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MELTING METALS

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This invention relates to a process for arc melting metals and more particularly to such a process carried out employing a so-called "cold mold" type furnace.

Melting metals in a cold mold arc furnace is accomplished employing a consumable or non-consumable electrode. Feed metal or the consumable electrode is progressively melted and transferred into a cold or cooled mold or crucible in which it progressively solidifies to form an ingot. Improved homogeneity and finer grain structure in the ingot may be obtained by stirring the molten pool of metal in the crucible during melting. This is most often accomplished by provision of a solenoid coil wound around the outside of the crucible and passing direct current therethrough. The magnetic flux, generated by the coil when energized, acts to rotate and stir the molten metal in the crucible. The direction of rotation and stirring imparted depends on the direction of current flow through the solenoid coil.

While magnetic stirring, as heretofore practiced, has resulted in improved homogeneity and finer grain in the ingot, it also produces a grain pattern which results in twisting of the ingot when it is forged and this tendency may be retained even in later products. From examination of a horizontal section it can be clearly seen that the grain pattern in a stirred ingot does not radiate from the center of the ingot in a straight line arrangement, but rather in a spiral pattern. This spiral pattern apparently causes a longitudinal twisting of forgings and other wrought products fabricated from such an ingot.

It is therefore a principal object of this invention to provide improvements in the method for melting metals in a cold mold arc furnace. Another object of this invention is to provide an improved method for arc melting metals in which the metal is stirred during melting. Yet another object of this invention is to provide an improved method for melting metals in a cold mold arc furnace to produce a fine grain ingot which will not twist during subsequent fabrication into wrought products. These and other objects of this invention will be apparent from the following description thereof.

This invention in its broadest aspects contemplates melting metal in a cold mold arc furnace and stirring the metal during melting by passing electric current through a solenoid coil surrounding the mold in the furnace. The magnetic field generated stirs molten metal in the mold. Periodically the direction of flow of electric current passed through the coil is reversed which reverses the direction of the magnetic flux in the magnetic field generated by the coil, and acts to reverse the direction of stirring of metal in the mold. The magnetic field acts to stir molten metal in the mold by causing a rotation about the vertical axis of the mold, the direction of rotation being reversed each time the direction of current flow in the coil is reversed.

The amount of current passed through the coil is not critical and may be adjusted to provide adequate or desirable velocity in the stirring metal.

The time periods during which the current flow is passed through the coil in each direction are however critical. These periods should each be greater than the time required to slow down and stop the metal rotating in its original direction and to impart rotary motion in the opposite direction. The reversal period will vary depending largely on the amount of metal molten in the mold, the

strength of the magnetic field and the internal diameter of the mold. Thus for a 12 inch internal diameter mold when melting metallic titanium and with a stirring field of 30 gausses at the center line the time required for stirring reversal was about 10 seconds. For a 28 inch mold melting titanium and using a stirring field of 15 gausses the time required for reversal would be about 3 minutes.

The minimum period for stirring under any conditions may readily be determined by stirring the metal under melting conditions and then reversing the direction of current flow through the stirring coil and observing the action of the pool of molten metal. This is readily accomplished by sighting through a suitable dark glass peep hole in the side of the furnace, and the time required for the reversed current flow to stop metal rotation in its original direction and to accomplish rotation thereof in the opposite direction may be easily determined. Preferred operation according to this invention requires stirring in each direction for periods greater than the time required for the magnetic field to reverse the direction of metal stirring in the mold.

Preferably the stirring periods in each direction should be substantially equal to avoid lengthwise non-uniformity of grain pattern in the ingot.

If each period of stirring is sufficiently long so that an appreciable amount of metal, and corresponding ingot length, is allowed to solidify during such period, the overall twisting tendency during subsequent working will be eliminated, but the ingot may have individual adjacent sections with tendencies to twist in opposite directions. I have discovered that it is possible to produce a completely straight ingot without any twisting tendencies and with uniform longitudinal grain pattern by also employing a critical upper limit to the length of each period of stirring during which the current is passed through the stirring coil in each direction. The upper limit of these periods is related to the minimum time needed for complete reversal of the stirring metal direction as described hereinbefore in each cycle, and should not be greater than about 30 times such time period. Preferably, in order to avoid mechanical and electrical difficulty in providing too rapid changes of direction in current flow through the stirring coil, and to provide most desirable ingot grain pattern and straightness, the periods of current flow in each direction through the stirring coil should be between 2 and 20 times the time required for the magnetic field to reverse the direction of metal stirring in the mold.

The following example will illustrate an embodiment of the practice of this invention.

Example 1

A cold mold arc furnace having a 12 inch internal diameter mold was employed for melting a titanium alloy containing 6% Al and 4% V in the form of a solid electrode 8 inches in diameter.

A copper solenoid coil was wound around the outside of the crucible and connected to a source of D.C. electric power at about 50 volts to provide a magnetic field. Current flow of 2 amperes provided a field of about 30 gausses at its center line.

In a preliminary melt, the electrode was melted employing 6000 amperes of electric power at 24–30 volts. Rotation of the pool of molten metal was observed through a peep hole in the furnace wall and then the D.C. power connections to the ends of the coil were reversed, thus reversing the direction of flow of current through the coil. The pool of molten metal was observed to slow down, stop and then start rotating in the opposite direction. The time required for reversal of rotation direction, that is, from the time the power leads to the coil

were reversed until full rotation in the opposite direction was observed, was 10 seconds. Melting was then stopped.

A new 8 inch electrode of similar titanium alloy was inserted in the furnace and melted into an ingot under the same operating conditions described above. The direction of current flow through the coil surrounding the mold was reversed every 30 seconds during the melting operation. The ingot produced in a 50 minute melting time was 20 inches long and weighed 350 pounds. The ingot was sectioned transversely and the section surfaces were polished and etched and showed no evidence of spiral grain pattern. A similar ingot melted under identical conditions showed no tendency to twist during subsequent forging.

Metals which may be melted by the process of this invention will be those which are necessarily or advantageously melted by an electric arc including among others titanium, zirconium, niobium, tantalum, molybdenum, tungsten, vanadium, and alloys of which they constitute the base metal as well as various steels and so-called superalloys.

The process of this invention eliminates twisting of ingots during forging and improves their grain structure. Surprisingly, the grain size is smaller and more uniform than when the pool of molten metal is stirred continuously in one direction. It will be appreciated that while the molten pool is undergoing change of stirring direction, its velocity slows down from maximum in the original direction to essentially zero and then accelerates to full velocity in the opposite direction. Since most effective stirring effect is not obtained at the lower velocities it is important for best results in grain size reduction to provide periods of stirring in each direction which provide some time for stirring at full velocity. Therefore, periods

of from 2 to 20 times the time required for reversal of the direction of rotation of the molten metal will provide the best over-all effect and desirable properties in the so-produced ingot.

I claim:

1. In a process for melting metal in a cold mold arc furnace the improvement to produce an ingot which will not twist during subsequent fabrication into a wrought product which comprises; stirring said metal while molten in the mold of said furnace by means of a magnetic field generated by passing electric current through a coil surrounding said mold and periodically reversing the direction of flow of current passed through said coil thereby periodically reversing the direction of the flux in the magnetic field acting to stir said metal, the periods of current flow in each direction through the coil being greater than the time required to reverse the direction of metal stirring in the mold and less than thirty times such time.

2. A process according to claim 1 in which the periods of current flow in each direction through the coil are between twice and twenty times the time required to reverse the direction of metal stirring in the mold.

3. A process according to claim 1 in which the periods of current flow in each direction through the coil are substantially equal.

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