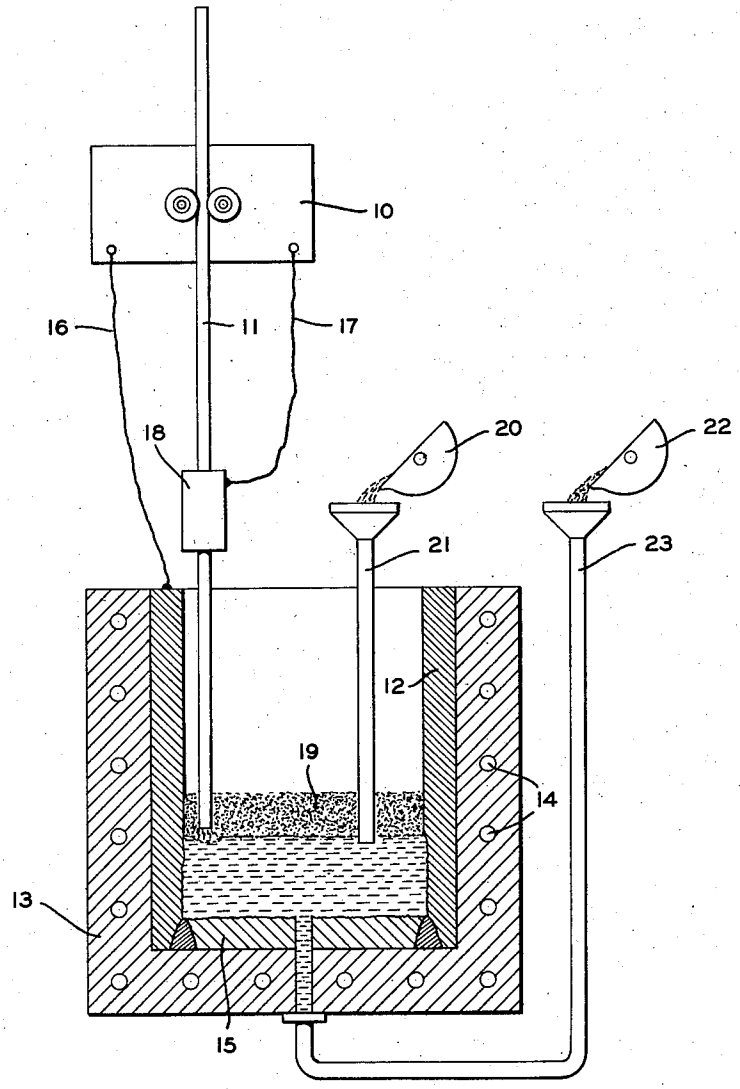
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MANUFACTURE OF METAL ARTICLES

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MANUFACTURE OF METAL ARTICLES

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This invention relates to the manufacture of metal articles and more particularly to the production of metal ingots of the character employed in the manufacture of worked articles such as plates, sheets, shaped forms, tubes and the like.

Metal, particularly carbon steel and alloys that include iron as a major constituent, from which worked articles such as plates, sheets, bars, tubes and the like are made, after being produced in the furnace is cast into ingots. The ingots are then usually worked to form intermediate workpieces such as slabs and billets and these further worked to produce the final articles. The ingots as removed from the molds show imperfections, particularly at and near the surface. These imperfections include folds, cracks, blow holes, porous areas, areas containing segregated impurities, and the like, and must be removed if acceptable articles are to be produced. The imperfections are usually removed as by grinding, drilling, gas or arc cutting, and the like. In the removal of the imperfections not only is the metal defining the imperfections removed but sufficient sound metal is also removed to form the surface voids produced with sufficiently gently sloped sides to prevent folding over of the metal at the edges of the voids during the subsequent working operations. Even with carbon steel and steels containing low percentages of alloying elements this operation represents a material proportion of the cost of the final articles. With alloy steels such as chrome steels, chrome nickel steels, tungsten steels, manganese steels and the like, of high alloying element content, which do not appreciably forge weld during working and as a consequence, it is necessary to remove even minor imperfections such as pin holes and small cracks that in carbon steel are disregarded. These steels, furthermore, because of their crystallizing characteristics show more surface imperfections than carbon steel. The amount of metal removed from ingots of these steels is, in the average case, a substantial proportion of the total metal cast.

With carbon steel it is sometimes necessary to remove further metal because of imperfections developed during rolling; with the high alloy steels it is always necessary to do this. In fact the metal body worked is gone over three or four times and the imperfections developed are generally so numerous that substantial proportions of the surface metal is removed during each going over.

It is an object of this invention to provide a simple and expedient method of producing ingots of ferrous metal and ferrous alloys that are substantially free from surface imperfections and can be worked directly into final articles.

It is also an object of this invention to provide a method for producing ingots and cast workpieces of the character mentioned in which a worked shell of the metal is used as a mold and cast metal united to the mold by electric energy discharge under a blanket of protective flux.

It is a further object of this invention to provide a method for producing ingots and cast metal bodies of special analysis which cannot be produced with the present commercial practice.

The further objects and advantages of the invention will be better understood from the following description taken with the accompanying drawing, in which, the single figure illustrates schematically a mode of carrying the invention out in practice.

The invention is of general application and may be used in connection with a wide variety of metals whether ferrous or non-ferrous. The invention is particularly useful when applied to ferrous metals and especially to those ferrous alloys known as high alloy steels, such as chrome steels, chrome-nickel steels, manganese steels, tungsten steels and the like that do not forge weld readily and when cast into ingots, in accordance with the usual present practice, develop a large grain structure and exhibit a surface of such poor character as to require an excessive removal of imperfections.

The apparatus shown in the drawing includes an electric current supply and electrode feed device 10. Device 10 is similar to the usual welding head employed in electric arc welding and should include arrangements for supplying electric current at controllable voltages and amperages and means for feeding an electrode at rates automatically controlled to maintain a discharge of predetermined characteristics. While device 10 is shown as feeding a single electrode 11 it is contemplated that device 10 feed a plurality of electrodes. When a plurality of electrodes are employed device 10 should be arranged to feed and to control their feed either individually or in groups. When a plurality of electrodes are employed it is also contemplated to electrically connect pairs of them in parallel or in series.

Device 10 feeds electrode 11 into mold 12 that is supported on mold stand 13. Device 10 and mold stand 13 may be so supported that rotation of one of them relative to the other can be effected when desired. Stand 13 is preferably made of metal, such as cast iron, and includes a plurality of conduits 14 through which may be passed a cooling medium, as for instance, water. Conduits 14 are preferably so arranged and connected that all or any portion of stand 13 may be cooled as desired.

Mold 12 as shown, is of cylindrical form but may be of any preferred form such as rectangular, polygonal etc. To the bottom of the cylindrical walls of mold 12 is welded a bottom plug

15 The cylindrical walls and plug 15 are made of metal substantially of the same composition as the desired cast body or ingot. Since the walls of mold 12 form the outside surface metal of the final ingot it is necessary to employ metal that is free from imperfections and is of a high quality. For this reason the cylindrical walls are preferably made of worked metal. Thus, the cylindrical walls may be made by shaping plate to the cylindrical form and welding the longitudinal edges together or they may be made from worked seamless cylinders. The cylindrical walls should be of a sufficient thickness to provide a tough, strong skin for the ingot during the working thereof. Depending on the size of the ingot and the reduction contemplated the cylindrical walls may range in thickness from one inch or less to six inches or more.

To form the ingot, molten metal is united to the mold 12 under the influence of the discharge of electric current through a gap between electrode, or electrodes, 11 and the metal of mold 12. Initially the discharge will take place between the sides or bottom of mold 12 and electrode 11 but as the operation progresses the discharge may also take place between the molten metal in mold 12 and electrode 11. To effect the current discnarge the electric current outlet of head 10 has one side connected to mold 12 by cable 16 and the other side connected by cable 17 to contact device 18 through which electrode 11 passes. Electrode, or electrodes, 11 are preferably located adjacent the walls of the mold 12 to assure fusion of a predetermined depth of the mold metal and an integral union, thereof with the molten ingot metal. This may be accomplished by employing a plurality of closely spaced electrodes disposed around the whole surface of the mold walls, or by using a small number of electrodes and rotating either mold stand 13 or device 10.

Molten metal for union with the metal of mold 12 may be supplied in various ways. Thus, it may be supplied entirely by the fusion of electrode, or electrodes, 11 of a composition to give molten metal of the required analysis. In such case, especially when high alloy steel ingots are to be made, a plurality of electrodes of different composition are employed and these electrodes chosen of such relative size and fed at such rates to produce a molten metal of the required analysis. Thus, if the ingot metal is to be a high chromium steel one of the electrodes may be of iron or steel and the other electrode may be of a chromium steel containing enough chromium to compensate for that lacking in the iron or steel electrode, also instead of using a chromium steel electrode, an electrode may be employed made up of ferro-chrome or this electrode may have a steel or iron lining filled with a ferro-chrome core.

The molten metal may also be supplied in part as cast metal and in part by the fusion of electrode, or electrodes, 11. When cast metal is supplied it may be top poured or bottom poured. When top pouring is employed the molten metal may be poured from ladle 20 through conduit 21, which is preferably of ceramic material, that extends either entirely or partly through flux blanket 19. When bottom pouring is employed the molten metal may be poured from ladle 22 through conduit 23, which likewise is preferably of ceramic material, that extends through the bottom of mold stand 13 and plug 15. Both the cast metal and the electrode may be of the same composition or they may be of such composition that together they will produce the required analysis. When supplying cast metal it is preferred to so locate and so move the electrode, or electrodes, 11 that the electric discharge will fuse a depth of the exposed wall metal of mold 12 to assure an intermingling of these metals and the production of a unitary structure. In place of cast metal a solidified rod unconnected to the supply of electrical energy may be fed to the region of the electric current discharge to be fused thereby. When either of these last mentioned expedients are employed for supplying molten metal the cast or solid metal as well as the electrode, or electrodes, may be steel and the required alloy constituents supplied during the operation in the form of ferro-chrome, ferro-manganese, etc., to the molten metal in the vicinity of the electric current discharge.

At present, I prefer, especially when forming ingots of high alloy steels, to employ a hollow electrode of one composition and supply the remainder of the required constituents through this hollow electrode, the rate of feed of the hollow electrode and rate of feed of the constituents supplied through it being controlled to produce the required analysis. Thus, in depositing chrome-steel, I prefer to employ a hollow electrode of iron or steel and supply the chromium as ferro-chrome through the hollow electrode at a rate controlled in accordance with the rate of feed of the hollow electrode so that the resulting molten metal will have the required analysis. I may use this expedient by itself, that is, employ one or more hollow electrodes, or I may use it in connection with a solid electrode or other source of metal. Thus, when depositing chrome-nickel steels I may employ an iron or steel hollow electrode as above stated, and pass the chromium therethrough as ferro-chrome and also feed a nickel electrode, which may or may not be connected to the source of electric current, at the proper rate to furnish the required nickel.

It will be apparent from the above that a wide variety of expensive alloys may be produced in the ingot form from comparatively inexpensive raw materials, and also that alloy ingots may be produced commercially of analyses not attainable by use of prior art practice. Thus, low carbon chrome nickel steels may be produced of such low carbon content that they are not appreciably subject to carbide precipitation, intergranular corrosion, etc., these steels having these desirable properties without containing columbium, titanium, etc. In producing ingots of such steels I employ commercial low carbon ferro-chrome to supply the chrome and some of the iron required, commercial low carbon or carbon free nickel to supply the nickel, and commercial low carbon iron or mild steel to supply the remainder of the iron. Low carbon iron or mild steel is available with carbon content ranging from .03% to as little as .01%; ferro-chrome may be obtained commercially that averagely contains 70% chromium, 0.06% carbon and the remainder substantially all iron. The iron or mild steel may be supplied as a hollow electrode and the ferro chrome passed through it to the current discharge; the nickel may also be passed through the hollow electrode or it may be passed in the form of a separate electrode. Alternatively the nickel may be the hollow electrode and the iron supplied as a separate electrode. With these materials 18 chrome 8 nickel steels may be produced with carbon contents of from .03 to .02%.

25 chrome 20 nickel steel and higher steels of this type will have somewhat lower carbon contents.

In order to assure a proper intermingling of the constituents of the molten metal and a proper refinement thereof in all of the variations of the novel method above set forth, the metal depositing operation is carried out beneath a protective blanket of flux 19.

The flux blanket 19 should preferably be such that it will not liberate deleterious gas either as to quantity or kind during the metal depositing operation and will not add substantial quantities of undesirable ingredients to or remove substantial quantities of desirable ingredients from the molten metal but will flux out impurities. The flux, furthermore, should be such that it will readily free itself from the molten metal. A wide variety of fluxes may be used satisfactorily. Silicates in general, either simple silicates or mixtures thereof, or complex silicates or mixtures thereof are satisfactory fluxes. Aluminates, titanates and similar compounds are likewise satisfactory and may also be used in connection with silicates both simple and complex. Flux thinners such as feldspar may also be employed to obtain a flux of desired melting characteristics. The flux need not be composed of reacted materials but may be made up of their dried or calcined unreacted components. Thus, in the case of calcium silicates the flux may be made up of calcium oxide and silica. At present, silicates of the alkaline earth metals, manganese and aluminum, are preferred as fluxes. The flux may be used in the solidified and comminuted condition or may be passed into mold 12 in the molten condition from a convenient source of supply.

In carrying out the metal depositing operation, electrode, or electrodes, 11 are fed until they approach the bottom of mold 12. An arc starter as, for instance, a ball of steel wool, a nail, a sliver of graphite and the like, is then interposed between the end of the electrode, or electrodes, and the metal of mold 12. The flux blanket 19 is then placed in the mold 12. Flux blanket 19 should be deep enough to exclude the atmosphere from contact with the molten metal and to protect the electrical discharge therefrom. Flux blankets ranging in thickness from an inch to six inches or more will be satisfactory for the average purposes.

When the electric circuit is closed the arc starter will quickly be destroyed to provide a path for the passage of the electric current between the end of the electrode and the metal of mold 12. The heat generated by the electric discharge will fuse the metal of electrode 11 and metal of the mold into a molten pool. When metal either in the solid or molten condition is supplied to the mold separately of electrode 11 the heat generated by the discharge will incorporate it into the molten pool. By reason of the flux blanket the heat is not rapidly dissipated so that thorough intermingling and refinement is assured.

Excessive penetration into the metal of mold 12 may be easily avoided by circulating a cooling medium through connected conduits 14. When casting ingots of metals that ordinarily crystallize with large grains the cooling of the mold may also be availed of to accelerate the cooling of the molten metal and thus produce a finer grain structure. Cooling medium may be circulated at or below the level of the molten metal at a rate to cause the solidification of the metal in mold 12 to a predetermined distance below the level of molten metal in mold 12. By removing heat in the manner just stated it is possible to so carry on the operation that a minimum of molten metal will be present when mold 12 is completely filled. In this way pipes and other shrinkage defects may be avoided or greatly minimized.

In order to prevent pipes and similar shrinkage defects it is also possible to control the deposition of the molten metal so that at the end of the operation there is little molten metal present. This may be done by tapering off the rate of deposition of molten metal after the bulk of the molten metal has been deposited so that in the final stages heat will be removed at a greater rate than that at which it is supplied. When this expedient is used water, or other cooling medium, may also be circulated through conduits 14.

At the end of the operation and when the whole of the metal within mold 12 is solidified, mold 12 is removed from stand 13. At this stage mold 12 is a solidified body of metal that includes an outer ring of high grade substantially flawless metal to which is integrally united a core of cast metal.

This body of metal may be subjected to working operations directly without the necessity of removing imperfections from its outer surface. Furthermore, during the working operations there is no need to handle the body with any special care as its worked tough outer skin will withstand the ordinary working operations without developing any serious imperfections.

I claim:

1. The method of manufacturing metal ingots which comprises forming a mold substantially free from surface defects with metal of the composition of the desired ingot, discharging electric current in said mold from the ends of a plurality of fusible electrodes of sufficient energy to fuse metal of said electrodes and metal of said mold into a common pool of molten metal, said electrodes all being made up of constituents of the desired ingot metal and at least one of said electrodes being of a composition different from the others, providing a blanket of flux over said discharge and said molten metal, and fusing said electrodes at rates to give said pool substantially the same composition as the desired ingot metal.

2. The method of manufacturing alloy ingots having a cast metal core surrounded by and integrally united to a protective worked metal shell of substantially the same analysis, which comprises, forming a mold of worked alloy metal substantially free from surface imperfections, depositing molten alloy metal of substantially the same analysis in the mold, the molten metal deposition being carried out in a manner to maintain the whole surface of the deposited metal in the molten condition, and simultaneously with said deposition discharging current through one or more gaps beneath the surface of a protective blanket of flux on the surface of the molten metal to fuse a depth of the mold metal at the level of the molten metal throughout its extent to unite the metals into an integral body made up of a cast metal core within a worked metal shell of sufficient thickness to protect the cast core during subsequent work deformation.

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