United States Patent

Uziie et al.

[15] **3,683,997**

[45] **Aug. 15, 1972**

[54] **ELECTROSLAG REMELTING PROCESS**

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[73] Assignee: **Metsubishi Jukogyo Kabushiki Kaisha,** Tokyo, Japan

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[21] Appl. No.: **151,497**

Related U.S. Application Data

[63] Continuation of Ser. No. 782,034, Dec. 9, 1968, abandoned

[52] **U.S. Cl.** **164/52,** 164/252, 164/85

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

[58] **Field of Search**.....164/50, 51, 52, 82, 85, 250, 164/251, 252, 273, 273 M, 281; 75/10 C

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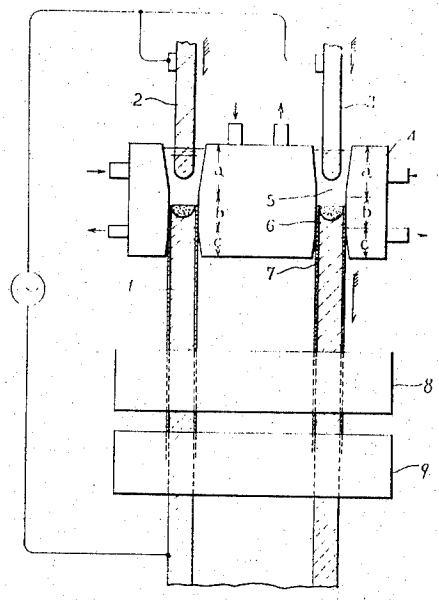
[57] **ABSTRACT**

A continuous electro-slag remelting process wherein metal electrodes are fed into a metal mold having the same shape in cross section as the product to be formed, the metal electrodes being melted in an electroslag bath and the molten metal thus obtained being solidified in the metal mold, and continuously drawn out. A large number of wire-shaped and/or plate-shaped metal electrodes are so arranged as to approximate the shape in cross section of the product to be molded.

3 Claims, 10 Drawing Figures



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SHEET 1 OF 4

FIG. 1

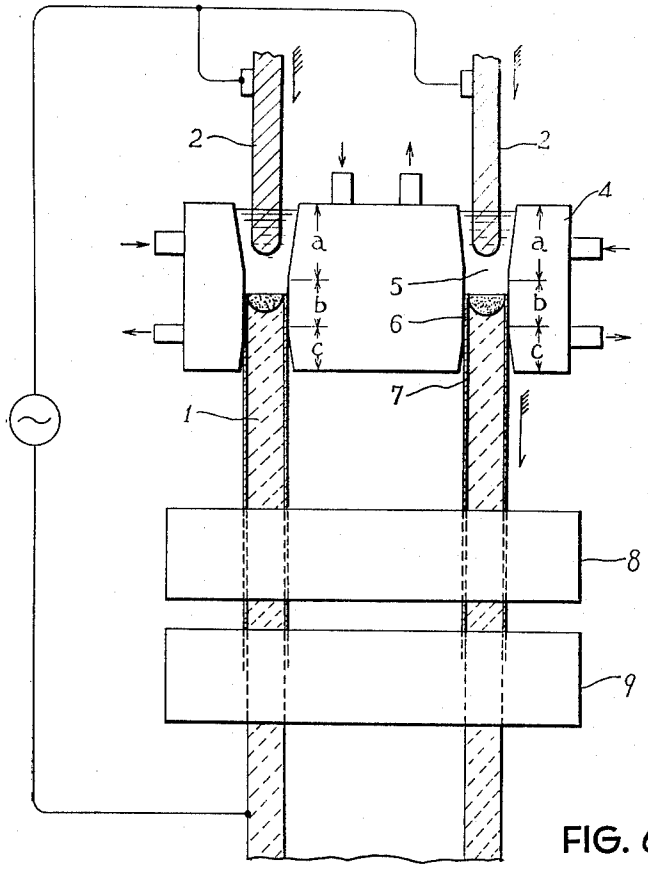

FIG. 6

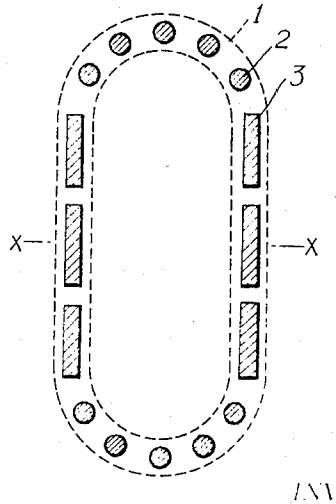

FIG. 5

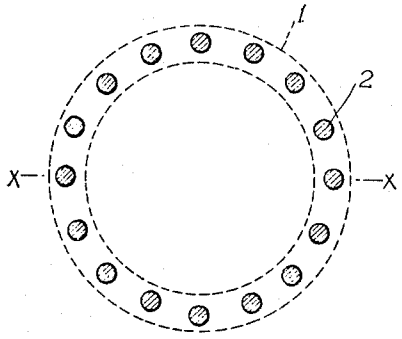

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FIG. 2

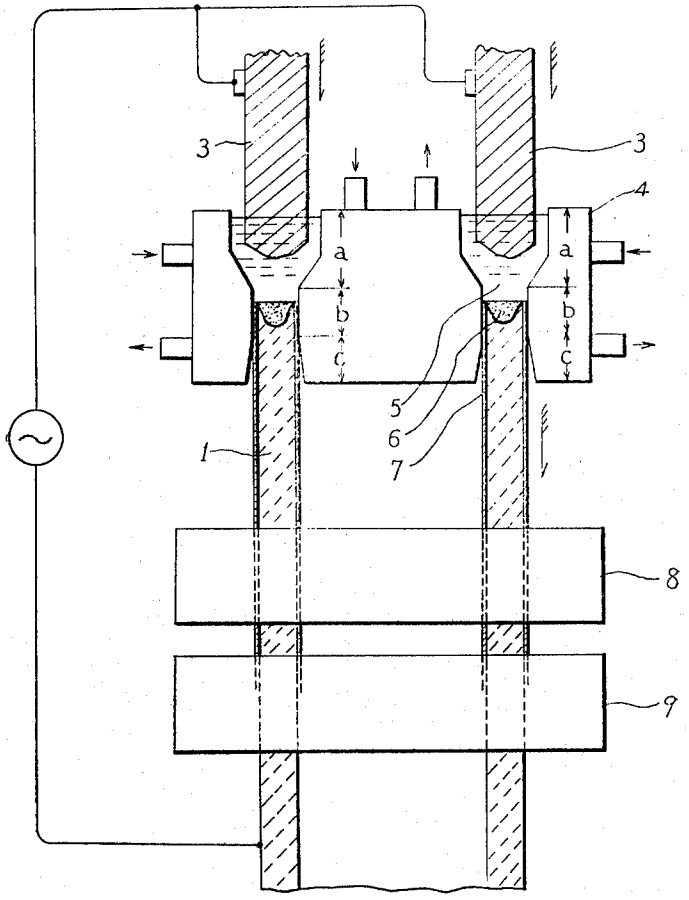


FIG. 7

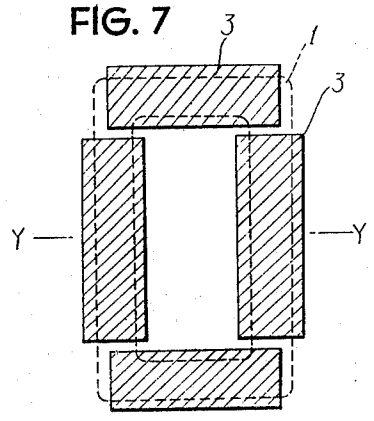


FIG. 3

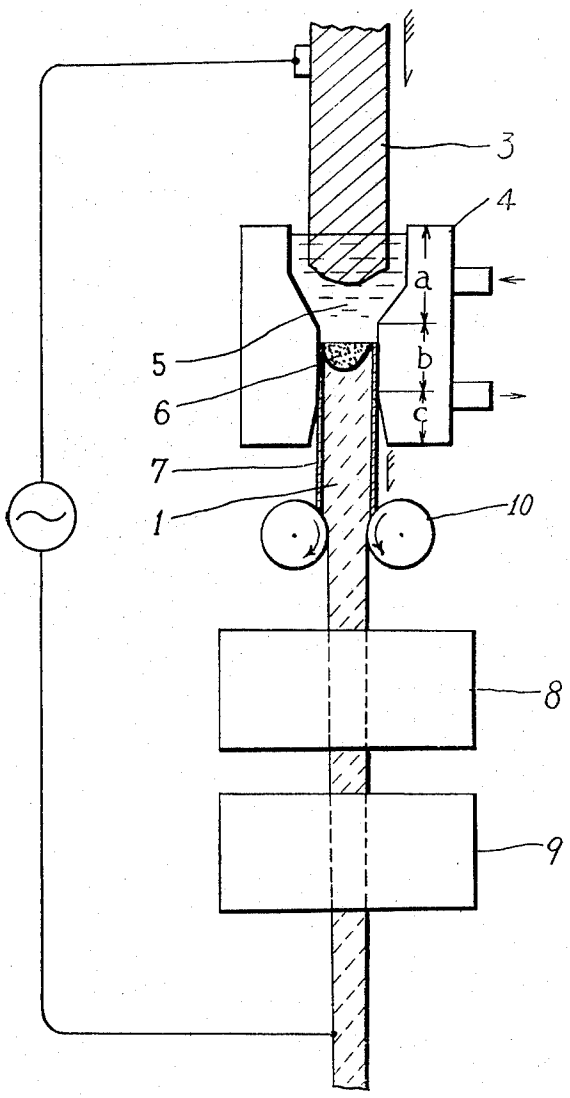


FIG. 8

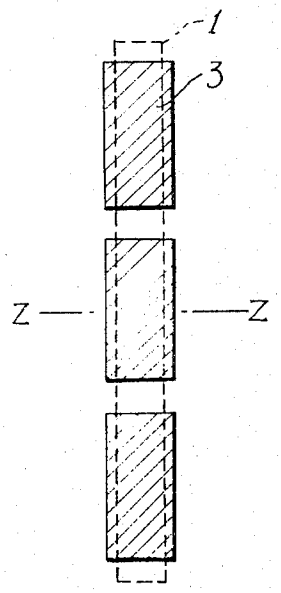


FIG. 9

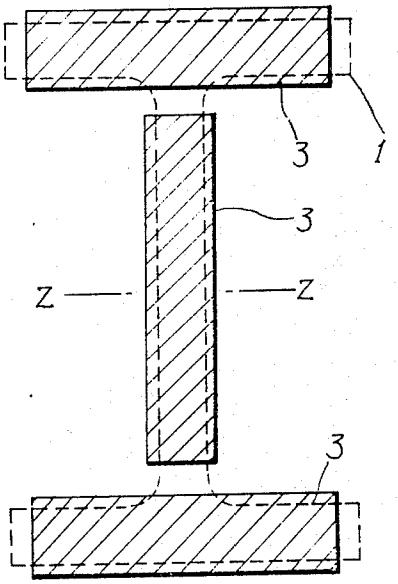


FIG. 4

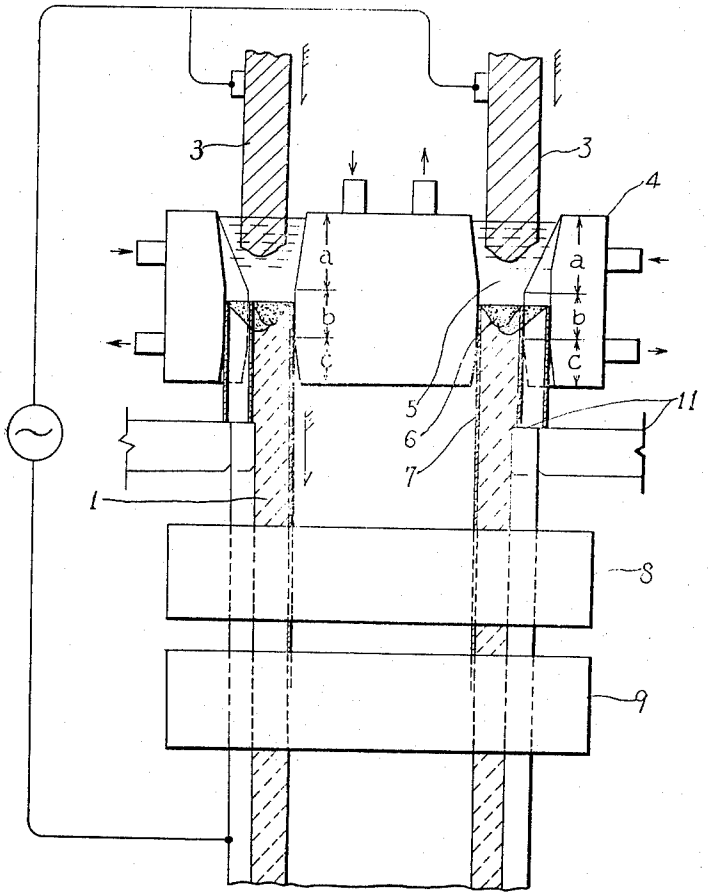
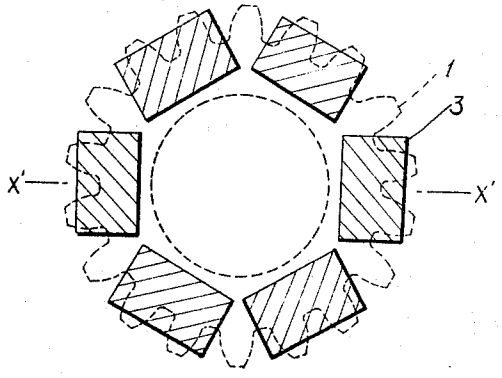


FIG. 10



ELECTROSLAG REMELTING PROCESS

This application is a continuation of Ser. No. 782,034, filed Dec. 9, 1968, now abandoned.

FIELD OF THE INVENTION

This invention relates to a continuous electro-slag remelting process for accurately manufacturing products as gear materials of fairly complicated cross-sectional shape, regardless of size.

BACKGROUND OF THE INVENTION

For example, when manufacturing long objects of the same cross section throughout such as a bar, tube or the like, it has heretofore been the common practice to sour melted metal from a melting pot into a mold where the melted metal is hardened, and to then continuously draw it out by the so-called continuous casting method. Alternatively metal electrodes are fed into a metal mold, melted in an electroslag bath, solidified in the mold and continuously drawn out by the so-called melt-molding method.

However, in the case of the first example, the maintenance of suitable temperature of the melted metal is not always sufficient, especially since the supply of melted metal is periodic to the pouring ladle the supply pressure is usually reduced and the metal temperature is liable to be lowered therefore the molds are made of graphite which has good heat maintenance but the mold is easily damaged and worn out.

With regard to the composition of the metal to be melted, it is possible to obtain tube or other configurations, fairly complicated in cross section, by using good-casting and non-ferrous metals or cast iron, whilst casting steels are merely capable of being formed into very simple shapes substantially uniform in cross section.

Turning now to the second example, i.e. the conventional and continuous electro-slag remelting method wherein metal electrodes are melted in a metal mold, because of the heat source in the mold it is usually of the water cooled type so that it is only possible to form only circular or rectangular cross-sectional shapes of large size, always of simple cross section. To form shapes of small and/or complicated cross-sectional shape is extremely difficult.

SUMMARY OF THE INVENTION

In view of the above-mentioned drawbacks, it is the primary object of the present invention to provide a method of accurately forming shapes fairly complicated in cross section and having little if any regard for the size.

The essentials of the present invention consist in feeding metal electrodes into a metal mold having the same shape in cross section as that of the product to be formed and melting the metal electrodes in an electroslag bath so that the melted metal thus prepared is hardened in the metal mold. Then continuously drawing the hardened metal out of the mold. A large number of wire-shaped and/or plate-shaped metal electrodes are utilized as the metal electrodes and are so arranged as to basically correspond to the cross-sectional shape of the product to be formed.

Thus, according to the above-mentioned arrangement of a large number of wire-shaped or plate-shaped metal electrodes alone or in suitable combination, these metal electrodes are fed into a metal mold having the same shape in cross section of the product being formed, and the melted metal in the metal mold keeps a uniform temperature and the distribution of the melted metal becomes uniform so that it is possible to accurately form any shape or material, regardless of cross-sectional, whether or not fluidity and casting properties of the melted metal is sufficient and regardless of the complexity in cross section.

The invention will be explained in detail by way of a few embodiments hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** to **4** are views in vertical section of apparatus for carrying out different embodiments of the present invention.

FIGS. **5** to **10** are plan views showing relative positions of the metal electrodes vis-a-vis the product configuration arranged such that the combined cross-sectional area of the metal electrodes approximates that of the product being produced.

DETAILED DESCRIPTION OF THE INVENTION

In FIG. **1**, reference **1** designates a hardened hollow tubular shape being downwardly drawn out, **2** represents number of wire-shaped metal electrodes which are hung down and fed from above as shown by the arrow, and **4** is a water-cool metal mold into which cooling water can be fed and from which it can be discharged as shown by the arrows. In this respect, FIG. **5** shows the relative position of the hollow tubular shape **1** and the metal electrodes **2**. It will be seen that a large number of parallel metal electrodes **2** depend into the metal mold **4** and are so arranged as to approximate the shape in cross section of the hollow tubular shape **1**, being formed.

The portion *a* of metal mold **4** serves as a reservoir for a melted slag bath **5** and decreases in cross-sectional area in the casting direction.

The portion *b* of metal mold **4** contains a melted metal pool **6**, where melted metal begins to solidify, and the radially inner and outer molding walls take the form of concentric cylinders.

The portion *c* of metal mold **4** increases in cross-sectional area in the casting direction so that the hollow tubular shape can be easily drawn out, even when contracted due to its solidification.

Reference numeral **7** designates a slag coating formed on the surface of the tubular shape **1** in hardened condition.

In the above-mentioned arrangement, when forming the tubular shape **1**, a starter piece (not shown) having nearly the same cross-sectional shape as the tubular product **1** is inserted into the portion *b* of metal mold **4**, a large amount of flux is introduced onto the upper surface of the start piece, and then the metal electrodes **2** are energized so that the flux is melted by the arcing of the metal electrodes **4** to form a molten slag bath **5** in the portion *a* of metal mold **4**.

The start piece is adapted to be actuated by suitable lowering means or driving rollers so that it can be lowered together with the solidified tubular material **1**.

After forming the above-mentioned molten slag bath **5**, a number of metal electrodes **2** are fed therein so

that the molten drops of metal, formed by melting the metal electrodes **2**, are allowed to drop down into the molten slag bath **5** so they can be collected in the molten metal pool **6**.

The portion *a* of metal mold **4** may be cylindrically shaped by extending the cylindrical portion *b*, but it is preferable to have it shaped as shown in FIG. **1**, in order to increase the capacity of the molten metal slag bath **5**.

Although the surface of the molten metal in the pool **6** is larger than the cross-section of the tubular shape **1** due to heat expansion and the slag coating **7**, the melted metal solidifies and contracts in portion *b* of the metal mold **4** whereby the cross-sectional size of tubular shape **1** is determined.

Since the portion *b* is cylindrical, no trouble occurs during the hardening procedure even when the solidification front is slightly changed up or down.

At the same time, since the slag coating **7** is formed in the portion *b*, and the molten metal during its solidification is at a fairly high temperature, the slag coating **7** serves as a lubricating fil, when removing the solidified metal from metal mold **4**.

The tubular shape **1** thus hardened, is drawn from the metal mold **4** by lowering means or rollers (not shown in the drawing).

At the same time, since the portion *c* has an inverted funnel shape, the draw-out operation of the tubular shape **1** is simplified. Moreover, during the drawing a heating means can be made available in case of need in the form of a heater **8**, which heater may electric or a gas burner. Furthermore a cooler **9** taking the form of a water spray or an air blast may be provided.

All the above-mentioned embodiments refer to the arrangement where a number of wire-shaped metal electrodes **2** are provided in a manner approximating the configuration in cross section of the tubular shape **1** as shown in FIG. **5**. Such an embodiment permits the forming of the hollow tubular shape **1**.

Alternatively, when the shape to be formed consists of an arcuate portion when viewed and a straight linear portion in cross section, as shown in FIG. **6**, a large number of wire shaped metal electrodes **2** are so arranged as to approximate the arcuate portion and also a large number of plate-shape metal electrodes **3** are so arranged as to approximate the straight linear portion.

The following are two examples for forming circular pipes, 150 mm in internal diameter and 14 mm in wall thickness. 1. Eighteen electrodes made of high-carbon 25 Cr–20 Ni stainless steel, 3.2 mm in diameter are arranged at intervals of 30 mm within the cross-sectional perimeter of the circular pipe to be produced. Then electric current, 2,200 Amperes and 50 Volts is supplied to the electrodes so that the operation can be carried out at a rate of 13 mm/min. 2. Eight electrodes made of high-carbon, 25 Cr–20 Ni stainless steel, 6 mm in thickness and 45 mm in width are arranged at equal intervals within the cross-sectional perimeter of the circular pipe to be formed. Then electric current, 1,800 Amperes and 40 Volts is supplied to the electrodes so that the operation can be carried out at the rate of 13 mm/min.

According to the method of the present invention, it is possible to use metals of poor fluidity and castability, the use of which has heretofore not been considered feasible. Thus the above mentioned high-carbon 25 Cr–20 Ni stainless steel is such a material, it has been formed by the usual casting or centrifugal casting methods whereas its use in electroslag remelting has been considered impossible heretofore.

The products obtained by the method of the present invention have an accuracy not obtainable by usual methods, for example in case of circular pipe, of, 50 mm in internal diameter having 10 mm wall thickness ± 0.5 mm the accuracy is Further embodiments will now be discussed and like numbers designate like elements.

The apparatus shown in FIG. **2** is used for melt-molding a box-shape product **1** of small thickness in cross section as shown in FIG. **7** instead of the tubular shape **1** as shown in FIGS. **1** and **5**.

In this embodiment the metal electrodes are so arranged as to approximate the cross-sectional shape of the box-shape product, the metal electrodes **3** are plates of larger thickness than the walls of the box-shape product **1**. These electrodes are accommodated in the portion *a* of the metal mold **4** which is in the form of an upwardly opening funnel as seen in FIG. **2**. Thus the drops of molten metal from the metal electrodes **3** are allowed to drop down not only in the molten metal slag bath **5** but also along the inclined side walls of the portion *a* of the metal mold **4** until at length they collect in the molten metal pool **6**.

The apparatus shown in FIG. **3** is used for forming a plate shaped product **1** as shown in FIG. **8**, or a H-shaped product as shown in FIG. **9**.

In this case, as in FIG. **7**, the metal electrodes **3** is plate shaped of larger thickness than the product and furthermore in this embodiment, there are provided press rollers **10** beneath the metal mold **4** as shown in the drawing, so that the thickness of the plate-shaped product **3** or H-shaped product **3** can be immediately reduced after solidifying, thereby improving the mechanical properties of the product.

The apparatus shown in FIG. **4** is used for forming a gear shape **1** having a cross-sectional shape as seen in FIG. **10**.

In this embodiment, the mold **4** of toothed shape is employed so that a product is formed which will approximate the finished size and the predetermined finish size is obtained by drawing through a die **11**.

In summary, as shown in the aforesaid embodiments of the present invention, metal electrodes are fed into a metal mold having the same shape in cross section as the product to be formed, the metal electrodes are then molten in an electroslag bath, the melted metal thus obtained solidifying in the metal mold and being continuously drawn out therefrom. A large number of either wire-shaped and/or plate-shaped metal electrodes OO are so arranged as to approximate the shape in cross section of the product being formed.

Thus according to the above-mentioned arrangement of all embodiments of the present invention, the temperature of the molten metal is maintained uniform and also the distribution of molten metal also becomes uniform so that it becomes possible to accurately form any product, regardless of its size, or the fluidity or casting properties of the metal, or if the product has a complicated cross-sectional shape.

The spirit and scope of this invention is set forth by the appended claims.

1. A process for producing hollow metal articles by electro-slag remelting comprising the steps of providing a metal mold of a short length which consists of an inner mold member and an outer mold member, the space defined between the mold members being composed of three vertically contiguous zones, an upper annular zone with a funnel-shaped vertical cross-section which has at the lower end portion the horizontal cross-sectional shape and size of the product being produced and is expanded upwardly therefrom, a middle annular zone with a rectangular vertical cross-section adjoining the lower end of the upper annular zone and which has the horizontal cross-sectional shape and size of the product being formed, and a lower annular zone with a trapezoidal vertical cross-section adjoining the lower end of the middle annular zone and which has at the upper end portion the horizontal cross-sectional shape and size of the product being produced and is expanded downwardly therefrom;

disposing a plurality of rod-like consumable metal electrodes of a size in horizontal cross-section to approximate the horizontal cross-sectional shape of the hollow metal article being formed, said electrodes depending into said upper annular zone; inserting a starting piece having the same horizontal cross-sectional shape and size as that of the hollow metal article being formed, from the lower end of the mold up to the upper end of the middle annular zone;

connecting the lower end of the starting piece thus inserted to withdrawal means located below the mold; pouring molten slag into the upper annular zone; supplying electric power from an electro-slag remelting power source respectively to said plurality of electrodes and the starting piece thereby producing an electro-slag remelting phenomenon therebetween; feeding said electrodes from above continuously at a controlled rate so that the electrodes continuously melt at the lower end and the molten metal drops through the molten slag to form a molten metal pool on the starting piece;

allowing the molten slag to flow down and form a slag coating in gaps which are formed between the molten metal pool and the inner and outer mold members due to contraction of the metal by the cooling effect of said mold members;

continuously withdrawing the starting piece together with the metal article formed thereon from the lower end of the mold, using the slag coating as lubricant at a suitable rate so that the molten metal pool can be always maintained in the upper portion of the middle annular zone of the mold, thereby forming a hollow metal article of a desired length.

2. The process as claimed in claim 1 wherein said hollow metal article is tubular in shape and said electrodes have circular horizontal cross-sections.

3. A continuous electro-slag remelting process to accurately form complicated cross-sectional shapes comprising the steps of providing at least one consumable metal electrode of a shape and a size in cross-section to approximate the cross-sectional shape and size of the product being formed;

providing a molten slag bath in a metal mold, which mold has the cross-sectional shape of the product being produced, and introducing the electrodes into said bath;

supplying electric power to the electrodes and the mold so that said electrodes melt and the molten metal passes through said bath to form a molten metal pool in said mold;

solidifying the metal from said pool and continuously withdrawing said solidified product which has a slag coating on its outer periphery, the cross-sectional shape being produced is annular having curved and essentially linear portions;

and two groups of consumable metal electrodes are provided, the first group is circular in cross-section and the electrodes are placed over the curved portion of the shape being produced, the second group is plate-shaped and the electrodes are placed over the essentially linear portion of the shape being produced, the size and spacing of both groups combined approximating the cross-sectional shape of the mold hence the product being produced.

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