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Casting and Rolling Module for Obtaining Rolled Wire from Refined Copper

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The technology and equipment, which are used for manufacturing metal products from recycled copper scrap and provide obtaining products competitive in price and quality for both domestic and international markets, were observed.

Keywords: COPPER SCRAP, FIRE REFINING, TRANSPORT CHUTE, CASTING AND ROLLING MODULE, ROLLED WIRE, ELECTRICAL COPPER

Introduction

Stable and sustainable development of an industrialized state under modern conditions is mostly connected with the extensive use of copper and copper alloys. High-quality indicators of products made of copper, including the electrotechnical parameters and ductility, are provided by a minimum content of impurities in it. Traditionally, copper production is based on the mining and processing of ores, first of all copper compounds with oxygen and sulfur [1, 2].

The main reserves of copper ores, from which we get high-quality copper, are concentrated in Chile, the USA, Poland, Russia, Kazakhstan and some other countries which have in total more than 80% of world reserves. The main producers of high-quality refined copper are the USA, Chile, Japan, Russia and the rapidly grow volumes of copper production in China. As a result of extraction of copper from the ores and its subsequent purification the so-called cathode copper with very low content of impurities is produced, and as a byproduct silver, platinum and other precious metals, which largely contribute to the payback of the technological process as a whole.

Meanwhile, most technologically advanced countries do not have commercial reserves of copper ores and use secondary raw materials for the production of copper and copper alloys: electrical industry waste, copper-containing scrap, etc. Because of the technological and economic limitations for recycling secondary raw materials special techniques based on removing from the melt of various accompanying impurities, including nickel, iron, tin, zinc, etc. are used. [3, 4]. The most urgent task is to develop technologies and equipment for the production of metal products on the basis of the combined casting and rolling technologies. Especially effective such a scheme is in case of production of rolled wire for electrical products, since the combination of casting and rolling processes can significantly minimize power consumption and reduce expenditure of labor on production in comparison with the traditional scheme of rolling ingots (anodes) [5, 6].

Results and Discussion

For The complex technology for producing high quality products from copper scrap for the electrotechnical industry is implemented in terms of PJSC "Artyomovsk Non-ferrous Metals Processing Works" (PJSC "AZOCM"). Technological process of manufacturing copper rolled wire combines the following operations in a single technological chain: smelting of the charge, casting billets, rolling it to the size of rolled wire, lighting, cooling, and coiling it.

High-purity copper is produced by fire refining, using as raw material a variety of secondary copper, which is characterized by unstable chemical composition and high content of difficultly retrieved components [3]. The works

produces more than 50 brands of high-quality copper alloys. Refiner for recycling copper scrap (heat size 120 tons) is equipped with two burners, one of which operates on the air-gas mixture, and the second is the additional oxygen one that is used for accelerating the process of melting of scrap. Above the level of the heel of metal there are five lances. In the back wall of the furnace blowout lances are installed, which during smelting sink under the heel by tilting the furnace and they are supplied with air or gas, depending on the course of a metallurgical process. In the process of refining copper special fluxes, which when melted interact with the melt, are used and the products formed by a chemical reaction pass into the slag. After each flux addition slag is to be removed from the surface of the melt through the slag notch.

Smelted in such way refined copper is transferred to the casting and rolling module. Schematic diagram of the continuous casting machines for copper casting of rotary type is shown in **Figure 1**.

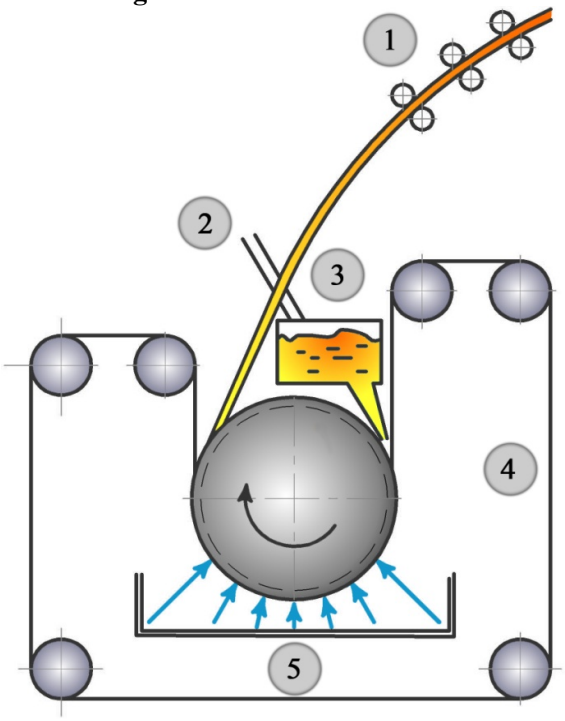

Figure 1. Schematic diagram of the copper casting in a rotary CCM: 1 - produced billet; 2 - runner for supplying copper from the receiver, 3 - intermediate ladle, 4 - steel strap, 5 - area of water cooling of the wheel

The copper produced in a furnace is supplied to the receiver by a system of heated runners, located in the immediate neighborhood from the CCM, and out of receiver it is continuously supplied by runner 2 to the intermediate ladle 3, from which it leaks at a given consumption rate with a spouting in the gap between the inner cavity of the wheel and the steel strap, pressed with the help of rollers to the surface edges of the wheel. The mould is formed by a trapezoidal groove in a rotating binding band and the adjacent steel strap, leaving the top of the wheel free to exit the hardened billet to the rolling stands.

The main characteristics of the rotary CCM ("Properzi") are as follows:

- Diameter of the casting wheel with the binding band - 2000 mm;
- Productivity - 6.0 - 14.5 t / h (662-1580 rph);
- Cross-sectional configuration of the billet - a trapezium;
- Billet height - 35 ± 10 mm;
- Width of the billet - 65/55 ± 10 mm;
- Sectional area of the cast billet - 2100 mm2 ± 10%;
- Material of the binding band the casting wheel - chromium bronze with the addition of zirconium;
- The length of the mould belt - 27200 (+ 300 / - 200) mm;
- Belt material - mild steel.

The working wheel of the CCM is made from chromium -zirconium bronze (%, Cu 99; Pb 0.006; Fe 0.009; Sn 0.0025; Zn 0.017; P 0.025; Ag 0.002; Cr 0.7; Zr 0.22), which is thermally treated to hardness 110-120 HB. The wheel goes down due to the emergence and development of fire cracks and bubbles on the working surface. The removal of these defects by grooving leads to a change in the geometric dimensions of the wheel, which affects the quality of the billet.

Water cooling system of the casting wheel and binding band is intended to provide stable billet mode crystallization, and includes a cooling tower (volume two tanks 35 m3 each), 2 pumps (capacity 148 m3/h), water filter, valves, and nozzles for spraying cooling water.

The process of forming the billet begins in the working cavity of a rotating wheel, which can be regarded as an open crystallizer (**Figure 2**).

In this case the copper melt enters the mould from the intermediate ladle, which is provided with nozzle-stopper equipment dosing. The outflow of copper is carried out through a special ceramic nozzle of a definite diameter. Grooving of the binding band is constantly covered with antipenetration coating.

The quality of billets is largely affected by the intensity of its solidification. Typically, the billet is completely solidified in the area of the wheel 1.5-2.0 m long. The greatest influence on the crystalline structure of the billet has a value of the contact period of the billet with the working

surface of the wheel. Thus, production of billets with transcrystalline structure is observed at the minimum permissible casting speeds according to the requirements of the technology (**Figure 3**). Production of rolled wire, corresponding to the technical requirements, from such workpieces usually turns out to be impossible.

a b

Figure 2. The picture of the submission process of copper into the mould (a) and exit of the billet from the rotary CCM wheel : 1 - intermediate ladle; 2 - ceramic nozzle; 3 - gas burner for heating the copper; 4 - melt flow; 5 - pressure roll; 6 - working wheel in a protection carter; 7 – billet.

Figure 3. Crystalline structure of copper billets of the rotary CCM

The formation of fine-grained crystalline structure can be achieved through the modification of copper with lead, while maintaining in the metal a certain amount of oxygen, as well as with increasing casting speed, which causes an increase in the length of the liquid phase zone (for example, with increasing wheel rotation speed). This is usually accompanied by an increased number of internal defects, such as "shrinkage porosity", which are located throughout the cross-sectional plane.

After exiting the wheel cavity the solidified billet goes down a steel curved guide barrel to the pulling rolls. At the same time the billet unbends to the straight state and is supplied into the bands, which is designed for straightening the billet in the horizontal and vertical planes and deburring both edges. Next the billet passes to the push rolls and then to the roughing stand of the rolling mill. In the process of rolling mill operation rolls and rolled wire are cooled by a special emulsion solution which, in turn, serves also as a lubricant.

Rolling of the billet is carried out successively in 9 stands. During rolling a universal scheme of grooving is used: "box groove» - "oval" - "circle". Selected for each stand drafting schedule allow obtaining rolled wire size with minimal deviations (tolerances) in diameter. Form of the billet section by stands is presented in **Figure 4**.

Regulation of the rolling speed is carried out by means of an automatic control system built into the process chain of equipment and consisting of interconnected thyristor electric drives. Rolling speed mode is set on the wheel drive, and then using a microcontroller all the other drives speed is automatically set by specially calculated

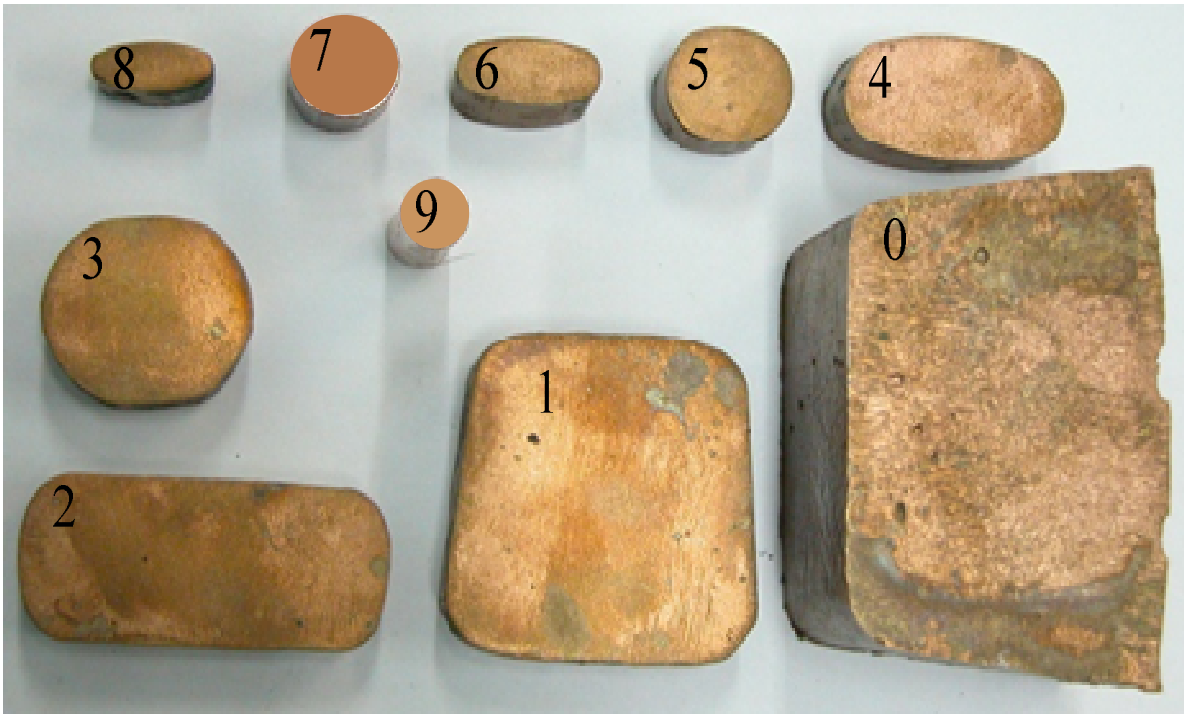

Figure 4. Form of the billet section by stands (grooves)

coefficients depending on a given wheel rotation speed. Adjustment of the rolling speed limit can also be accomplished within a certain range in manual mode without changing the rotational speed of the casting wheel. Drives speed of the remaining equipment in this case is changed automatically.

After rolling mill the obtained rolled wire passes through a line of cooling and lightening. Then cooled light rolled wire goes through the pulling rolls to the protective finishing line , and then passes through a system of defectoscopy, integrated directly into the rolling line and consisting of two main channels: defectomat determining surface defects and ferromat determining the ferromagnetic inclusions. Registration of defects is performed over the entire length of each rolled wire coil. At the final stage rolled wire goes to the coiler that rotates and puts it in coils of variable diameter. These coils are removed periodically with the accumulation of the fixed mass (200 kg).

In general, the achieved level of the rolled wire quality made of copper of fire refining produced at PJSC "Artyomovsk Non-ferrous Metals Processing Works" corresponds to the requirements of the accepted international standard system ASTM B49-90 and ISO 1553. The developed complex technology of continuous casting and rolling allows producing metal products that meets all the requirements for the electrotechnical industry products. Further studies should be developed in terms of increasing productivity of casting and rolling modules and quality of copper billets by optimization of heat transfer in the mould using various types of protective coatings applied to its working surface.

Conclusions

Combining the processes of smelting, refining, casting and rolling for production high quality copper products made it possible to implement in an industrial environment a highly effective technology for processing copper scrap to the level of electrotechnical production which is competitive with well-known technology solutions, including and based on the production of cathode copper.

Improvement of the technology of production of copper rolled wire provided a choice of optimum temperature and speed modes of the casting process, resulting in better quality (fixed by the readings of defectoscopes) and increase in volumes of output products. Quality of the produced rolled wire meets the requirements of the accepted international standard system ASTM B49-90 and ISO 1553.

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Литейно-прокатный модуль для получения катанки из рафинированной меди

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Рассмотрены технология и оборудование, используемые для производства металлопродукции из вторичного медного лома и позволяющие получать изделия конкурентоспособные по цене и качеству как на внутреннем, так и мировом рынках.