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[54] **METHOD FOR THE CONTINUOUS HOT SHAPING OF COPPER BARS**

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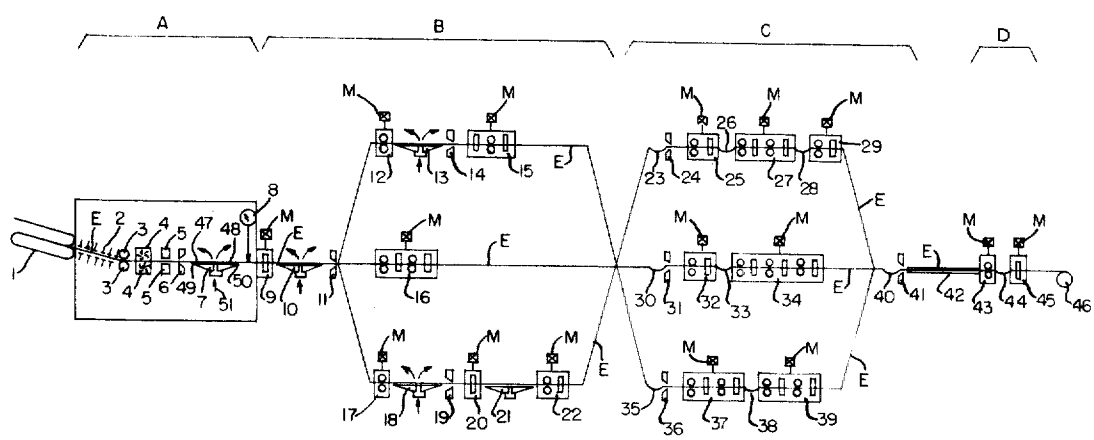
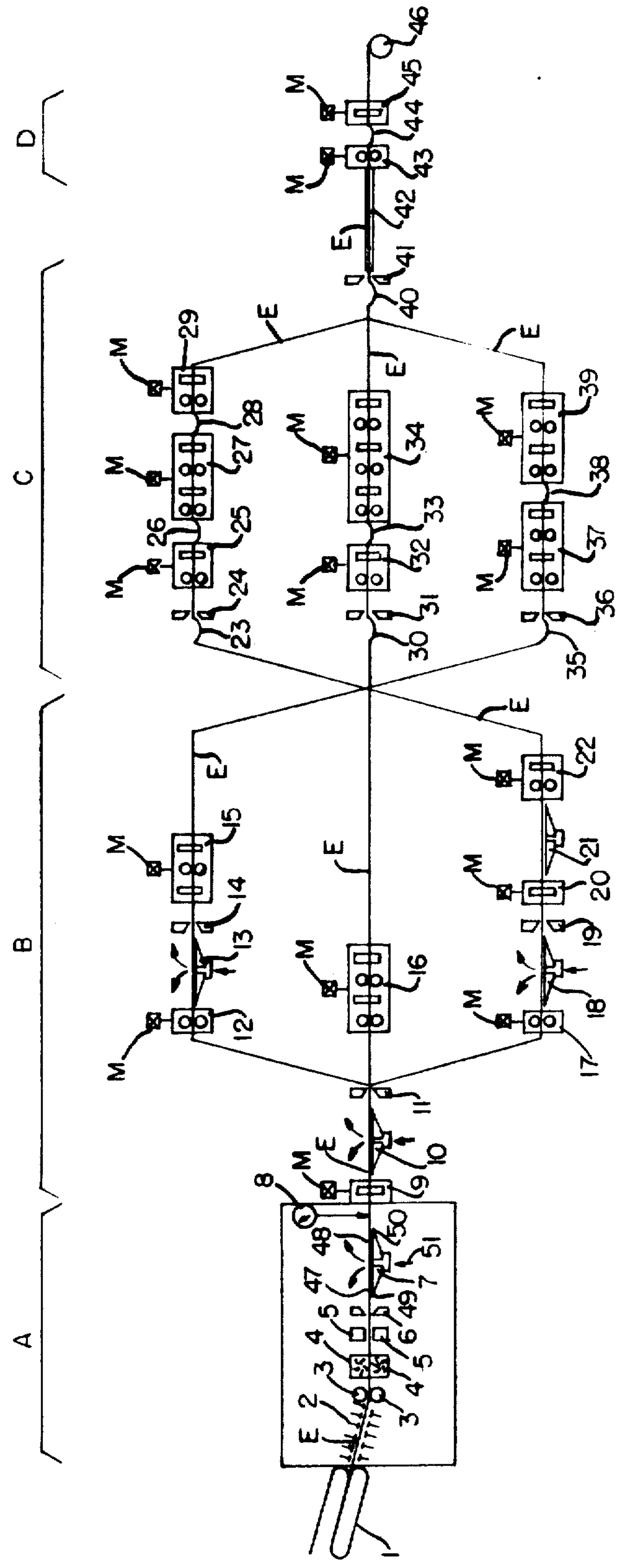
[57] **ABSTRACT**

A process wherein, during the conveyance of copper bars from a continuous casting device to the point of evacuation of the bars in their final form, tensions are suppressed at various points during the conveyance, torsions are suppressed in the length of the bar, and cooling of the bar is controlled during the conveyance.

19 Claims, 1 Drawing Figure





METHOD FOR THE CONTINUOUS HOT SHAPING OF COPPER BARS

This invention relates to the hot shaping of metals, more particularly of copper. The process according to the invention:

- eliminates on the one hand, internal as well as external cracks, crystal discontinuities and heterogeneities and all so-called aspect faults in the metal copper rods in order to give it the greatest suitability for wire drawing.

- confers on the other hand by means of a strict control and a suitable choice of the temperature at different stages of the rolling, to the copper rods the physical features chosen according to their final use.

Many hot shaping processes are known, in which metal kept at hot shaping temperatures is rolled, forged or otherwise worked. In continuous processing, rolling is generally done under tension by subjecting the rod to torsions, while lowering progressively the temperatures in the course of processing.

Changes in continuity and surface quality of the copper rod may be due to the tensions and the torsions undergone by the rod whilst being rolled, which, under certain conditions, may be highly detrimental to wire drawing.

Final physical characteristics also depend on the choice of an adequate temperature of the final rolling whilst ensuring during the main part of the rolling a temperature sufficiently high to obtain a good hot rolling.

For carrying the invention into effect, it is known to cool a rectangular rough shape on its four sides, for instance as it leaves a linear casting machine which has a casting section sufficient to obtain rolling to the core of the copper rod and is conveyed in a straight line to the hot shaping device and is supported during the entire length of the run.

In this way the preliminary shape is not affected by the straightening at high temperature, which is a cause of cracking in the shortest generatrix of the material, as it happens in continuous rod casting systems of the known type using casting wheels. When avoiding every tension, bending, straightening or torsion of the cast bar the possibility of cracking is reduced and even the formation of internal and external cracks is reduced.

The invention consists in a method for continuous hot shaping of copper rods leaving a continuous casting device, characterized by the fact that, during the conveyance of the bar between the said casting device and the evacuation of the bar in its final form, means are provided to suppress or reduce tensions at different spots of this run and to suppress torsions in the length of the bar, and that means are also provided for controlling the cooling of the bar during the said conveyance.

The tensions in the preliminary shape during the rolling are distributed so that the preliminary shape is practically not subjected to any tension during the first passes (called roughing passes) at the points where mechanical resistance of the hot rough shape is low, after which the preliminary shape is subjected in the intermediate stands to a tension which is sufficiently low to avoid cracking or deformation of the preliminary shape through tension, but is sufficiently high to straighten the material in order to reduce or to avoid contact with the guides, and finally all tension is avoided in the last passes (called finishing passes).

Another feature of the present invention is that the cast bar, when leaving the casting device, is supported by pinching rollers with a linear speed slightly lower (± 1%) than the casting speed. These pinching rollers support the cast bar and withhold the flux of liquid copper in the casting machine by means of the said solidified cast bar.

Still another feature is that one of the pinching rollers can rotate freely and act directly upon the speed of the hot shaping device.

Still another feature is that the cast bar, in the course of roughing, is continuously supported as long as a sufficient rolling has not yet conferred to it a tensile strength which it needs to support its own weight without damage. The flexibility needed to ensure roughing without tension in at least the first two roughing passes is obtained through the devices incorporated in the ramp preceeding the roughing stands and comprising two movable parts pivoting around their outer end. These two movable parts of the ramp, normally in line, and equipped with rollers, are supported at their inner movable ends through a lifting system exerting an upward force which is slightly stronger than the combined action of the weight of the two movable parts and of the weight of the rough shape to be supported. The slightest lengthening of the rough shape causes an upward movement of the lifting system, which, by means of a known apparatus, produces immediately a proportional acceleration of the next roughing stand. Such a system of bar support and regulation of tension is very sensitive (vertical shift less than 15 cm) and enables an extremely precise regulating of the speed of the roughing stands, whilst avoiding all tensions which might be detrimental to the quality of the copper rod.

Another feature of the invention is that hot rolling during roughing, in the alternately vertical and horizontal stands, is effected through three succeding passes square – flat – oval – square on angle or round, whether preceded or not by box passes, which eliminates every torsion of the rod whilst ensuring the best possible rolling to the core.

("Box passes" are rectangular or square passes of which one median is perpendicular to the axis of the cylinders and the other is parallel to it).

Another characteristic feature is that the rolling during the intermediate and finishing stages is ensured by means of alternately vertical or horizontal stands and by stands which are alternately inclined through 45° on either side of a vertical line, by applying rolling passes alternately oval and round or oval-oval, thus suppressing all torsion of the preliminary shape and all drawbacks connected with said torsion.

Another feature of the invention is that the cast rod with a rectangular cross-section, before being carried in the hot shaping device, is subjected to a bevelling on the four edges by means of rotating milling cutters followed by a brushing system, in order to avoid burrs which are obtained when the bevelling is carried out with a fixed cutting tool, and to avoid the tension which should be applied to get the rod through such fixed tools.

Such burrs of the cast bar must be avoided, because ultimately they are the cause of creases and other surface faults in the copper rod.

Another feature of the invention consists in providing, between the outlet of the casting machine and the inlet of the first pass of the hot shaping device, means to make the temperature uniform in the cross-section of the bar and all along the bar. To this end, cooling means and, if necessary heating means, are provided in order to accelerate such uniformity and to obtain at the inlet of the rolling mills a temperature of 800° to 850° C, which is required for copper. The fact that the conveyance of the said preliminary shape, which is supported along its entire length between the outlet of the casting device and the shaping device is effected in a straight line, facilitates the adjustment of the devices for controlling the temperature uniformity.

Another feature of the present invention is that the cooling of the rough shape is controlled during the entire rolling process so as to keep the temperature at a constant level which is chosen to get the best hot rolling of the metal and afterwards a special cooling is applied before the finishing passes, to bring the temperature of the rough shape down from the above mentioned constant level to the final rolling temperature chosen to obtain the best selected physical properties of the metal.

Although it is advantageous to carry out the major part of the rolling process at a relatively high temperature in order to ensure the best hot rolling it is the rolling temperature in the finishing passes which determines the physical properties of the copper rods. As regards copper, the level of temperature at which the rough shape should be maintained in the course of rolling in order to obtain a satisfactory hot rolling, is comprised between 800° and 850°C, whereas the final rolling temperature at the inlet of the finishing passes, which alone determines the physical properties of the copper rod, can be chosen according to the pursued aim: if it is desired to obtain a soft and ductile copper rod, enabling a high rate of cold reduction, the final temperature is comprised between 700° and 800° C. If it is desired to obtain a copper rod intended to produce a wire which is drawn at low recrystallization temperature and having a favorable electric conductivity, the final rolling temperature is set between 500° and 600°, thus producing an almost instantaneous precipitation of the last traces of impurities (which are in solid solution at higher temperatures).

The invention will be better understood by means of the accompanying drawing, showing the different stages A, B, C of copper rolling according to the invention.

In order to obtain copper rods of 8 mm in diameter a cast section of for instance 50 × 90 mm is used, which is hot rolled for instance in 15 passes.

The preliminary shape E leaving the casting device is supported during its whole run to the rolling mills and between the different roughing passes till reaching the stage in which the rolling applied is sufficient to give the rod on the one hand in the course of rolling the necessary tensile strength to support its own weight, and to reach on the other hand a section which is sufficiently weak to allow the formation of loops without damage.

When leaving the casting device **1**, the preliminary shape enters zone A, which is the so-called homogenizing and conditioning zone. That zone comprises in the first place a secondary cooling device **2** which ensures a complete solidification of the metal and lowers its temperature to 900° C. The solidified and still hot bar is then taken by pinching rollers **3**, the peripheral speed of which is controlled by the casting device and is slightly lower (−1 %) than the casting speed in order to withhold, by means of the said cast and solidified bar E, the flux of liquid copper in the casting machine **1**. One of the cylinders of the pinching rollers **3** can rotate freely and control the speed of the first roughing stand.

The pinching rollers **3** also direct the solidified bar E exactly in the axis of the rolling line.

The pinching rollers **3** then introduce the hot bar E in the device with rotating milling cutters **4** for bevelling the four sharp edges of the cast bar. Two devices with rotating milling cutters are provided, which work alternately and ensure a continuous operation, as soon as normal casting conditions are reached.

After bevelling, the preliminary shape passes through metallic brushes **5** to eliminate any chips which might stick to the preliminary shape.

Pendular or other shears **6** are provided which serve in the first place to cut the cast rough shape into removable pieces as long as normal casting conditions and the required quality are not yet reached and serve afterwards as emergency shears when there is an obstruction or another difficulty in the line A.

This same conditioning and homogenizing zone A comprises the first supporting and regulating device **7** in order to avoid every tension before the first roughing stand **9**. This device **7** comprises two movable parts **47** and **48**, in a line, which can pivot around their outer ends **49** and **50**, the two contact ends being supported by a lifting device, not illustrated, which is situated at **51**, exerting a light upward pression. As soon as the rough shape tends to lengthen, the lifting device **51** causes a slight upward movement and gives immediately rise to a proportional acceleration of the first roughing stand **9**, by known means. Such vertical shift enables a precise regulation to be obtained of the speed of the first roughing stand **9** and causes only a small deflection (maximum **150** mm), whilst ensuring a continuous support of the rough shape.

Before leaving the conditioning zone A, the temperature of the preliminary shape is measured and such temperature must be the same in the length as well as in cross-section. The temperature measuring and controlling device **8** regulates the cooling or causes a reheating of the cast preliminary shape, by known means (not illustrated) in order to keep the said temperature at a constant level comprised between 800° and 850° C. The whole zone A must be sufficiently long to obtain perfect uniformity and homogeneity of the rough shape. The whole machinery of zone A may be set up in one or several rooms which may be heat-indulated and under a controlled atmosphere.

A roughing stage B, comprising for instance five stands, alternately vertical and horizontal, driven by engines or motors which are shown at M, and of which the first two passes at least ensure a rolling without tension and a roughing without torsion.

Roughing can be done according to the following variants: a) a vertical independant stand **9**, driven by an engine or motor M, followed by a supporting device **10** similar to the one described under **7** and by an emergency shear **11** built according to the already described principles, a horizontal independant stand 12 the speed of which is controlled by the supporting and controlling device 10, itself followed by a supporting and controlling device 13 and by an emergency shear 14, and afterwards a unit of three stands (15) alternately vertical and horizontal, which the preliminary shape leaves in the form of a square on angle or of a round.

In this variant there are three roughing passes without tension (9 – 12 and the first pass of 15) and two passes with a very weak tension. The speed of the three independent stands, 9 – 12 and first pass of 15, is controlled by the supporting devices which precede immediately the said stands. The passes succeed each other as follows: box-pass 9 – box-pass 12 and then square on flat, oval, square on angle, or round, thus avoiding any torsion.

b. Another variant, less favorable from the quality point of view, but less expensive, consists in sending the preliminary shape through the independant roughing stand 9, afterwards on the regulating device 10 and shear 11 and in introducing it afterwards in the unit 16 with four stands, alternately horizontal and vertical, synchronized in such a way that the tension is reduced to a minimum.

Such a succession, comprising two stands without tension (9 on the first stand of unit 16), comprises the following pass sequence: vertical box-pass — horizontal box-pass and then again square on flat — oval — square on angle or round, thus avoiding any torsion.

c. The third variant which is the most expensive is also the most favorable as regards quality. It ensures four roughing passes without tension through the following laying out: the vertical stand 9, followed by a regulating device 10 and emergency shear 11, is followed by an horizontal stand 17 with regulating device 18 and emergency shear 19, then by a vertical independant stand 20, by a regulating device 21 and finally by a unit of two synchronized stands (horizontal — vertical) 22, the speed of which is controlled by the preceding device 21. Such an arrangement ensures roughing without tension up to, and including the fourth stand, whilst the tension between the fifth and the sixth stand is reduced to a minimum.

The pass sequence in this variant is as follows: box-pass 9, box-pass 17, square on flat 20 and then oval - square on angle or oval — round 22.

In order to ensure a good gripping of the bar in the course of roughing, the diameter of the roughing train cylinders, at least of those of the first stands, must be relatively large (minimum 400 mm).

The roughed bar enters alterwards the intermediate train C comprising for instance 8 passes, in alternately horizontal — vertical stands, if the roughed bar is round, or is alternately inclined at an angle of 45° with regard to the vertical if the roughed bar has the form of a square on angle. In the latter case the free loop formed at the outlet of the roughing train B must slide all along an inclined plane at an angle of 45° in order to present the rough shape without tension at the first oval pass.

That intermediate train which has always a sequence pass oval — oval or oval — round (false round) may, as shown in the drawing, be grouped in units of synchronized stands according to different variants, each unit being preceded by a free regulating device 23 followed by a shear 24.

After roughing, the roughed bar is sufficiently rolled and has a cross-section which is sufficiently weak to enable the formation of a free loop, which permits, by known means for instance a set of rotating mirrors and photoelectric cells) to regulate the speed of the next unit.

a. The first variant of the intermediate train C consists of a free regulating device 23, an emergency shear 24, a unit of two stands 25, a regulating device 26, a unit of four stands 27, a free regulating device 28 and a unit of two stands 29.

b. The second variant comprises the same free regulating device 30, an emergency shear 31, a unit of two stands 32, a free regulating device 33 and a unit of six synchronous stands 34.

c. The third variant comprises still the same free device 35, and the shear 36, followed by two units of four synchronous stands 37 and 39, separated by a regulating device 38.

Variants a) and c) are the most favorable, because of the greater adaptability which they allow, by reducing to a minimum the time needed to replace the flutings of a single unit, which must be replaced simultaneously.

Between the stands of one and the same unit of the intermediate train C, which are driven by one and the same engine, the reduction of the successive sections and the successive linear speeds are regulated in such a way that the minimum tension is obtained which is required to straighten the rolled rough shape in order to avoid every contact with the guides. This tension however must be as weak as possible in order to avoid mechanical deformation and intercrystalline cracks and a heterogenous reduction from one point to the other.

From the intermediate train C, the rolled rough shape (round - or false round) is conveyed via a regulating device 40 and an emergency shear 41, via a temperature regulating device 42 into the finishing train (D), comprising two independent stands allowing hot finishing, at the temperature chosen without any tension.

Between the outlet of the intermediate train C and the finishing train D, a device 42 is provided allowing cooling down of the rolled rough shape to a predetermined temperature, before it enters the last two passes without any tension and without torsion.

The controlled cooling, made possible by this device, allows of regulating the rolling temperature at will in the finishing stands D. That temperature determines the physical qualities of the copper rod: if the wiredrawer wishes to obtain a very ductile wire rod, in order to facilitate handling and to allow high speed wire-drawing without process annealings, a final rolling temperature between 700° and 800° C is chosen. If on the other hand the wire-drawer prefers to obtain a better annealing possibility and the most favorable electric conductivity, if necessary by giving up some of the ductility of the wire rod, and wishes to obtain a wire that is particularly intended for process annealings at low temperature or for enamelling, the final temperature is set between 300° and 600° C.

In this way this device makes it possible to meet all the desiderata of the wire-drawers according to the object pursued.

The two final finishing stands 43 and 45, alternately horizontal and vertical or inclined at an angle of 45° on either side of the vertical, are fully independent and are driven by individual motors **14**, the speed of which is controlled, by known means, through the free loops **40** and **44**. Here the succession of passes, which ensures very close tolerances, is oval-round.

The whole train (roughing B, intermediate C and finishing D) is fed with soluble oil.

The emergency shears may be interconnected by known means so that they are put into operation one after the other or simultaneously when some difficulty occurs in the line.

From the last pass the copper rod is conveyed to the winding machines **46**. Since the temperature during winding must be lower than ± 80° C in order to avoid any formation of superficial oxide, it is possible to proceed to descaling, thorough rinsing, and protective coating of the commercial copper rod. The copper rod is afterwards wound in reels of considerable unitary weight.

The various devices above mentioned are intended to be placed under a controlled atmosphere.

What I claim is:

1. A method for continuous hot shaping of copper bars leaving a continuous casting device which comprises:

a. reducing tensions of the bar during the first hot shaping passes by supporting it at the outlet of the casting device, by means which follow the upward movement of the bar and which regulate the speed of the first hot shaping passes in accordance with the said upward movement;

b. reducing tensions of the bar during the roughing stage subsequent to said first hot shaping pass by supporting it at the outlet of said first hot shaping pass by means which follow the upward movement of the bar and which regulate the speed of subsequent hot shaping roughing passes in accordance with the said upward movement of the bar and which regulate the speed of subsequent hot shaping roughing passes in accordance with the said upward movement;

c. reducing tensions of the bar during the intermediate passes to a sufficiently low level to avoid internal and external cracks but sufficiently strong to straighten in a satisfactory way the rough shape by regulating the reduction of successive sections of the intermediate passes and regulating successive linear speeds of the intermediate passes;

d. reducing tensions of the bar during the finishing passes to a value as small as possible by controlling the speed of the passes of the finishing stages;

e. suppressing torsions along the copper bar in each of the roughing, intermediate, and finishing stages by mechanically working the copper bar;

f. and controlling the cooling of said copper in the course of shaping to keep the chosen temperature constant during substantially the entire duration of conveyance with the exception of the finishing stage; and

g. cooling immediately before the finishing passes in order to lower the temperature of the preliminary shape to the temperature required for obtaining pre-determined physical properties of the copper.

2. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1** in which the cast copper bar, when leaving the casting device and before being subjected to the first passes of hot shaping, is supported and conveyed by pinching rollers, the linear speed of which is slightly lower than the output of the casting device,

3. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **2**, in which one of the pinching rollers rotates freely and acts directly upon the output of the roughing passes of the hot shaping process.

4. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1**, in which, between the outlet of the casting device and the inlet of the first passes of the hot shaping device heating means and cooling means are provided to obtain a uniform temperature in the cross-section and along the bar.

5. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1**, in which, when the cast bar has a rectangular form, the external aspect faults of the cast bar are eliminated, before the bar enters the hot shaping device by subjecting the bar to a bevelling of the four edges by means of rotating milling cutters followed by a brush arrangement.

6. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1** in which the torsions during the roughing stage are eliminated by providing a succession of three passes square on flat — oval — square on angle and the torsions during the intermediate and finishing stages are eliminated by stands which are alternately inclined through 45° on either side of a vertical line, by applying passes alternately oval and round.

7. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1** in which the torsions during the roughing stage are eliminated by providing a succession of three passes square on flat — oval — square on angle and the torsions during the intermediate and finishing stages are eliminated by stands which are alternately inclined through 45° on either side of a vertical line, by applying passes oval-oval.

8. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1** in which the torsions during the roughing stage are eliminated by providing a succession of three passes square on flat — oval — round, and the torsions during the intermediate and finishing stages are eliminated by alternately vertical and horizontal stands, by applying passes alternately oval and round.

9. A method for continuous hot shaping of copper bars leaving a continuous casting device, as claimed in claim **1** in which the torsions during the roughing stage are eliminated by providing a succession of three passes square on flat — oval — round, and the torsions during the intermediate and finishing stages are eliminated by alternately vertical and horizontal stands, by applying passes oval-oval.

10. The method of claim **6** wherein the passes in the roughing stage are preceded by box passes.

11. The method of claim **7** wherein the passes in the roughing stage are preceded by box passes.

12. The method of claim **8** wherein the passes in the roughing stage are preceded by box passes.

13. The method of claim **9** wherein the passes in the roughing stage are preceded by box passes.

14. The method of claim **1** wherein the chosen temperature during substantially the entire duration of conveyance is between 800° and 850° C.

15. The method of claim **6** wherein the copper is conveyed from the roughing passes to the intermediate passes by sliding along an inclined plane at an angle of 45°.

16. The method of claim **7** wherein the copper is conveyed from the roughing passes to the intermediate passes by sliding along an inclined pland at an angle of 45°.

17. The method of claim **1** wherein the temperature required for obtaining predetermined physical properties of copper is between 700° and 800° C.

18. The method of claim **1** wherein the temperature required for obtaining predetermined physical properties of the copper is between 300° and 600° C.

19. The method of claim 1 wherein the roughing stage contains first stands which are cylinders having a diameter of at least 400 mm.

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