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(54) **METHOD FOR THE COMBINED CASTING AND ROLLING OF COPPER ALLOYS FROM COPPER SCRAP**

(57) The invention relates to nonferrous metallurgy, particularly to the methods of processing of the secondary copper-bearing raw material, for further use of metal in the articles of electrical engineering purpose. The method includes the preparation of copper melt at the first stage, copper refining and recovery at the second stage with the carbon-bearing material and the increase in temperature, formation and pulling of the continuous cast section, preparation of the produced articles for further transportation and storage. According to the invention, after melting the copper melt passes into a distribution chamber through graphite with the density of 1,56-2,2 g/cm^3 in the form of perforated element at the temperature of 1140-1175°C, and the cast section is subject to rolling by the way of its passing with the linear speed of 1,5-2,5 m/sec through a induction heater providing the high-temperature heating up to 650-800°C with the subsequent shock cooling of the cast section to 50-55°C. Consequently, the cast section is subject to double metal structure recrystallization, at the first stage - at rolling, and at the second stage - at high-speed and high-temperature heating and shock cooling. For provision of efficiency of oxygen extraction from the copper melt and provision of the set performance the area of channels of the perforated graphite element should make 10 - 23 m^2, and the copper melt outflow speed to the distribution chamber through the perforated graphite element makes 0,1-0,12 m/sec.

The technical result of the invention is the possibility to produce the articles of electrical engineering purpose from 100% copper alloys with the copper content in it of at least 98%.

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Description

[0001] The invention relates to nonferrous metallurgy, particularly to the secondary copper-bearing raw material processing methods, for further use of metal in the articles of electrical engineering purpose.

[0002] The method of processing of the secondary copper-bearing raw material in the form of copper wires with varnish, polymeric and cotton insulation, including loading of the initial batch into molten salt, melting in the salt-bath furnace at the temperature exceeding copper melting point, with the subsequent ingot and semifinished product pouring, is known. Iron is preliminary removed from the secondary raw material, the batch is loaded into molten salt of alkaline and alkaline-earth metals and is melted higher than the copper melting temperature by 10-310°C, then the liquid copper is recovered, the formed carbon deposit is removed from the salt surface, thereafter the cycle is repeated, in this case the correlation of volumes of loaded batch and molten salt is maintained within the limits of (2-3,4):1 (RU 2181386, cl. C22B7/00, 2002).

[0003] But this method doesn't allow to recover copper of high quality due to the inhomogeneity of its structure stipulated by the availability of cracks, pores, various inclusions, as well as by the high content of oxygen not allowing to use copper in the articles of electric engineering purpose.

[0004] The method of fire refining of copper at processing of the secondary copper-bearing raw material (RU 2391420, cl. C22B15/14, C22B9/10, 2010) is known. The method involves the slug feed of batch materials and metal batch. The temperature of copper melt is maintained at the level of 1220-1240°C. Whereupon the oxidation refining of the copper melt is conducted by air blasting of the melt with loading into the bath of flux containing the mixture of aegirine concentrate and quartz sand into the bath. The flux is loaded portionwise proportionally to its melting in the bath and to the temperature of slag melting in the furnace 1220-1240°C. The concentrate includes, in mass %: 82,5 of aegirine - Na, $Fe[Si_2O_6]$; 6,7 of nepheline - KNa_3 $[AlSiO_4]_4$; 4,3 of sphene- $CaTiSiO_4$; 3.1 of apatite - Ca_{10} $(PO_4)_6$; 3,4 of the other substances comprising mainly of the titanomagnetite. Upon the completion of oxidation refining of the copper melt its air blasting was shut off and the slag was removed. After slag removal the copper melt was deoxidized according to the familiar technology with the aid of natural gas.

[0005] But the copper recovered in this way is contaminated by the various impurities and contains the high quantity of oxygen, its use is not allowed in the articles of electrical engineering purpose, because the high requirements to availability of impurities are specified to such articles.

[0006] The method of combined casting and rolling of copper alloys (RU 2163855, cl. B22D11/12, 2001), including the recovery of melt, its accumulation in mixers, alloying, feeding of melt by chute to the receiving pit of casting machine, formation of continuous casting in the rotary-type mold, yield of cast section from the mold, feeding of the case section to the continuous rolling mill and reeling on of the rods into bulls, is known. Prior to entry of the melt into the receiving pit of casting machine the oxygen is removed from the melted copper by the way of formation on the way of the liquid copper running of the part filled with the ignited pet coke and/or with the graphite pieces. The melt mirror in the receiving pit of casting machine is covered with the pet coke and/or the graphite pieces.

[0007] The part on the way of liquid copper running filled with the graphite pieces won't be able to provide the sufficient contact of copper with graphite along the whole section, that is why the oxygen content will remain at the sufficiently high level up to 300 ppm. Such oxygen content doesn't meet the requirements lodged to the oxygen-free copper, and hence the breakage level is increased at the rolling and drawing of the cast section, it has an impact on the quality of wire.

[0008] The prototype is the method of horizontal casting of copper including the copper melting at the temperature of 1084°C by the way of covering of the surface with the ignited charcoal and carbon oxide atmosphere creation over the melt. At the second stage the copper refining and recovery at the temperature of 1180-1200°C to the oxygen content in it of no more than 8 ppm is made. The melt is stabilized by the chemical composition and temperature with simultaneous removing of the gas products of the reaction. The casting is made through the graphite mold with the stepwise pulling of the article. Speed, step and frequency of steps are calculated depending on the type of the recovered articles. The preparation of the produced articles for further transportation and storage is made (RU 2458758, cl. B22D11/04, C22B15/14, 2012).

[0009] But for fulfillment of the familiar method it is necessary to use the high-grade raw material - the cathode copper of M0, M1 (State standard 859-2001) grades, and the extraneous impurities uncontaminated by oil and referred to A class,1 group, 1 grade (State standard 1639) are used as copper-mine tailings. It is possible to refer to the defects the high energy consumption affecting the end cost of the articles, because the eddy-current furnace, as well as the possible fast breakdown of lining, and, subsequently, the additional expenses for performance of lining works.

[0010] The task of this invention is the development of the method of combined casting and rolling of the cast section with the increased physical and technical characteristics complying with State standard due to the decrease of oxygen in the copper melt to 3-5 ppm.

[0011] The technical result of invention is the possibility of recovery of the articles of electrical engineering purpose from 100% copper scrap with the content of copper in them of at least than 98%.

[0012] The task set and, as a consequence, the specified technical result are achieved due to the fact that the method of combined casting and rolling of copper alloys from copper scraps includes melt preparation, by the way of copper melting at the first stage, copper refining and recovery at the second stage with the use of the carbon-bearing material and temperature increase, formation and pulling of continuous cast section, preparation of the produced articles for the further transportation and storage. According to the invention, after melting the copper melt is fed to a distribution chamber through graphite with the density 1,56-2,2 g/cm^3 in the form of the perforated element at the temperature 1140-1175°C, and the cast section is rolled by the way of its passing with the linear speed of 1,5 - 2,5 m/sec through a induction heater providing the high temperature heating to 650-800°C with the subsequent shock cooling to 50-55°C. So, the cast section is subject to double metal structure recrystallization, at the first stage - at rolling, and at the second stage - at high-speed and high-temperature heating and shock cooling.

[0013] For provision of efficiency of oxygen extraction from the copper melt and provision of the set performance the area of channels of the perforated graphite element should make 10 - 23 m^2, and the copper melt outflow speed to the distribution chamber through the perforated graphite element - 0,1-0,12 m/sec.

[0014] Passing of the copper melt to the distribution chamber through the graphite provides the additional copper recovery to the content in it of the oxygen to 5 ppm and lower. In this case at the moment of crossflow of the metal from degasification chamber to the distribution chamber the temperature should be increased to 1140-1175°C, it will allow to decrease the copper density. If the temperature of melt in the crossflow area decreases lower than 1140°C, the crystallization of metal can occur in the graphite channels, as well as the blocking of perforation channels and graphite pores, and the temperature rise higher than 1175°C is inexpedient, because it results in the excessive energy consumption. The copper viscosity due to the maintenance of temperature mode of crossflow is maintained at the level of 7860 kg/m^3, it creates its free egress at the speed of 0,1-0,12 m/sec and conduces the compliance with the required capacity of the unit. Choice of the graphite with density of 1,56-2,2 g/cm^3 in the form of perforated element encourages the efficient copper deoxidation. In this case the graphite parameters were chosen experimentally, because at decrease in its density less than for 1,56 g/cm^3, the deoxidation efficiency decreases and the extraction of oxygen from the melt decreases due to the decrease in the weight percentage of carbon, and increase in density for more than 2,2 g/cm^3 increases the graphite value resulting in the increase in the cost of production. Graphite block perforation channel area is also chosen by practical consideration and should be within the limits 10-23m^2, because the deoxidation efficiency decreases in case of decrease in the contact area, and its increase decreases the physical and mathematical characteristics of the graphite itself and results in the fast deterioration of the graphite perforated element.

[0015] The cast section pulling is made on the rolling mill with recovery of "rod" which is subject to combined high-temperature heating and shock cooling. The high-temperature heating provides the soft condition of the "rod" allowing to expand the range of "rod" sections from 30 to 100mm^2, in this case the linear speed of rod passing through the induction heater, heating and cooling temperature were chosen experimentally. The chosen parameters provide the close-bodied, homogeneous structure of the "rod", increase its physical and mechanical characteristics required for the articles of electrical engineering purpose.

[0016] The example of fulfillment of the method was conducted at recovery of the rod with the diameter of 8 mm. The tests were implemented on melting and casting unit "Copper Up Line ZG" with the capacity of 2t/hour by melt.

[0017] The delivery of batch materials included the fractional loading through the charging door of the melting bath of furnace with the help of the power-driven loader. The batch was loaded into the bath in portions by 500 kg - the secondary copper-mine tailings with copper content of at least 95% - at the switched on burner and natural gas burning with the excess air coefficient of 1,1. Loading of the subsequent batch portion was made after melting of the previous portion. The melting temperature was maintained at the level of 1200 - 1260°C. Due to welding deposition by the melting chamber, the metal was fed by crossflow into the degassing chamber of the furnace, where it was adjusted to the predetermined chemical composition and to the oxygen content level of no more than 100 ppm.

[0018] The further copper deoxidation was made on the way of metal crossflow from the degassing chamber into the reduction chamber by the way of passing of the melt through the high-carbon perforated element - graphite. The graphite with density of 1,75g/cm^3 was used in our case. The total contact area with graphite made 20m2, the melt egress speed at the unit capacity of up to 2t/hour made 0,11m/sec. The melt temperature in the crossflow area was maintained by the way of induction heating at the level of 1168°C. The oxygen content in melt at the entry to the distribution chamber in those conditions made 10 ppm. In the distribution chamber the oxygen in melt was additionally decreased to the level of 5 ppm and lower, after that the melting was fed to the water-cooling vertical mold for formation of the round cast section with the diameter of 18,5mm. The rolling into bulls up to 6,0 tons was made after cooling of the cast section.

[0019] Then the cast section was welded for the purpose of provision of process continuity and directed to the cold pilger mill, where the rod with the diameter 8,0 mm was produced by the way of unidirectional deformation and the total relative reduction by 81,3%, i.e. the rolling from the diameter of less than 18,5 mm. Then the rod in the continuous process was fed to the high-speed heating by the way of its passing with the linear speed of 2,4 m/sec though the built-in annealing (heating) to the temperature of 800°C with the subsequent combined shock cooling to the temperature of 54°C

[0020] Accordingly, the rod with the diameter 8 mm from 100% copper scraps was produced. Due to the development and compliance with the new modes the oxygen-free metal with the homogeneous finely crystalline structure and with the homogeneous physical and mechanical characteristics complying with State standard was produced.

Table 1

№	Melt parameters			Finished rod parameters		
	Casting temperature, °C	Crossflow temperature in the reduction chamber, °C	Oxygen content in the distribution chamber, ppm	Rod diameter, Ø MM	Breaking strength, kg/mm^2	Breaking strain, %
1	1180±5	1140	3	8	22	42
2	1180±5	1160	4	8	21,5	42
3	1180±5	1175	5	8	21	38

[0021] The finished rod took
the soft condition, i.e. the strain and the breaking strength complying with State standard, moreover, the highly efficient gas-shielded unit was used in the applied method, where the main source of energy was the natural gas (or any liquid fuel), it essentially decrease the expenses for production of 1 ton of article in comparison with the prototype.

[0022] At present the method passed the experimental and laboratory tests and its test on the industrial-scale plant is being prepared.

Claims

1. The method of combined casting and rolling of copper alloys from the copper scraps including the preparation of copper melt at the first stage, copper refining and recovery at the second stage with the use of carbon-bearing material and the increase in temperature, formation and pulling of the continuous cast section, preparation of the produced articles for further transportation and storage, **characterized by** the fact that after melting the copper melt passes into a distribution chamber through graphite with the density of 1,56-2,2 g/cm^3 in the form of perforated element at the temperature of 1140-1175°C, and the cast section is subject to rolling by the way of its passing with the linear speed of 1,5-2,5 m/sec through a induction heater providing the high-temperature heating up to 650-800°C with the subsequent shock cooling of the cast section to 50-55°C.

2. The method according to claim 1, **characterized by** the fact that the perforated graphite element channel area makes 10-23m^2.

3. The method according to claim 1, **characterized by** the fact that the copper melt egress speed to the distribution chamber through the perforated graphite element makes 0,1-0,12 m/sec.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/RU 2013/001155

A. CLASSIFICATION OF SUBJECT MATTER

B22D 11/12 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22D 11/12, 11/06, B21B 1/46, 13/22, C22B 15/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatSearch (RUPTO internal), USPTO, PAJ, Esp@cenet, DWPI, EAPATIS, PATENTSCOPE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, D	RU 2458758 C2 (OBSHCHESTVO S OGRANICHENNOI OTVETSTVENNOSTIU "REVERS-IMPEKS") 20.08.2012	1-3
A	RU 2089334 C1 (BERENT VALENTIN IANOVICH) 10.09.1997	1-3
A	JP 11-092837 A (KOBE STEEL LTD et al.) 06.04.1999	1-3

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
26 August 2014 (26.08.2014)	04 September 2014 (04.09.2014)
Name and mailing address of the ISA/	Authorized officer
Facsimile No.	Telephone No.

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- RU 2181386 **[0002]**
- RU 2391420 **[0004]**
- RU 2163855 **[0006]**
- RU 2458758 **[0008]**