation processes of hot extrusion and drawing of semi-finished copper scrap metal mixture with double brass L63. The main objective of this phase of work was to study the potential use of graded loose scrap metal waste of non-ferrous metals and alloys as a raw material for making various kinds of scrap metal compositions in the solid phase; to study the formed microstructure as well as the level of mechanical properties of the material. As a result, it was found that the proposed structure is obtained in the process of flow diagram and wire rods and consists of alternating layers formed from copper and brass scrap metal separately,

between which, as a rule, there is an intermediate region formed by mutual penetration of these components by percolation on the boundaries of the scrap metal diffusion processes. The level of strength and ductility characteristics of wire scrap metal mixture prepared in the proportions of 50 % copper 50% brass, occupies an intermediate position of various relative reductions between the properties of the wire, made only of copper or brass shavings L63 separately.

The final stage of study has been conducted to assess the impact on the character of structure formation and the formation of a certain level of mechanical properties of rods and wires and quantitative composition of the bitmap used for the manufacturing of scrap metal compositions formed by mixing of certain proportions of copper scrap metal waste and of certain types of bronzes. As a result it was found that by adding bronze to any copper scrap metal there was some increase in the strength characteristics of the material. The nature of the phase changes in the mechanical characteristics of the deformation degree of the accumulated total for all the tested materials remained virtually identical and independent of the fractional deformation. The formation of rod structure derived from mixtures of different types of scrap metal in each case carries its own distinctive features. Wherein the structure of the wire made up of any material has a specific stroke structure that results in stretching of the scrap metal particles in the deformation direction. When an increase of bronze content was added to the copper substrate scrap metal, the size of the fibers increased as proportion varies between components – sufficient level of copper ductility and stronger bronze. In some cases, to obtain a wire with a small diameter of about 3 mm from some scrap metal compositions of the «copper + bronze» without intermediate annealing is virtually impossible. This is due to the fact that the deformation plasticity resource for this category is clearly limited.

KEY FINDINGS OF WORK RESULTS

1. Providing a clear organization of work on the collection of scrap metal at source as well as conducting relevant activities for the disposal , storage , and keeping for subsequent processing allow to use the waste as a sortable scrap metal bulk material for products competitive to compact metals and alloys and meeting the requirements of GOST or TU.

2. The flowchart of manufacturing semi-finished products of scrap metal (according to specific conditions) is an alternative to the traditional way of re – melting scrap metal waste. It includes basically compacting scrap metal briquettes, hot and cold metal forming under pressure. Effectiveness of the implementation stages determined temperature-deformation terms.

3. To ensure a high enough level of density of intermediate billet, compacting scrap metal briquettes are generally performed at temperatures above the recrystallization onset temperature of the scrap metal or the component constituting the basis of mechanical scrap metal mixture, and the magnitude of the applied pressure of the hot pressing should be lower than the yield strength of the material at a selected processing temperature.

4. When choosing hot forming operations with pressed scrap metal briquettes preference should be given to those that are characterized by high degrees of

deformation with a high level of shear deformation and a stress state favorable scheme, among which, in the first place, these criteria are responsible for the extrusion process (extrusion) through the metal matrix, the working aperture of which corresponds to a given configuration of the intermediate product.

5. One of the practical implementations of the considered approach is in the development of schemes related to the creation of new specific functional composite or structurally inhomogeneous materials, the production of which is based on the consolidation of the various kinds of digital media with a specific combination of components in the solid phase.

SUMMARY OF THESIS
PUBLISHED IN THE FOLLOWING

Publishing recommended the high attestation commissions

1**. Rogovoy A.** The role of developing shear deformations in the implementation of the method of processing thermo deformation sortable metal shavings from non-ferrous metals and alloys / Zagirov N., Ivanov E., Rogovoy A. / / Journal of Siberian Federal University. Technology and Engineering. 2013 , № 6 (3) . - With . 315-323

2. **Rogovoy A.** Investigation of the effect of particle morphology of graded scrap metal waste of brass L63 properties and wire rods produced by pressure treatment / Zagirov N., Konstantinov I., Ivanov E., Rogovoy A. / / Proceedings of the universities . Non-ferrous metallurgy . 2014 . № 3 (4)

Other Publications

1. **Rogovoy A.** Rating effect of additional twisting rod in the implementation of the extrusion process on the structure and properties of the press – scrap metall products from mixtures of copper with brass double / Horn AA / / Special engineering education - training of modern engineering personnel : abstracts regional scientific - technical conference undergraduates [Electronic resource] / Br. for the release of EA Shipilova . - Electron . dan. - Krasnoyarsk: Sib. Fader . University, 2013 . - p. 104 - 108.

2. **Rogovoy A.** Peculiarities of structure and properties of the preparation of the composite wire of graded metal shavings from copper and its alloys / Zagirov N., Ivanov E., Anikina V., Rogovoy A. / / Non-Ferrous Metals - 2013: Sat Nauchn . articles. - Krasnoyarsk: Verso, 2013 . - P. 595 - 599.

3. **Rogovoy A.** Peculiarities of the structure and properties of the preparation of wire scrap metal mixture of copper and zinc / Zagirov N., Ivanov E., Anikina V., Rogovoy A. / / Process and solid laminates. 2013 , № 1. - With . 13-19 .