

Candidate's examination paper
(Examination paper B/1990 Electricity/Mechanics)

To: European Patent Office
München

Dear Sirs,

Re: European Patent Application No. in the name of

In response to the Official letter dated I enclose in triplicate amended and retyped pages 1, 1a, 3, 4, 4a, 5 and 6, and a fresh set of claims. I request that these replace pages 1 and 3-6 of the description currently on file, and also the claims currently on file.

The amendments made to the description and claims are in response to the Examiner's objections, and it is believed that the invention as now claimed is both novel and inventive over the cited prior art.

New claim 1 has been drafted as a combination of original claims 1 and 8. In this regard, I submit that neither Document I nor Document II discloses a channel of the kind now required by claim 1.

Although the Examiner contends in paragraph 6 of the Official letter that Document I discloses a channel of the type now claimed, Document I actually discloses the reverse. The bottom channel 21 of the prior art furnace is elongate rather than square, and the channels 8, 9, 10 are square rather than elongate. Furthermore, Document I makes no mention of the problems associated with the "pinch" effect, and does not address how to overcome it.

In contrast to Document I, Document II does mention the "pinch" effect. However, the furnace of Document II uses the effect (c.f. lines 21-22, page 1) to help dissolve the allow components, and therefore it is using the vigorous action of the pinch effect to its advantage. In a coating bath or the like, as envisaged by the present applicants, it is most undesirable for there to be any vigorous action in the bath, since this causes disturbance of the sediment and debris at the bottom of the hearth. Such disturbance will cause the dipping zone to become contaminated and hence spoil the coating results.

A description of the problems associated with the "pinch" effect was included in the present application as filed, and is now present in the application specification on page 4.

As will be appreciated by the Examiner, by overcoming the "pinch" effect (by using a channel as defined in the characterising part of claim 1) a much higher power input can be applied to the transformer winding, thus heating the metal in the furnace more quickly. This can be most beneficial during initial start-up of the furnace or, alternatively, when a sudden burst of heat is required during use.

In the light of the foregoing, I trust that the Examiner will allow this application to proceed to grant with the claims as they stand. In this regard, since claim 1 is allowable, so too must be all the dependent claims.

I take this opportunity to reserve the applicant's right to file one or more divisional applications in respect of the subject matter set out in the enclosed statement.

Yours faithfully

Enclosure Statement (re: Divisional application under Art. 76 EPC)

Independent Claims which could be used as the basis for divisional applications (under Art. 76 EPC):

1. An induction furnace comprising ... the features of the pre-characterising part of new claim 1 ... characterised in that the induction winding (10) is arranged to generate a magnetic field which rotates with respect to the core (6) axis.

This claim covers a different invention to that claimed by new claim 1. The invention of this claim is novel over the cited prior art which nowhere discloses the use of a winding which generates a rotating magnetic field. Such a field has the advantage that it drives the molten metal around the loop(s) far more efficiently than the technique envisaged in Document II, penultimate paragraph.

2. An induction furnace comprising ... the features of the pre-characterising part of new claim 1 ... characterised in that the loop has a cross-sectional area which increases linearly from one end of the loop to the other.

This claim covers a feature which is excluded from the scope of the new claim 1, but which is not disclosed in either Document I or Document II, and which the applicants may therefore wish to protect by means of a separate patent application. The feature is novel and is arguably not obvious, and may therefore be able to support a patent.

Induction Furnace

The present invention relates to an induction furnace comprising a furnace hearth, at least one channel communicating at both ends with the hearth to form a loop, and an induction heater, comprising a transformer core passing through the loop and an induction winding on the core, wherein the channel and induction heater are located under the hearth and the induction heater generates, in use, a magnetic flux intersecting a portion of the channel so as to heat metal in the channel by magnetic induction. Particularly, but not exclusively, the invention relates to such a furnace adopted for use as a zinc coating bath; such baths are used in industry for

zinc coating items as diverse as fence posts and car bodies dipping them in the bath.

The traditional zinc bath consists of a general purpose furnace for melting metal, for example a refractory pot or hearth in which the solid metal is heated up from cold by a gas heater, usually mounted below the pot; once the zinc is liquid and the bath is ready for use the gas must be switched off as the coating process produces dross, oxide and other impurities which sink to the bottom of the bath. If the bath were heated during dipping these impurities would rise by convection into the dipping zone. It is therefore important to keep the bottom portion of the bath undisturbed so that impurities may settle there.

The traditional bath has the disadvantage that plating has to be interrupted at regular intervals, firstly to reheat the zinc, which of course cools with time, and secondly to allow the impurities to be removed or to resettle after the heating. A zinc coating bath which overcomes this disadvantage is known from Document I, which makes use of induction heating.

The channels must initially be kept free of solid zinc, which could slow down convection during start-up, and after use the molten zinc must be drained by means of the plugs shown in Fig 2 of Document I, as otherwise restarting would be slowed by the solidified zinc. Since heated zinc is supplied by the heater to the top of the bath and there is little convection, a substantial temperature gradient exists which can adversely affect the quality of coated products.

Document II discloses an induction furnace wherein the channels and induction heater are positioned below the hearth. Further, this prior art also discloses the use of additional heaters which may be temporarily entered into the hearth to heat the metal during start-up. When initial heating has occurred and the channels are full of molten metal, the induction heaters are switched on. If the induction heaters are provided with high power, the so-called "pinch" effect is produced in the molten metal which results in vigorous circulation of the metal. Clearly such vigorous circulation of the molten metal would be most undesirable in a coating bath or the like.

The invention accordingly has as its object the provision of a furnace using an induction heater, the furnace requiring a minimal charge of molten metal and being usable as a zinc coating bath in which impurities are hindered from rising into the coating zone and an even temperature is maintained in this zone.

In accordance with the invention the or each loop has a constant cross-sectional area and the loop width in a direction parallel to the core axis decreases linearly with distance from the hearth, whereby the loop cross-section is elongate adjacent the hearth and square at its point furthest from the hearth. This arrangement avoids the aforementioned problem which arises in induction heaters, the so-called magnetic pinch effect. Whenever current flows in a conductor, the magnetic field which is set up exerts a compressive effect on the conductor perpendicular to the direction of the current; in a liquid conductor this effect may be great enough to cut the conductor and thereby break the continuity of the

circuit. This can be disastrous in a bath as the result is a series of shock waves through the molten metal as the circuit through the metal is interrupted and the current collapses; once the current has collapsed the pinch effect ceases and the circuit is re-established so that the process repeats itself. The resultant shock waves can damage the sensitive refractory lining of the furnace and can be dangerous to the operating personnel. By use of the above-mentioned cross-section the pinch effect can be avoided and a higher power input to the heater enabled.

The channel may consist of a single loop. Alternatively, the channel may consist of two loops, and the induction heater comprise a transformer core passing through both loops. The two loops can share a common channel over part of their lengths. The two-loop embodiment is particularly suitable if the furnace of the invention is used as a zinc coating bath as for a given throughput the speed of flow is slower.

In use of the furnace of the invention as a zinc coating bath additional precautions are preferably taken to control the speed of convection in order to prevent impurities from reaching the dipping zone, whilst maintaining an even temperature in this zone. In one embodiment, the induction winding is arranged to generate a magnetic field which rotates with respect to the core axis. The rotating magnetic field can regulate the speed of flow through the heater in accordance with the working parameters of the hearth.

Finally, in a further modification a plug is provided at the lowest point of the loop or loops and by turning off the power to the induction windings at regular intervals, the impurities can be allowed to settle and be drained off.

The furnace of the invention is as noted above particularly suitable for use as a zinc coating bath.

A detailed explanation of the invention can be found in the accompanying description and drawings.

In the drawings:-

Fig. 1 is a part sectional view of a first zinc coating bath according to the invention;

Fig. 2 is a part sectional view of a second zinc coating bath according to the invention;

Fig. 3 shows the use of a rotating magnetic field to control flow speed and direction in the Fig. 1 embodiment;

Fig. 4 shows the use of two magnetic fields rotating in opposite directions to control flow in the Fig. 2 embodiment; and

Fig. 5 shows in section a modification of the Fig. 1 bath, whilst Figs. 5a and 5b respectively show a section taken on the line V-V in Fig. 5 and cross-sections of the channel at differing locations.

The zinc coating bath shown in Fig. 1 comprises a cylindrical hearth 1 whose walls are made in known manner of a refractory layer

of substantial thickness. The refractory layer has a flat bottom to which a channel 2 with refractory walls 3 is mounted, the channel forming a loop in a vertical plane and communicating with diametrically opposite sides of the hearth bottom. The channel has a constant cross-section over most of its length but at its ends flares outwardly towards the hearth, the hearth and channel walls cooperating to minimise turbulence in the flow of the molten zinc. The refractory walls of the hearth and channel can be formed in known manner of, for example, refractory bricks, the rigidity of the assembly being assured by rings of concrete 5 with an additional outer metal casing 4 adjacent the channel.

An induction heater is located below the hearth. The heater includes a transformer core 6 of circular cross-section passing through the middle of the loop formed by channel 2. Transformer yokes, 8,9 extend around the exterior of the channel assembly and, together with the core 6, form a closed magnetic circuit for the magnetic flux generated by induction windings 10 mounted on the core. Cooling means (not shown) surround the windings and serve to prevent the build-up of excessive heat.

The windings serve to generate an axial magnetic field which permeates the transformer core and yokes; this axial field penetrates the molten metal and in known manner induces heating currents in it. The windings also generate a rotating magnetic field which serves to regulate the circulation of the molten zinc inside the channel. Referring to Fig. 3, it will be seen that the ...

Claims

1. An induction furnace comprising a furnace hearth (1), at least one channel (2;2a,2b,2c) communicating at both ends with the hearth (1) to form a loop, and an induction heater (6,8,9,10; 6,8,10), comprising a transformer core (6) passing through the loop and an induction winding (10) on the core (6), wherein the channel (2;2a,2b,2c) and induction heater (6,8,9,10; 6,8,10) are located under the hearth (1) and the induction heater (6,8,9,10; 6,8,10) generates, in use, a magnetic flux intersecting a portion of the channel (2;2a,2b,2c) so as to heat metal in the channel (2;2a,2b,2c) by magnetic induction, characterised in that the or each loop has a constant cross-sectional area along its length and that the loop width in a direction parallel to the core (6) axis decreases linearly with distance from the hearth (1), whereby the loop cross-section is elongate (21) adjacent the hearth (1) and square (20) at its point furthest from the hearth (1).
2. An induction furnace as claimed in claim 1, characterised in that the channel consists of two loops (2a,2b,2c), and that the induction heater comprises a transformer core (6) passing through both loops.
3. An induction furnace as claimed in claim 2, characterised in that the two loops (2a,2b,2c) share a common channel (2c) over part of their lengths.

4. An induction furnace as claimed in any one of claims 1-3, characterised in that the induction winding is arranged to generate a magnetic field which rotates with respect to the core axis.
5. An induction furnace as claimed in any preceding claim, characterised in that the or each loop has at its lowest point a plug (25) closing an opening through which molten metal and/or impurities may be drained.
6. A zinc coating bath comprising an induction furnace as claimed in any preceding claim.