

Title: Machine for forming metal bars**Description**

The present invention regards a machine for forming metal bars in particular suitable
5 for melting and the subsequent continuous solidification of precious metal such as
gold, silver, precious alloys, as well as other pure metals or different alloys, for
producing ingots, as described in the introducing part of claim 1.

As known, producing ingots, in particular made of gold, silver, precious alloys, other
pure metals and different alloys, is usually obtained by means of two different
10 methods.

When producing light ingots, from 5 g up to 50 g, there is used a cold moulding and
coining process, starting from semi-finished products, such as cylindrical-shaped
preformed pads or billets.

When producing ingots with weight varying between 50 g and 50 Kg there is instead
15 used the melting method and subsequent solidification of the metal in the special
moulds.

In practice, the metal to be melted is placed within ladles, in form of powders,
granules or loose raw materials of various sizes, wherein it is brought to melting.

Then the molten metal is poured in single ingot moulds, generally shaped to form a
20 truncated-trapezoid wherein, solidifying, it takes the form of an ingot.

Such two operations, the melting one and the subsequent one for solidifying the
material, must be carried out with special care, given that the obtained end-product
must meet strict and specific standard requirements.

Actually the ingots available in the market, besides having an exact purity if made of
25 pure metal, or an exact percentage of pure metal if made of an alloy (the so-called
“count”), must have extremely precise dimensions and weight, an external

configuration with regular surfaces, without depressions or cracks, a uniform coloration and, above all, they must have a perfect internal metal-graphic structure, without blowholes, microporosities and structural tensions.

In order to avoid obtaining faulty ingots not capable of allowing obtaining the
5 “punching”, which would thus be considered as waste material, it is necessary that the entire production cycle be carried out with a lot of care, in particular during the steps of melting, solidifying and cooling the metal.

According to the current state of the art, production of ingots occurs, besides manually, by using melting furnaces provided with a crucible from which the molten
10 metal is poured into the ingot moulds, also using plants of considerable dimensions, wherein the main work steps are performed through a continuous automatic cycle.

The most important documents of the prior art are: JP 4 305359 A, US 2001/050157 A1, DE 200 12 066 U1 and US 2007/289715 A1.

An object of the present invention is to provide a machine for forming metal bars, in
15 particular for producing ingots, made of precious and non-precious material and, which, though including the steps of melting and solidifying the material, does not have the drawbacks revealed by the plants of the known type.

Such object is attained by providing a machine, in which there are present six operating stations, arranged in succession wherein:

20 - in the first station, defined as the “loading area”, there occurs the deposit of the solid metal in the ingot mould, the addition of a specific chemical additive, which interacts with the crystalline structure of the material, to prevent the formation of unevenness and internal tensions during the subsequent melting step, the positioning of the cover for closing the ingot mould and in which there is present a pushing device for moving
25 all the ingot moulds forward over the entire operating cycle;

- in the second station, generally defined “melting furnace”, there occurs the melting of the metal contained in the ingot mould, according to the predefined temperature/time parameters;
- in the third station, defined as a “secondary addition”, there is deposited on the still
5 liquid metal a chemical additive, which eliminates the unevenness that tends to form on the surfaces of the ingots during the subsequent solidification step”.
- in the fourth station, defined “solidification area”, there occurs the solidification of the metal in the ingot mould, according to the predefined temperature/time parameters;
- 10 - in the fifth station, defined “cooling area”, there occurs the cooling of the solid ingot and in it, when there is required a quick cooling, the aforementioned is unloaded into a vat containing the cooling fluid, from which it is collected when it is completely cooled;
- in the sixth station, defined “unloading area”, there are unloaded the ingot moulds,
15 which may contain the ingots, in case of normal cooling, or they may be empty, in case of quick cooling and the cooled ingots are recovered separately.

The characteristics of the invention will be made clearer through the description of a possible embodiment thereof, provided by way of non-limiting example, with reference to the attached drawings, wherein:

- 20 - fig 1 represents an elevational view of the machine according to the invention;
- fig 2 represents a detailed view of the ingot mould in the loading station;
- fig 3 represents the t/T° (time/temperature) diagram in the metal melting station;
- figs 4.1 and 4.2 represent detailed views of the ingot mould, in the solidification station, with different cooling modes;

- fig 5 represents three different configurations of the sliding plate of the ingot moulds, during the solidification step.

As observable from the figures, the machine according to the invention, generally indicated with reference 100, comprises:

- 5 - a station for loading and pushing, indicated with reference 101, the ingot moulds 1;
- a metal melting station contained in the ingot moulds, indicated with reference 102;
- a station for the "secondary addition" on the still liquid metal, indicated with reference 103;
- a station for solidifying the molten metal, indicated with reference 104;
- 10 - a station for cooling the solid ingot, indicated with reference 105;
- a station for unloading the ingot moulds, indicated with reference 106.

As can be seen in fig 1, on a loading surface of the first operating station 101 there are positioned the empty ingot moulds 1, interposing between an ingot mould and the subsequent one or between groups of two or more mutually adjacent ingot moulds, spacers 2, made of graphite or any other refractory material, which have the function of maintaining a predefined distance between the single ingot moulds or between the groups of ingot moulds, in a manner such that the ingot moulds 1, forming a "train of ingot moulds" are positioned, during the forward movement, always correctly within the work area; furthermore said operating surface is also provided with a pushing device 3, driven variously, such as by a worm screw, a pneumatic means, hydraulic means or any other means, which provides for pushing, with a predefined "pitch", the aforementioned train forward, and then returning and thus freeing space on the aforementioned loading surface, to allow depositing further empty ingot moulds.

From an operational point of view, in each single ingot mould 1 there is poured an exact weight of metal, in form of powder, grits or swarf of various sizes (pouring

element “A”) and there is added a chemical additive (dosing element “B”), which creates a chemical reaction with the impurities contained in the metal and which is made up of Boric acid, Borax, Potassium Nitrates, Ammonium, Sodium, lithium and Potassium and Sodium Chlorides, used separately or mixed.

- 5 Lastly, in said first station 101 there occurs the positioning of the cover 4 for closing the filled ingot mould.

From a constructional point of view, as can be seen in the detailed fig 2, the ingot mould 1 may have a dimension in height such that, when it is filled with the exact weight of metal, the cover 4 thereof rests on the metal, but remains raised with
10 respect to the abutment of the edge of the ingot mould, this allowing the bottom of the cover to compress and thus regularly compact the powders, the grits or the swarf so that, during the subsequent melting step, when the volume occupied by the mass of metal reduces gradually even up to one third of the initial solid volume, the cover lowers progressively as the metal melts, until it rests on the aforementioned abutment,
15 thus hermetically closing the ingot mould.

Furthermore, the interior space of the ingot mould 1 is made up of two distinct volumes; the lower volume 1.1 constitutes the actual “mould”, wherein there are determined the form and the dimensions of the ingot, according to the international standards, such as for example the LMBA standards, or with the other specific
20 requirements of the client and a second upper volume 1.2, which can be differently configured, with the aim of facilitating the deposit of the metal during the loading step.

Then, the pushing device 3 pushes the “train” from the station 101 for supplying the ingot moulds to the melting station 102, wherein there may be a heating furnace 5, in
25 which the ingot moulds and the spacers slide on a refractory surface in absence of

controlled atmosphere, or a tunnel 6, in which the ingot moulds and the spacers slide on the surface of the tunnel or on guides, variously heated, through electrical resistors, by electromagnetic induction, through burners of the gas type or of any other type, up to the operating temperature; by way of example, regarding the ingots
5 made of silver (Ag) such temperature is of about 1150°C. While for the ingots made of gold (Au) it is of about 1250°C and in the tunnel or in the guides there is insufflated inert gas, such as nitrogen, nitrogen-hydrogen mixture with max. 4.5% of hydrogen (H), to create an “inert” environment, which prevents the ingot moulds and the covers from being subjected to oxidation and thus prevents a quick wear and
10 keeps the molten metal protected from oxygen.

Practically, the difficulty of repetitively and constantly adjusting the melting temperature of the ingots within the tunnel is partly overcome by using the “induction” heating, wherein the increase of the heating temperature (thermal gradient) occurs with at least two ramps (fig 3), with a quick ramp (a), up to reaching
15 at least 90% of the set value of the melting temperature and one or more ramps (b.c) with less inclined profile (see fig 3).

Furthermore, with the aim of reducing the heat and the atmosphere of the inert gas, within the tunnel 6 there is provided for, at the lateral openings for the inlet and outlet of the “train”, the application of mobile partitions 7 obtained, for example, with the
20 guillotine technique, which create a mobile or flexible insulating refractory barrier, the movement thereof being manual or automatic.

Then, still from an operational point of view, once the melting time elapses there is activated the pushing device 3, which provides for moving the “train” forward; the ingot moulds present on the loading surface are pushed into the furnace/tunnel 5/6
25 and the same, in turn, push the ingot moulds present in the tunnel/furnace 5/6 to exit,

with the aim of allowing the latter, containing the molten metal, then pass in the station of "secondary addition" 103 and, subsequently, in the solidification station 104.

From an operational point of view, in the station 103 there occurs the raising of the
5 cover of the ingot mould, by means of grippers of the mechanical type, pneumatic type or any other type, while dosing systems of the mechanical type, pneumatic type or any other type, add in each single ingot mould 1, on the molten metal, an accurate amount of chemical additive (dosing element "C"), which creates a chemical reaction with the impurities contained in the molten metal, the additive being made up of
10 Boric acid, Borax, Potassium Nitrates, Ammonium, Sodium, Lithium and Potassium and Sodium Chlorides, used separately or mixed; subsequently the cover is repositioned on the ingot mould.

Also in the process of "secondary addition" there should be created an "inert" environment, regarding which there is introduced a flow of inert gas such as
15 Nitrogen, Argon or Nitrogen-Hydrogen mixture, which prevents the oxidation of the ingot moulds and the covers and protects the metal still in liquid form against oxygen. Then, in the solidification station 104 the incandescent temperature ingot moulds, containing the molten metal and closed by the cover, slide until they stop on a cooling surface 10, cooled with water by means of passage holes present therewithin and
20 made using copper, aluminium or alloys thereof or other materials suitable for the controlled dispersion of heat, in which they remain for a predefined period of time, averagely 1 to 5 minutes, as a function of the amount of material to be solidified, up to the complete solidification of the entire mass.

Also in the solidification process there should be created an "inert" environment,
25 hence there is introduced a flow of inert gas such as Nitrogen, Argon or Nitrogen-

Hydrogen mixture, which prevents the oxidation of the ingot moulds and the covers and protects the metal being solidified against oxygen.

Specifically, depending on the internal metal structure the ingot is required to obtain, which should have large, medium or small crystals and a more or less marked
5 solidification shrinkage, the solidification station 104 may be provided with further insulating or refractory cooling plates for slowing the thermal dispersion 11; such plates may be possibly provided with notches for defining the localised heat areas, which are placed near or in contact with one or more sides of the ingot mould and of the cover (see fig 4.1), and/or further heating plates for slowing the cooling 21, made
10 of graphite, metal or refractory or insulating materials, smooth or provided with suitable millings in relief or recessed, which may be placed between the cooling plate 10 and the ingot mould 1 (see fig 4.2).

Alternatively, when there is required an accurate control of the thermodynamic solidification gradients, with the aim of obtaining an ingot with the most suitable
15 solidified metal structure the solidification station 104 may be provided with heating panels 12 for example heated using electrical resistors, gas or using any other means, also positioned around the ingot mould and on the cover.

Furthermore, with the aim of having a further possibility of accurately determining the thermodynamic gradients, depending on the internal metal structure the ingot is
20 required to take, the cooling plate 10 may have the sliding surface - on which the ingot moulds stop in the solidification step - having a flat and smooth surface, or provided with millings in relief or recessed; furthermore the passage of the cooling fluid may be executed longitudinally and/or transversely to the direction of movement of the "trains" of ingot moulds (see fig 5).

Due to construction reasons, in some cases the “secondary addition” station 103 and the solidification station 104 may be incorporated in a single station 103/104, where there the addition and solidification steps are performed sequentially.

Subsequently, the ingot mould passes in the cooling station 105 and such operation
5 may occur through two different operating modes, according to the set production times and as a function of the type of material and the “size” of the produced ingots.

Specifically, the two cooling methods are:

- normal cooling: the ingot moulds with the ingots still very hot are subjected to a controlled cooling in a free environment and thus they are sent to the unloading
10 station 106.

- quick cooling of the ingots: when the ingot moulds, with the solid ingots still very hot, are brought to the cooling area they are emptied and the ingots are dropped in a cooling water vat 13, while the empty ingot moulds are sent to the unloading station
106.

15 From an operational point of view, the quick cooling provides for the raising of the cover of the ingot mould, by means of grippers of the mechanical type, pneumatic type or any other type, while actuators of the mechanical type, pneumatic type or any other type lock the ingot mould at the base.

Then, the aforementioned actuators rotate and tilt the ingot mould and, by gravity, the
20 hot ingot falls into a basket 14, submerged in the cooling vat 13 which after a suitable cooling time, through a translation movement, exits from the aforementioned vat to allow the collection of the cooled ingot 20.

Still subsequently, on the contrary, after the empty basket 14 returns, the repositioning of the empty ingot moulds and the lowering of the covers, the head
25 pushing device 3 moves the “train” forward, so that the empty ingot mould, sliding,

ends up positioned in the unloading station 106, from which it is collected together with the ingot 20.

In particular said unloading station 106 may be suitably extended, so as to allow the “train” of ingot moulds to remain exposed on the cooling surface over a long period
5 of time, so as to be able to gradually reach a temperature suitable to allow an easy handling by the operator who should collect them empty (in case of quick cooling), or should remove the covers and collect the cooled ingots from the ingot moulds (in case of normal cooling).

The invention thus conceived can be subjected to numerous variants and
10 modifications and the construction details thereof can be replaced by technically equivalent elements, all falling within the inventive concept defined by the following claims.

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Claims

1. MACHINE FOR FORMING METAL BARS, in particular suitable for melting and the subsequent continuous solidification of precious metal such as gold, silver, precious alloys, as well as other pure metals or different alloys, in form of powder, grits or swarf of various sizes for producing ingots having mass varying from 50g to 50 kg, said machine (100) being characterised in that it has six operating stations, arranged in succession wherein:
- in the first station (101), defined "loading area", there is present a pouring element "A", which deposits the solid metal in the ingot mould and a dosage element "B" adapted to allow adding a specific chemical additive which interacts with the crystalline structure of the material, there being present a pushing device for moving all ingot moulds forward over the entire operating cycle;
 - in the second station (102), generally defined "melting furnace", there occurs the melting of the metal contained in the ingot mould, according to the predefined temperature/time parameters;
 - in the third station (103), defined as "secondary addition", there is present a dosage element "C" which provides for depositing a chemical additive on the still liquid metal;
 - in the fourth station (104), defined as "solidification area", there is present a channel or a cooling bath, whereby there occurs the solidification of the metal in the ingot mould, according to the predefined temperature/time parameters;
 - in the fifth station (105), defined as "cooling area", there are present further means adapted to determine the cooling of the solid ingot as well as, when there is required a rapid cooling, a vat containing the cooling fluid, there further being provided means suitable for collecting the ingot when it is completely cooled;

- in the sixth station (106), defined as “unloading area”, there are present means which allow unloading the ingot moulds, suitable to contain the ingots, in case of normal cooling, or are empty, in case of quick cooling and the cooled ingots are recovered separately.

5 2. OPERATION OF THE MACHINE FOR FORMING METAL BARS (100), obtained according to claim 1, said operation being characterised in that in the first operating station (101), on a loading surface there are positioned the empty ingot moulds (1), interposing between an ingot mould and the subsequent one or between groups of two or more mutually adjacent ingot moulds, spacers (2), made of graphite
10 or any other refractory material, which have the function of maintaining a predefined distance between the single ingot moulds or between the groups of ingot moulds, so that the ingot moulds (1), forming a “train of ingot moulds”, are positioned, during the forward movement, always correctly within the subsequent operating stations, said operating surface being also provided with a pushing device (3), driven
15 variously, such as a worm screw, a pneumatic means, hydraulic means or any other means, which provides for pushing, with a predefined “pitch”, the aforementioned train forward, and then returning and thus freeing space on the aforementioned loading surface, to allow depositing further empty ingot moulds.

3. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to
20 claim 2, characterised in that in the first operating station (101), in each single ingot mould (1), there is poured an accurate amount of metal, in form of powder, grits or swarf of various sizes (pouring element A) and there is added a chemical additive (dosing element B), which creates a chemical reaction with the impurities contained in the metal and which is made up of Boric acid, Borax, Potassium Nitrates,

Ammonium, Sodium, Lithium and Potassium and Sodium Chlorides, used separately or mixed and then the cover (4) is positioned for closing the filled ingot mould.

4. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to claim 2, characterised in that the ingot mould (1) has a dimension in height such that, when it is filled with the exact weight of metal, the cover (4) thereof may rest on the metal, but remain raised with respect to the abutment of the edge of the ingot mould, this allowing the bottom of the cover to compress and thus regularly compact the powders, the grits or the swarf, so that, during the subsequent melting step, when the volume occupied by the mass of metal reduces gradually, even up to one third of the initial solid volume, the cover lowers progressively as the metal melts, until it rests on the aforementioned abutment, thus hermetically closing the ingot mould, said ingot mould (1) having an internal space made up of two distinct volumes and precisely the lower volume (1.1) constitutes the actual "mould", wherein there are determined the form and the dimensions of the ingot, according to the international LMBA standard or other specific requirements of the client and a second upper volume (1.2), which can be differently configured, with the aim of facilitating the deposit of the metal during the loading step.

5. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of claims 2 to 4, characterised in that the pushing device (3) pushes the "train" from the station (101) for supplying the ingot moulds (1) to the melting station (102), wherein there is present a heating furnace (5), in which the ingot moulds (1) and the spacers (2) slide on a refractory surface in absence of controlled atmosphere.

6. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of the preceding claims, characterised in that the pushing device (3) pushes the "train" from the station (101) for supplying the ingot moulds (1), to the

melting station (102), wherein there is present a tunnel (6), heated variously, preferably using the “induction” heating, the increase of the heating temperature (thermal gradient), occurring with at least two ramps, a quick ramp (a), up to reaching at least 90% of the set value of the melting temperature and one or more ramps (b.c) with a less inclined profile, wherein there is insufflated inert gas, such as Nitrogen, Nitrogen-Hydrogen mixture with max. 4.5% of Hydrogen (H), to create an “inert” environment, there being provided, at the lateral openings for the inlet and outlet of the “train”, mobile partitions (7) obtained, preferably, with the guillotine technique.

7. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of claims 2 to 6, characterised in that, once the melting time elapses, the pushing device (3) moves the “train” forward so that the ingot moulds present on the loading surface are pushed into the furnace/tunnel (5/6) and these in turn push the ingot moulds present in the tunnel/furnace (5/6) to exit, then pass in the “secondary addition” station (103), wherein in each single ingot mould (1) there is added to the molten metal a chemical additive (dosing element C), which creates a chemical reaction with the impurities contained in the molten metal and which is made up of Boric acid, Borax, Potassium Nitrates, Ammonium, Sodium, Lithium and Potassium and Sodium Chlorides, used separately or mixed.

8. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of claims 2 to 7, characterised in that in the solidification station (104) the incandescent temperature ingot moulds containing the molten metal and closed by the cover slide until they stop on a cooling surface (10), cooled with water by means of passage holes present therewithin and made using copper, aluminium or alloys thereof or using other materials suitable for the controlled dispersion of heat, in which they remain for a predefined period of time, averagely 1 to 5 minutes, as a function of

the amount of material to be solidified, up to the complete solidification of the entire mass and in which there is created an “inert” environment, with introduction of a flow of inert gas such as Nitrogen, Argon or Nitrogen-Hydrogen mixture, which prevents the oxidation of the ingot moulds and of the covers and protects metal being solidified against oxygen.

9. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of claims 2 to 8, characterised in that the operations described in claims 7 and 8 are carried out in a single operating station (103/104).

10. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of claims 2 to 9, characterised in that in the cooling station (105) the ingot moulds, with the ingots still very hot, are subjected to a controlled cooling in a free environment and they are then sent to the unloading station (106).

11. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to one or more of claims 2 to 10, characterised in that in the cooling station (105) there is obtained a quick cooling, which provides for that the ingot moulds with the solid ingots still very hot, when they are in the cooling area, are emptied and the ingots fall into a cooling water vat (13), while the empty ingot moulds are sent to the unloading station (106).

12. MACHINE FOR FORMING METAL BARS, according to claim 1, characterised in that in the solidification station (104) the cooling plate (10) has a sliding surface, on which the ingot moulds stop in a solidification step, having a flat and smooth surface, or provided with millings in relief or recessed, the passage of the cooling fluid being executed longitudinally and/or transversely to the direction of movement of the “trains” of ingot moulds.

13. MACHINE FOR FORMING METAL BARS, according to claims 1 or 12, characterised in that in the solidification station (104), between the cooling surface (10) and the ingot mould (1), there are interposed other heating plates for slowing cooling (21), made of graphite, metal or refractory or insulating materials, smooth or
5 provided with suitable millings in relief or recessed.

14. MACHINE FOR FORMING METAL BARS, operating according to claim 8, characterised in that in the solidification station (104) there are present cooling or thermal insulation plates (11), provided with notches for defining the localised heat areas, which are placed near or in contact with one or more sides of the ingot mould
10 and the cover, furthermore there being provided, when there is required an accurate control of the thermodynamic solidification gradients, with the aim of obtaining an ingot with the most suitable solidified metal structure, the addition of heating panels (12) of the electrical resistor type, gas-type or heated with other means, also positioned around the ingot mould and on the cover.

15. OPERATION OF THE MACHINE FOR FORMING METAL BARS, according to claim 11, characterised in that the quick cooling provides for the raising of the cover (4) of the ingot mould (1), by means of grippers of the mechanical type, pneumatic type or any other type, while actuators of the mechanical type, pneumatic type or any other type hold the aforementioned ingot mould; then the aforementioned
20 actuators rotating and tilting the ingot mould and, by gravity, the hot ingot falls into a basket (14), which is submerged in a cooling vat (13).

16. OPERATION OF THE MACHINE FOR FORMING METAL BARS, as described in claim 12, characterised in that, after a suitable cooling time, through a translation movement, the basket (14) exits from the vat (13), to allow the collection
25 of the cooled ingot (20) and, still subsequently, there occurs the repositioning of the

empty basket (14), the repositioning of the empty ingot moulds and the lowering of the covers and, still subsequently, the head pushing device (2) moves the “train” forward, so that the empty ingot mould, sliding, ends up positioned in the unloading station (106), from where it is collected together with the ingot(20).