A method for producing a mold tube from copper or a copper alloy for a continuous casting mold, a tube blank being formed on a mandrel, which determines the inner shape of the mold, by the external application of force, and, following the shaping process, the mandrel being removed from the mold tube (1, 1a); the action of force resulting in response to the movement of the tube blank relative to the die surrounding the same; the die having a shaping structure for a cold formed profile (6, 6a; 7, 7a) on the outer surface (5) of the mold tube (1, 1a), so that the cold formed profile (6, 6a; 7, 7a) is produced by the die upon shaping of the tube blank on the mandrel.
METHOD FOR PRODUCING A MOLD TUBE

0001. The present invention relates to a method for producing a mold tube from copper or a copper alloy for a continuous casting mold in accordance with the features set forth in the definition of the species in claim 1.

0002. Tubular chill molds made of copper or copper alloys for casting profiles made of steel or other metals having a high melting point have often been described in the related art. Mold tubes typically have a uniform wall thickness in a horizontal cross-sectional plane that increases in the direction of the strand due to the inner conicity of the mold tube. The inner conicity is adapted to the solidification behavior of the strand and the continuous casting parameters. The heat flux has a predominantly two-dimensional characteristic and leads to widely differing cooling rates of the strand. A particularly strong shell growth and shrinkage behavior of the strand is evident in the corners of the mold tube, since it is here that substantial amounts of heat are dissipated due to the unequal casting surface to cooling surface ratio. The rate of cooling is lower in the lateral surfaces of a mold tube than in the corner regions due to the virtually equal casting surface to cooling surface ratio. At the same time, a greater heat flux is imposed thereon. The leads to a reduced shell growth relative to the corner regions.

0003. Due to the different cooling ratios within a mold tube, a different strand shell growth rate results over the horizontal cross section. Consequently, tensile and compressive stresses occur in the strand shell. Since the strength of the strand shell is relatively low immediately following solidification, such stresses readily lead to internal and external defects in the form of cracks in the billets. There is also an increased risk of the strand shell rupturing underneath the mold.

0004. Therefore, efforts are currently underway to optimize the mold tube by providing a homogeneous dissipation of heat over the horizontal cross-section, as well as a maximum dissipation of heat over the entire dwell time of the strand in the mold. This is all the more important since the thermal loading of the mold tubes increases in response to rising casting rates. It is, therefore, necessary to seek a most optimal possible cooling to prevent damage to the mold tube, the aim being to prolong the service life of the mold tubes.

0005. A higher rate of heat dissipation can be achieved by providing additional cooling grooves, as is described, for example, in the European Patent Application EP 1 792 676 A1. The cooling grooves are adapted in the depth and configuration thereof to the amount of heat to be removed, the corner regions of the mold tube being excluded. The grooves are produced by cutting-type machining since they are formed as depressions in the surface.

0006. The German Patent Application DE 36 15 079 A1 describes a method for producing open-ended molds for continuous casting for continuous casting machines, where a tube is calibrated by an inner mandrel and, on the outside, is pulled through a die that imparts the outer contour to the mold. Molds having curvilineur shapes can also be manufactured in this manner.

0007. It is, therefore, an object of the present invention to provide a method for producing a mold tube that will make possible the inexpensive manufacture of mold tubes featuring optimized heat dissipation. This objective is achieved by a method having the features of claim 1.

0008. Advantageous refinements of the present invention constitute the subject matter of the dependent claims.

0009. The method according to the present invention for producing a mold tube from copper or a copper alloy provides for a tube blank to be formed on a mandrel, which determines the inner shape of the mold, by externally applied force, and, following the shaping process, for the mandrel to be removed from the mold tube. In the process, the tube blank is passed through a die that has a shaping structure for a cold formed profile on the outer surface of the mold tube, so that the cold formed profile is produced by the die upon shaping of the tube blank on the mandrel.

0010. The method according to the present invention, therefore, provides for a noncutting production of the cold formed profile that is achieved by a special shaping structure in the die. By applying the method according to the present invention, the cold formed profile is able to be produced much faster and more economically than if cutting-type machining were used.

0011. In the context of the present invention, it is self-evident that it is not ruled out for a cutting-type machining to be additionally carried out in order to make local adaptations, for example, to mill in grooves used for fastening the mold tube to the interior of a water jacket. However, the basic principle is based on the approach of producing the cold formed profile in a continuous casting process using noncutting shaping.

0012. This enables the cold formed profile to extend from the top to the bottom end of the mold tube. With regard to the exact embodiment of the cold formed profiling, consideration must be given to the heat dissipated from the strand during the dwell time in the mold tube.

0013. The heat dissipation is derived, inter alia, from the outer surface of the mold tube that is in contact with cooling water. This is represented by the mathematical formulation: \[ Q = \alpha \cdot \Delta t \cdot A \cdot \Delta T \] describing the heat flux, \( \alpha \) the heat-transfer coefficient of the outer mold surface into the cooling water, and \( \Delta T \) the increase in the temperature of the cooling water during the cooling phase along the mold tube. In this context, the amount of heat to be dissipated is in proportion to the heat-transfer surface. Increasing the size of the outer surface by the cold profiling allows more heat to be released to the ambient environment, i.e., to the cooling water. Thus, the cold profiling results in an enlarged surface area, this increase in the surface area being determined by the structure of the die.

0014. The present invention provides for the cold formed profile to be produced preferably in response to the pulling of the tube blank through the die. The corner regions of the mold tube may be thereby excluded in order not to additionally increase the size of the heat-transfer surface in this region. The cold formed profile may itself be configured as a grooved profile having an undulated structure or as a zigzag profile. An undulated profile or also a zigzag profile may be more readily realized by the process of pulling through the die than are individual, mutually spaced apart grooves having a rectangular cross section, for example.

0015. In the context of the present invention, it is considered to be especially advantageous for the cold formed profile to be produced with an amplitude height range of from 0.5 to 5 mm; in the case of a zigzag profile, an opening angle being produced between two adjacent zags within a range of from 15° to 90°, and, in the case of an undulated profile, the distance between two adjacent grooves being 1 to 14 mm.

0016. In one advantageous embodiment, the amplitude height is 0.5 to 1.5 mm. The opening angle is preferably within a range of from 45° to 60°.
In principle, the method according to the present invention is suitable for all known forms of mold tubes, whether the cross section be circular, rectangular or square. In the same way, T-, double-, U- or L-shaped cross-sectional profiles may be produced using the method according to the present invention.

The mandrel used in the method according to the present invention may have a conical shape. It may have a one-part or a multipart design. The mandrel itself may also be curvilinear, thereby making it possible for the method according to the present invention to be used for producing the mold tubes for circular-arc continuous casting machines.

The present invention is described in greater detail in the following on the basis of the exemplary embodiments illustrated in the drawings, whose figures show:

FIG. 1 a sectional representation through the wall region of a mold tube having a zigzag-shaped cold formed profile;

FIG. 2 a sectional representation through the wall region of a mold tube having an undulated, cold formed profile; and

FIG. 3 a perspective view of the corner region of a mold tube.

FIG. 1 shows a detail of a mold tube 1. Specifically, it is a question of one fourth of a mold tube which, if fully represented, would define a rectangular interior space. Therefore, mold tube 1 has a corner region 2, as well as side walls 3, 4, in the top portion of the image plane, side wall 3 being longer than side wall 4, which is to the right in the image plane.

Illustrated mold tube 1 is made of copper or of a copper alloy and is produced by the pulling of a tube blank (not shown in detail) through a die. In this context, the mold blank had been formed on a mandrel (likewise not shown in detail). The inner contour of mold tube 1 is formed by the external force applied by the die. The geometry of the die determines the outer geometry of mold tube 1. It is the outer geometry of the mold tube that is relevant to the inventive method. FIG. 1 shows that, in some regions, outer surface 5 features a cold formed profile 6, 7 while, in other regions, it does not. Specifically, in this exemplary embodiment, corner region 2 is smooth, i.e., configured without any cold formed profile. Cold formed profiles are only located in the region of side walls 3, 4. While cold formed profile 6 of upper side wall 3 in the top portion of the image plane extends directly to the beginning of corner region 2, i.e., ends where the curvature of corner region 2 begins, cold formed profile 7 of shorter side wall 4, which is to the right in the image plane, is located at a somewhat greater distance from corner region 2. This means that corner region 2 initially merges transitionally into a region 8 in which outer surface 5 of side wall 4 is unrounded and smooth. Only then does cold formed profile 7 begin.

Cold formed profiles 6, 7 are identical in design. It is a question of zigzag profiles. Overall, therefore, the grooves of the zigzag profile are identical in form. They have a uniform amplitude height H, which, in this exemplary embodiment, has dimensions on the order of 0.5 to 1.5 mm and, in particular, 1 mm. Angle W, which is measured between mutually adjacent flanks of two zags, is within the range of 15 to 90°. In this exemplary embodiment, it is 60°.

The specific embodiment of FIG. 2 differs from that of FIG. 1 merely in the shape of cold formed profiles 6a, 7a. Cold formed profiles 6a, 7a are not shaped as zigzag profiles, but rather as undulated profiles. The amplitude height is within the range of 0.5 to 5 mm and, here, may also be preferably within a range of from 0.5 to 1.5 mm, in particular may be 1 mm. Overall, therefore, it is discernible that both profiles 6a, 7a are uniform. Mutually adjacent grooves 9 between two crests 10 are all spaced apart at the same distance. The distance is 1 to 14 mm. Between the flanks, illustrated angle W1, in turn, is 60°.

In a perspective view, FIG. 3 shows corner region 2 of mold tube 1 illustrated in FIG. 1. On outer surface 5 thereof, corner region 2 is smooth, while a cold formed profile 6 is produced on side wall 3 which is to the left in the image plane. Situated in the image plane above cold formed profile 6 as a recess milled into side wall 3, is a transverse groove 11. Another transverse groove 12 is located in other side wall 4. Transverse grooves 11, 12 extend into corner region 2. Mold tube 1 may be fixed in position via transverse grooves 11, 12. No further cold formed profile is configured in the image plane above transverse grooves 11, 12. Cold formed profile may be removed by a cutting-type machining, for example, in order to produce a smooth surface for sealing mold tube 2 in a water cooling box.

LIST OF REFERENCE NUMERALS

1—mold tube
1a—mold tube
2—corner region
3—side wall
3a—side wall
4—side wall
4a—side wall
5—outer surface
6—cold formed profile
6a—cold formed profile
7—cold formed profile
7a—cold formed profile
8—region
9—groove
10—crest
11—transverse groove
12—transverse groove
W—angle
W1—angle
H—amplitude height
H1—amplitude height
1. (canceled)
2. (canceled)
3. (canceled)
4. (canceled)
5. (canceled)
6. (canceled)
7. (canceled)
8. (canceled)
9. A method for producing a mold tube from copper or a copper alloy for a continuous casting mold, comprising: forming a tube blank on a mandrel, which determines an inner shape of the mold, by externally applying force; and following shaping, removing the mandrel from the mold tube (1, 1a), the action of force resulting in response to movement of the tube blank relative to a die surrounding the same, wherein the die has a shaping structure for a cold formed profile (6, 6a, 7, 7a) on an outer surface (5) of the mold tube (1, 1a), so that the cold formed profile (6, 6a, 7, 7a) is produced by the die upon shaping of the tube blank on the mandrel.
10. The method as recited in claim 9, wherein the cold formed profile (6, 6a; 7, 7a) is produced in response to the pulling of the tube blank through the die.

11. The method as recited in claim 9 wherein the corner regions (2) of the mold tube (1, 1a) are excluded from the production of the cold formed profile (6, 6a; 7, 7a).

12. The method as recited in claim 10 wherein the corner regions (2) of the mold tube (1, 1a) are excluded from the production of the cold formed profile (6, 6a; 7, 7a).

13. The method as recited in claim 9 wherein the cold formed profile (6a, 7a) is configured as a grooved profile having an undulated structure.

14. The method as recited in claim 10 wherein the cold formed profile (6a, 7a) is configured as a grooved profile having an undulated structure.

15. The method as recited in claim 11 wherein the cold formed profile (6a, 7a) is configured as a grooved profile having an undulated structure.

16. The method as recited in claim 9 wherein the cold formed profile (6, 7) is configured as a zigzag profile.

17. The method as recited in claim 10 wherein the cold formed profile (6, 7) is configured as a zigzag profile.

18. The method as recited in claim 11 wherein the cold formed profile (6, 7) is configured as a zigzag profile.

19. The method as recited in claim 13 wherein a cold formed profile (6, 6a; 7, 7a) is produced in an amplitude height (H, H1) range of from 0.5 to 5 mm, and, in the case of a zigzag profile, an opening angle (W) being produced between two adjacent zags within a range of from 15° to 90°, and, in the case of an undulated profile, the distance between two adjacent grooves (9) being 1 to 14 mm.

20. The method as recited in claim 16 wherein a cold formed profile (6, 6a; 7, 7a) is produced in an amplitude height (H, H1) range of from 0.5 to 5 mm, and, in the case of a zigzag profile, an opening angle (W) being produced between two adjacent zags within a range of from 15° to 90°, and, in the case of an undulated profile, the distance between two adjacent grooves (9) being 1 to 14 mm.

21. The method as recited in claim 13 wherein a cold formed profile (6, 6a; 7, 7a) is produced in an amplitude height (H, H1) range of from 0.5 to 1.5 mm.

22. The method as recited in claim 16 wherein a cold formed profile (6, 6a; 7, 7a) is produced in an amplitude height (H, H1) range of from 0.5 to 1.5 mm.

23. The method as recited in claim 19 wherein a cold formed profile (6, 6a; 7, 7a) is produced in an amplitude height (H, H1) range of from 0.5 to 1.5 mm.

24. The method as recited in claim 13 wherein the opening angle (W, W1) is within a range of from 45° to 60°.

25. The method as recited in claim 16 wherein the opening angle (W, W1) is within a range of from 45° to 60°.

26. The method as recited in claim 19 wherein the opening angle (W, W1) is within a range of from 45° to 60°.

27. The method as recited in claim 21 wherein the opening angle (W, W1) is within a range of from 45° to 60°.