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[54] **METHOD FOR THE PRODUCTION OF METALLIC INGOTS**

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[51] **Int. Cl.** **B22d 27/02**

[58] **Field of Search** 164/52, 252, 89, 122, 136

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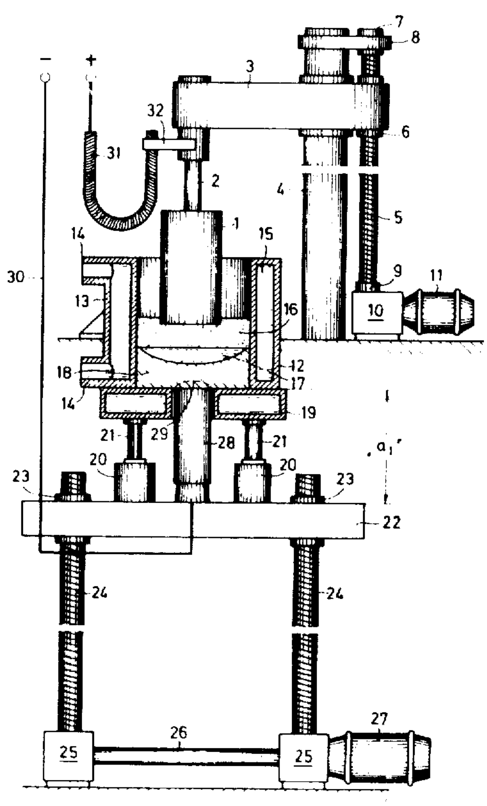
[57] **ABSTRACT**

An arrangement for the production or formation of metallic ingots from solid or liquid sources of materials. Crystallization takes place in an upward direction from the bottom of a chilled mold, which is liquid cooled. The chill mold has a liquid-cooled bottom which is movable from the mold. After the formation of a solid portion at the bottom of the ingot, the heat transfer from the ingot to the movable mold bottom is reduced in a stepwise manner.

3 Claims, 2 Drawing Figures



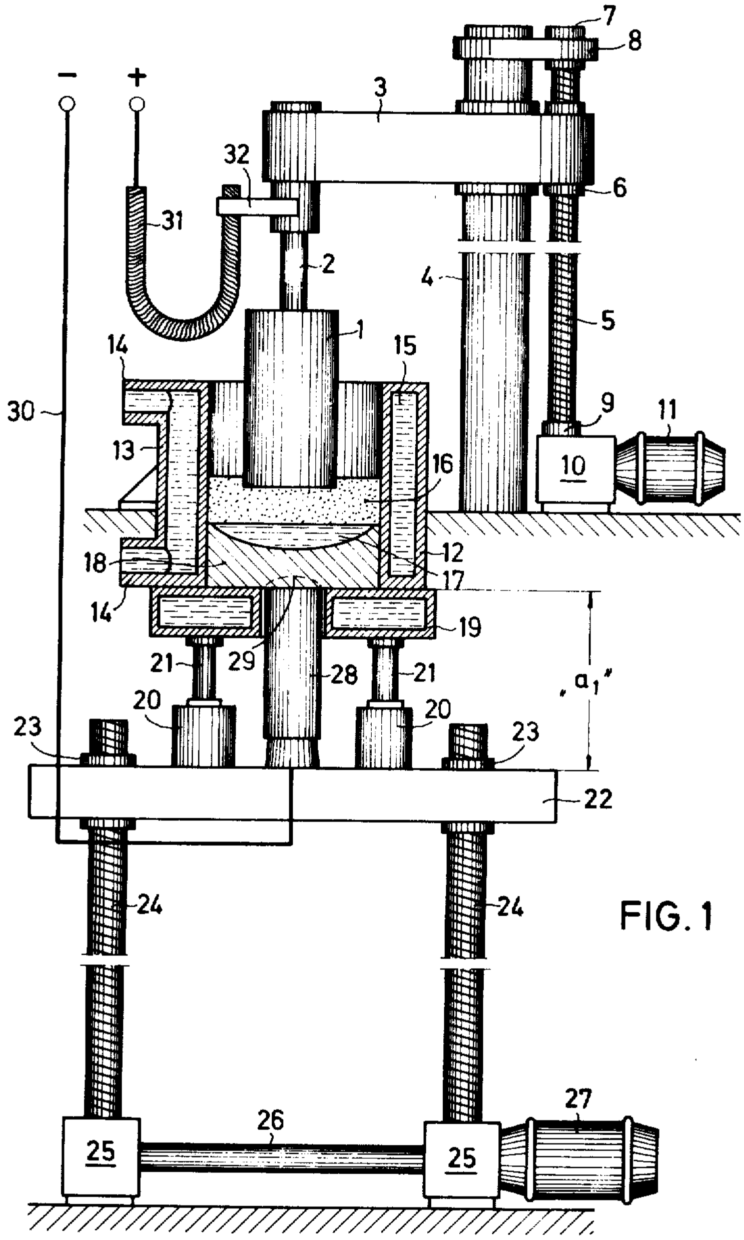


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FIG. 1

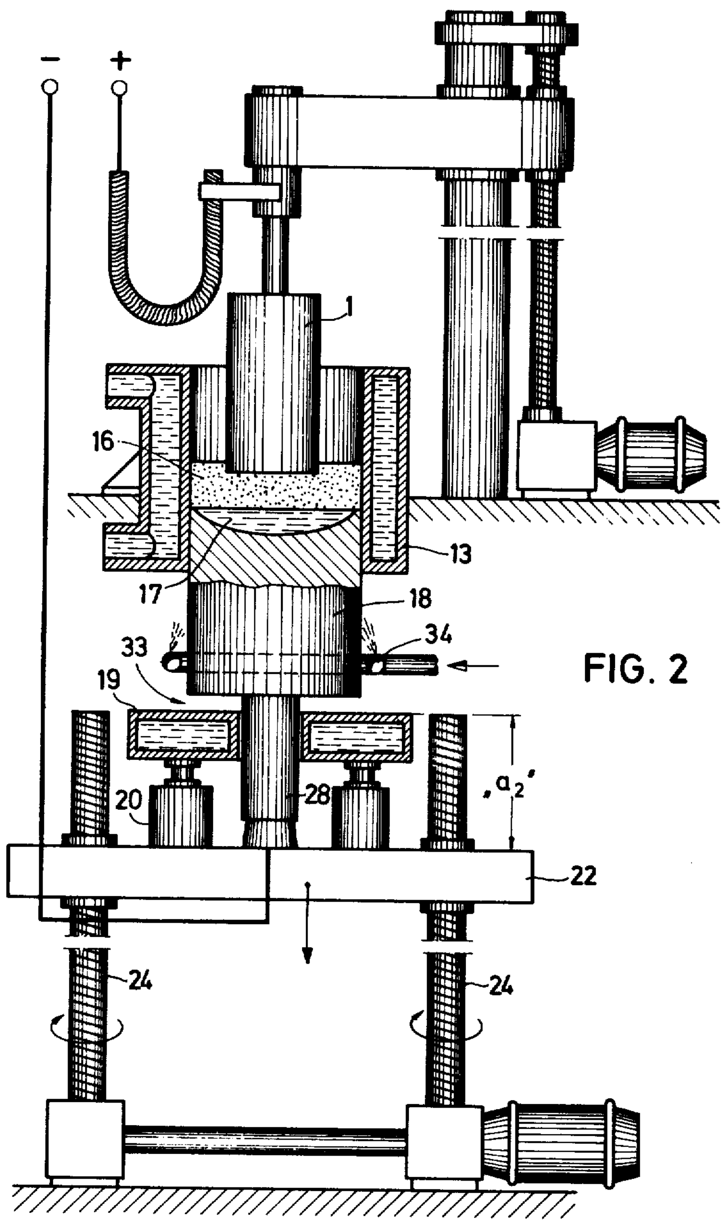

FIG. 2

METHOD FOR THE PRODUCTION OF METALLIC INGOTS

BACKGROUND OF THE INVENTION

The present invention relates to a method and means for the formation or production of metallic blocks or ingots from sources of materials that are either in the liquid or solid state. In the formation or production of the ingot, crystallization extends upwards from the bottom of a liquid-cooled chill mold or crucible equipped with a removable bottom.

Such methods are used when the metallic ingots have any desired cross-section and length which exceeds the length of the casting mold. In such cases, the ingot is moved with substantially uniform velocity out of the chill mold from the bottom, after the upper surface of the ingot is substantially solidified. The same object may be achieved by lifting the mold in the upward direction. As a result of applying this method, the freshly-formed surface of the ingot is still at substantially high temperature, and when exposed to the surrounding atmosphere or environment, an extensive amount of heat loss takes place due to radiation and convection.

The heat transfer or heat flow does not only take place from the cylindrical or rectangular surface of the ingot. Instead, the heat transfer also takes place over a considerable portion of the fluid-cooled bottom of the chill mold, upon which the ingot is supported as a result of its own weight. The rate of heat flow or heat transfer depends upon the temperature difference and thereby upon the prevailing ingot length and space between the still liquid upper surface of the ingot and the bottom of the ingot. As a result of this situation, the heat transfer from the bottom of the ingot does not occur uniformly during the formation of the ingot. Instead, a considerably larger portion of heat is conducted away through the bottom of the ingot during the initial period of ingot formation. Less heat is conducted in this manner, when the ingot is in the process of being completed. The temperature gradient is, thereby, very steep at the beginning of the process, and becomes substantially flat near the end of the melting process. The situation is such that the ingot material itself serves as a thermal insulator between the liquid melt and the bottom of the chill mold.

A varying heat transfer is, however, undesirable, particularly when ingots are to be formed with relatively limited lengths. Such ingots are produced with substantially slow solidification rate. Such a case is, for example, incurred when melting blocks or ingots through the use of the electroslag melting or remelting process. The formation or production of ingots requires, thereby, a considerable amount of time. Thus, for an ingot of approximately 200 tons, substantially 200 melting hours are required. While the upper portion of the ingot is held at the melting temperature, the lower portion of the ingot becomes cooled. Ingots of such sizes are needed for the production of turbine rotors which are made of a specific alloy steel as, for example, 28 NiCrMo 74 (material number 1.6589). For these and similar steel alloys, a critical cooling rate prevails below a predetermined temperature limit which is not to be passed through. Otherwise, cracks or tears take place in the ingot which lead to the discarding of the ingot.

The initial phase of an electroslag remelting process requires a water cooled bottom for reasons that are well known in the art. This water cooled bottom must

connect with the cylindrical or rectangular wall of the chill mold. From the viewpoint of the water cooling requirement and material characteristics, this bottom of the chill mold is in the form of a hollow copper plate. After a series of melting hours when sufficient space exists between the liquid melt and the bottom edge of the ingot, it is possible to drop below the critical temperature limit in the region of the mold bottom, whereby the feared cracks or tears in the ingot may appear.

SUMMARY OF THE INVENTION

It is an object of the present invention to limit the varying influence of the cooled bottom of the chill mold during formation or building of the ingot. In particular it is the object of the present invention to substantially prevent such influence of the bottom of the mold.

Another object of the present invention is to provide an arrangement for the production of ingots of the foregoing character, which is simple in design and construction.

A further object of the present invention is to provide an arrangement, as set forth, which may be economically fabricated and readily maintained.

The objects of the present invention are achieved by providing that the heat flow or heat transfer from the ingot to the bottom or base of the chill mold is decreased or reduced in a stepwise manner after the bottom portion of the ingot has become solidified. This aim of the present invention can be carried out in various ways. For example, the bottom of the mold can be dropped from the lower side of the ingot — at least for a period of time, whereby a rod-shaped member provides for maintaining the current and provides for mechanical support. This rod-shaped member becomes integral with the lower side of the ingot at the beginning of the remelting process. At the same time, the cooled bottom of the mold can be removed or lowered from the bottom side of the ingot for a substantially short period of time. After introducing an insulating intermediate layer in the form of, for example, asbestos, the bottom can be again laid against the undersurface of the ingot. In this case, it is possible to avoid particular means for supporting the ingot, since the ingot is held for a short period of time by the chill mold as a result of unavoidable frictional effects. The temporary interruption of current for several seconds, can be considered to have negligible effects. In conjunction with both embodiments, it is possible to provide auxiliary means through which the lower side of the ingot becomes heated. A gas-heated ring burner is particularly well adapted for this purpose. This burner surrounds substantially the ingot in the vicinity of the bottom of the mold.

Through the use of the present invention, the heat flow or heat transfer from the ingot to the bottom of the chill mold is reduced immediately upon dropping or lowering of the cooled chill mold bottom. The heat transfer from the liquid melt zone of the ingot to the bottom zone is such, that the lower portion of the ingot retains for a substantially very long time, a temperature which is above the critical limit temperature. This is due to the conductivity of the metal. Through the use of a rod-shaped member which is made integral with the ingot in the initial phase, an unallowable high temperature gradient occurs only at this rod-shaped member. This is, however, unobjectionable since the rod-shaped member has a substantially smaller cross-section than the ingot, so that the heat flow becomes thereby restricted. Furthermore, the rod-shaped member is not a part of the ingot; this member is usually severed from the ingot after the latter has been completed.

The arrangement for carrying out the method in accordance with the present invention has, moreover, a driven platform on which is mounted the bottom of the chill mold for taking into account the downward motion of the ingot. Means are also provided for varying the space a_1 between the platform and the bottom of the chill mold.

In order to obtain secure support of the ingot upon the platform for a longer period of time, the present invention provides that the bottom of the chill mold has at least one opening for admitting a rod-shaped member to become integral with the ingot. This rod-shaped member is, for example, inserted at the beginning of the remelting process, and abuts against the platform on one end. This member projects with the other end through the bottom of the chill mold and into the interior space of the mold. Besides serving as a pure mechanical support, this rod-shaped member also serves to apply the melting current to the ingot.

In some time consuming remelting processes, it is possible that the temperatures of the bottom zone of the ingot become again closed to the critical temperature limit. This is because the heat flow form the liquid melt cannot compensate any more the heat loss through the projecting surface from the chill mold. In order to avoid this situation, the present invention provides for a further arrangement which may be introduced into the space between the wall of the chill mold and the bottom of the mold. This auxiliary arrangement provides for external heating of the ingot from the lower edge or surface. The reduced heat flow between the lower end of the ingot and the lowered bottom of the chill mold, prevents thereby also that the additional heating be transmitted directly again through the bottom of the chill mold.

After the melting process has ended, the bottom of the chill mold is again raised, and assumes again the support of the ingot. In this manner, the mold can be raised over the upper edge or end of the ingot for the purpose of removing the completed ingot. In this case, a thermal insulating intermediate layer is also desirable.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is an elevational sectional view of an electroslag remelting arrangement, shortly after the formation of a solid portion at the bottom of the ingot, in accordance with the present invention;

FIG. 2 is an elevational view of the arrangement of FIG. 1 after melting has taken place over a substantially longer period of time and the bottom of the chill mold has been lowered, in accordance with the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawing and in particular to FIG. 1, an electrode **1** to be melted is made of an alloy adapted to turbine rotors. The electrode **1** is secured to an electrode holding arrangement through a rod **2** and a feeder **3**. The feeder **3** is movable longitudinally along a vertical column **4**. Vertical motion of the feeder **3** is accomplished through a threaded rod **5** which engages a threaded nut **6** within the feeder **3**. The column **4** serves as a support for this feeder **3**. The upper end of the threaded rod **5** is retained by a bearing **7** which is secured to the guide column **4** by means of a transverse member **8**. The lower bearing **9** of the threaded rod is on a speed reducer unit **10** which reduces the speed of a driving motor **11** to the desired speed of the spindle. Parts **2–11** represent the transport or moving arrangement for the electrode.

At least a part of the length of the electrode **1** to be melted, is within a chill mold **12**. The latter has a mold wall **13** in the form of a cylindrical hollow wall provided with connections **14** for the entrance and exit of cooling fluid **15**. During the first melting phase, a liquid slag layer **16** is present within the chill mold **12**. The electrode **1** dips into this slag layer **16**, to a small extent. The electrode melts in a drop-wise manner through the slag layer **16**, and collects in a liquid puddle **17** beneath the layer **16**. The puddle **17** becomes part of the ingot **18**, after solidification resulting from heat removal.

A mold bottom **19** is provided for closing the lower end of the mold wall. This bottom or base **19** is liquid cooled. The bottom or base **19**, furthermore, is carried on a platform **22** made movable through a hydraulic cylinder **20** and piston rod **21**. The expression "platform" here is to be considered as not limited only to a planar construction. Instead this expression is also applicable to any reference plane type of arrangement which provides for relative motion with respect to the wall **13** of the mold. At the beginning of the remelting process, the bottom **19** of the chill mold is at the distance a_1 from the platform **22**.

The platform has a series of threaded nuts **23** which cooperate with threaded rods **24**. These threaded rods or spindles **24** are driven through a drive **25** which is connected to a shaft **26** passing through the device **25**. The shaft **26** is, in turn, driven or set into motion through a driving motor **27**. The parts **23** to **27** form the drive for the platform **22**.

The bottom **19** of the chill mold is provided with a circular-shaped opening at its center which coincides with the axis of the electrode **1** and wall **13** of the mold. A cylindrical rod-shaped member **28** is present within this opening, after being inserted at the start of the process. The lower end of the rod **28** abuts against the platform **22**. In the starting phase of the remelting process (not shown), an internal melting of the upper side of the rod **28** takes place with the lower side of the block or ingot **18** within the portion outlined by the broken line **29**. Through this melting process within the area or zone approximately outlined by **29**, the ingot **18** and rod **28** become integral. The application of the melting current results, on the one hand, through a line **30** to the platform **22**, and from there through the rod **28** and to the ingot **18**. The other flow path of the current takes place through a flexible cable **31**, a terminal **32**, and the rod **2** leading to the electrode **1**. The arrangement as shown in FIG. 1 at an instant of time at which a portion of the ingot 18 has already been formed and closes, thereby, the bottom part of the chill mold without the aid of the bottom section 19. It is now possible to lower the ingot 18 together with the mold bottom 19, by means of the platform 22, with a velocity which corresponds to the solidification rate or growth rate of the ingot.

FIG. 2 shows an arrangement after the elapse of a considerable amount of time. Thus, FIG. 2 corresponds to an instant of time at which a larger portion of the ingot has already been formed. Elements which are the same in both FIGS. 1 and 2 are denoted by the same reference numerals. In addition to the lowering of the platform 22, a lowering of the mold bottom 19 has taken place relative to the platform, so that now the distance a_2 prevails between the platform and the bottom 19. As a result, a ring-shaped air gap 33 is present between the lower end of the ingot 18 and the mold bottom 19. This air gap serves to improve the thermal insulation between the ingot and the mold bottom. Further dropping or lowering of the platform 22 results now with equal distance between the bottom 19 and platform 22. In this case, the ingot 18 abuts the platform 22 through the rod 28 which also retains the application of the melting current. In the space between the wall 13 and the bottom 19, is a heat source 34 in the form of a ring gas burner for the purpose of heating the ingot. This heat source is advantageously in the form of two parts, so that it can be placed in the position shown. This heat source can be lowered together with the platform 22, and to introduce additional heat sources in the continuously increasing space between the wall 13 and the bottom 19. The position of the heat source or sources can also be made variable within this space.

The application of the present invention is not to be limited to electroslag remelting processes. The present invention is equally applicable in an advantageous

manner to electric arc furnaces, particularly the vacuum electric arc type of furnace.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of electrode remelting processes, differing from the types described above.

While the invention has been illustrated and described as embodied in electrode remelting processes, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

We claim:

1. A method for producing a metallic ingot comprising the steps of: passing melted material into a liquid-cooled chill mold, said mold having a liquid-cooled bottom movable from the walls of said mold; solidifying said material through crystallization directed upward from the bottom to produce an ingot; and separating the bottom of said mold from the bottom of said ingot over at least a period of time, so that heat flow from said ingot is substantially reduced after solidification of a lower portion of said ingot.

2. A method for producing a metallic ingot comprising the steps of: passing melted material into a liquid-cooled chill mold, said mold having a liquid-cooled bottom movable from the walls of said mold; solidifying said material through crystallization directed upward from the bottom to produce an ingot; positioning said liquid-cooled bottom of said mold relative to said walls so that heat flow from said ingot is substantially reduced after solidification of a lower portion of said ingot; and separating the bottom of said mold from the bottom of said ingot over at least a period of time.

3. The method as defined in claim 2 including the step of inserting a heat insulator into the space between the bottom of said ingot and said bottom of said mold.

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