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(54) Quenching anode effect by anode rocking.

(57) A method of quenching anode effect during the production of aluminium by electrolytic reduction by tilting the anode about a suitable axis for a short period, as soon as anode effect has started, so that the wearing surface of the anode forms an angle of 0.1–20° C with the horizontal, and subsequently returning the anode to its normal position; said method being called "anode rocking".

The orders to start or stop, as well as the duration and the scope of anode rocking, are given by a control device which measures the voltage across the electrolytic cell, or some other suitable parameter, and compares it with a preset value. This control device also organizes the usual operating manoeuvers for the pot line. Simultaneously with the tilting operation, or whilst stationary in the inclined position, the anode may also be moved up and down. During anode rocking, the angle formed by its wearing surface with the horizontal can vary.

By the method according to the invention, the duration of the anode effect can be substantially reduced with consequent reduction in the energy consumed by the electrolytic process, thus improving the economy of the operation.

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Quenching anode effect by anode rocking

This invention relates to a method of quenching anode effect during the production of aluminium by electrolytic smelting. The invention is particularly suitable for the automatic operation of pots and potlines.

Aluminium is normally produced by the Hall-Heroult method which involves the use of an electrolytic cell operating in the temperature range 950^{o} - 980^{o} C, decomposing alumina dissolved in a bath of molten cryolite. Normally, over 100 such cells or pots are connected in series.

The individual electrolytic cell consists of a flat vessel with low sides, built of steel plates. Inside this steel shell there is a refractory layer which surrounds a carbon lining. The carbon lining contains the molten bath, which consists of cryolite with various additives. The carbon walls of the vessel are usually covered with frozen bath which continues some way out along the bottom. Most of the carbon bottom is free of frozen bath and serves as the cathode. The entire bottom is covered with molten aluminium, extracted from the alumina, and this aluminium has a higher specific gravity than the molten bath.

The anode, which is made of carbon, is partly immersed in the bath which, as mentioned above, consists mainly of molten cryolite and dissolved alumina. The distance between the bottom of the anode and the molten metal on the cathode is called the ACD (anode-cathode-distance) or the interpolar distance and is in the region of 2-7 cm.

The bath can also contain other substances to influence the solubility of the alumina and the freezing point of the bath. This subject is discussed in a number of publications, but, as will be understood, these additives are of no interest in connection with the present invention. The bath around the anode is covered with a crust of frozen bath. On top of this crust the alumina is laid so that it is pre-heated before being pushed down into the bath.

During normal operations, the electrolytic reduction process takes place with a voltage drop from anode to cathode of between 4 and 6 V, depending upon the cell design chosen. At the beginning of the reduction process the concentration of the alumina in the bath can lie around 6-8 %. The electrolytic process decomposes the alumina. The metal thus extracted sinks down on to the cathode, whilst the oxygen is liberated on the underside of the anode. The anode is thus oxidized and is consumed, whilst at the same time the alumina content is the bath is reduced. When the alumina concentration in the bath falls below a certain critical value - about 2 % - depending upon the temperature of the bath and the current density of the anode etc., the steady electrolysis process is replaced by an anode effect. This reveals itself in the form of a sudden increase in the resistance of the electrolytic cell, which in the course of seconds can increase tenfold. This increase in resistance is normally attributed to a layer of gas under the anode, see for example Norwegian Patent No. 123318, or U.S. Patent application No. 676500 dated 19/10/1967.

Attempts have been made in order to avoid the occurrence of the anode effect by changing the composition or shape of the anodes or by changing the used electrolytic cell equipment. Such an attempt is known from the U.S. Patent 3,501,386. In this patent various methods are described to provide an inclined wearing surface of the anode during the whole process of reduction of alumina in the electrolytic reduction cell. Most of the mentioned methods concern improvements in the composition and shape of the anodes, but there is also a method for tilting the anodes mechanically by means of an especially constructed anode supporting and tilting apparatus. By this method the anodes of the reduction cell are kept in an inclined position at least until the lowered under surface is flattened because of the different electrical load of the different parts of the anode, whereby this flattening,depending upon the angle of inclination of the anode will normally occur after 1 to 24 hours. After the wearing surface of the anode being flattened, the anode is tilted in a different way, in order to provide an inclined under surface again.

Since these methods require complicated and expensive equipment either for the production of the special anodes or for keeping the anodes in a tilted position during the whole electrolysis, and because of some disadvantages in connection with the unbalanced current density in the reduction cell during the whole reduction process, none of the methods according to U.S. Patent No. 3,501,386 are in practical use, as far as the applicant knows.

In practice, methods are preferably used which allow to recognize and quench or terminate an ocurring anode effect as immediately as possible.

To indicate the presence of an anode effect an electric incandescent lamp is connected across the cell. It lights up on anode effect because of the higher voltage. The normal practice is to endeavour to quench or terminate an anode effect as soon as possible, because it brings with it a number of disadvantages. The sharp increase in resistance can result in a loss of energy in other pots in the series , thus disturbing operations. The extra energy resulting from this higher resistance causes the pot undergoing anode effect to heat excessively causing the electrolyte to evaporate with consequent large direct loss of bath vapours, mainly fluorides. This emission of fluorides to the atmosphere requires costly scrubbing.

If an anode effect is allowed to remain active too long, the operation of the pot is substantially disturbed and this requires extra efforts on the part of personnel to bring the pot back into normal operation, whilst at the same time output falls.

To quench anode effect, the alumina concentration in the bath under the anode must be raised. The previous method of doing this was that the operator manually broke the crust around the anode, whereby the alumina which had been laid on top of the crust for pre-heating, fell down into the melt. The operator used a heavy iron implement to mix the alumina into the bath and then to rake under the anode with vigorous movements. Another method of quenching anode effect was to knock a hole in the crust and insert a wooden pole down into the bath under the anode. The gas liberated from the pole resulted in a powerful stirring of the bath, thus quenching the anode effect. The pole has subsequently in a number of instances been replaced by an air lance, i.e. a tube which is used to blow compressed air down into the bath und thus to bring about a particularly vigorous stirring under the anode.

These methods of quenching anode effect require heavy work in a hot and gas-filled atmosphere. A number of attempts have therefore been made to mechanize and automate these operations.

British Patent No. 853056 describes a method whereby an audiofrequency vibrator is used for quenching anode effect. How this procedure quenches anode effect is not explained.

In U.S. Patent No. 2,560,854 a procedure is described for terminating anode effect by slowly swinging the anode from a region in the electrolyte with low concentration of alumina to a region with a higher alumina concentration. It is clear that this method will mix alumina and bath und thus help to quench the anode effect, but it requires complicated and expensive equipment.

Norwegian Patent No. 123318 discloses a method of quenching anode effect which is built on the principle that the entire anode is lowered to between 30 and 6 % of the normal interpolar distance and then raised again. This lowering is started when the voltage drop across the cell exceeds 150 % of the normal working voltage, and the anode is raised again under the control of a timing device incorporating a cam mechanism. Whilst the anode is in its lower position, an apparatus for feeding alumina to the bath is activated, so that an alumina concentration of 2-6 % in the bath is achieved. This procedure will doubtless reduce the amount of manual work involved in quenching anode effect, but it has nevertheless certain disadvantages. When the anode is lowered, the level of the bath rises because the anode must of necessity displace fluid. The pot shells have therefore to be somewhat higher than usual. As the bath rises, it will come into contact with the crust along the sides of the pot. This will, in time, result in a mixing of bath and alumina which solidifies forming a crust. This crust will have better heat conductivity than pure alumina and will thus lead to heat loss along the sides. In those cases where bath overflows in connection with this so-called anode pumping, the heat content in the bath which flows out over the crust will be dissipated to the surroundings and the spilt bath causes extra work.

In modern smelters, computers are used to control many of the pot operations. An important parameter in control strategy is the reference resistance of a pot. This is around 20 $\mu\Omega$ and is defined as the pot voltage minus the decomposition voltage divided by the potline amperage.

In addition to the disadvantages inherent in NP 123318, there is also the increase in the reference voltage, which means a higher consumption of energy in production.

The inventors have now found a method of quenching anode effect, whereby the above mentioned difficulties are avoided. The principle of the method is that the anode is temporarily lowered at the one end whilst at the same time the other end is raised, when anode effect has ocurred and is to be quenched. In other words, instead of lowering the entire anode, only a part of it is lowered, whilst the opposite end is raised. The anode is thus for a short period rocked about an axis, which axis may lie either in the longitudinal direction of the anode or in the transverse direction. This method is called anode rocking and has obvious advantages: 1) The surface of the bath remains at the same level. The bath will merely flow from the one end to the other. This can be advantageous for mixing of low and high alumina concentration in the bath. 2) The wearing face of the anode will be inclined, so that the gas and the gas film can more readily escape. 3) It is not necessary to make the cathode shells higher in order to contain the bath. 4) The energy consumption is kept down because the thermal insulation efficiency of the crust is not impaired by its being mixed with molten bath and alumina. 5) The loss of energy through molten bath flooding over the crust is avoided. 6) There is no spilling of bath on to the floor.

The method of quenching anode effect according to the invention as characterizing step contains the placing of the anode into an inclined position for a short period when anode effect has started, so the wearing surface forms an angle of 0.1 - 20° with the horizontal and placing it then back into its normal position.

The wearing surface of the anode can be held stationary in the inclined position during the lasting of the anode effect, that is usually for about 1-120 sec, and for an additional preset period of about 1-120 sec.

The anode also can be moved up and down in the inclined position for a predetermined period of a few seconds to about 3 minutes.

The anode also can be moved so that the angle formed by its wearing surface with the horizontal varies for a predetermined period of a few seconds to about 3 minutes. The above indicated possibilities of anode rocking can be parts of a working programme. In a preferred embodiment of the method according to the invention such a working programme can comprise the following steps: Rocking of the anode, when anode effect has started for a period of about 1 - 80 sec, whilst the anode is in an inclined position, followed by a resting period of about 60 sec, whereafter, in case that anode effect does not reoccur, the anode is placed back into its normal position.

In case that after the resting period anode effect does reoccur, the inclined anode is lowered for about

10 mm for a short time,for example 10 sec, and is then placed back into its normal position.

The order to start or stop and also the duration and scope of anode rocking are preferably given by a control device which measures operational characteristics and organizes the other operating manoeuvres for the pot line, whereby the measured operational characteristic preferably is the voltage across the cell. When this voltage exceeds a certain preset value, anode rocking is initiated.

It is obvious that the performance of anode rocking imposes certain requirements on the mechanical equipment, but the type of equipment in general use today in modern pots can usually be readily adapted, only minor additional installations being required.

The anode is usually suspended in jacks, which are operated by lifting motors at each end of the anode. These motors have to be operated independently of one another, only through impulses from a common control device.

The working programme for anode rocking can be easily fitted into existing programmes.

The work rhythm for a modern potroom prepared for the quenching of anode effect by anode rocking will comprise the usual operations in the usual sequence: alumina feed onto the crust, crust breaking outside anode effect and crust breaking during anode effect, followed by anode rocking.

Even if these operations are performed in all potlines, the routines will not be identical in the different plants.

On the basis of trials, the inventors have arrived at a preferred work method, being a preferred embodiment of the method according to the invention.

On the occurrence of anode effect , i.e. on exceeding a preset cell voltage (reference voltage), anode rocking is initiated by a control device, and preferably lasts from 1-80 sec, whilst the anode is in an inclined position. This is followed by a resting period of preferably about 60 sec to see whether the anode effect will reoccur. If it does not so, the control device completes the order cycle for anode effect quenching by straightening up the anode and placing it into its normal position. Should, on the other hand, occur a new anode effect, the anode will be lowered about 10 mm, whilst still in the inclined position, but will be returned into normal position after a short time, for example 10 sec, whereupon the order cycle will be terminated by straightening up the anode.

The times and durations stated here refer to given pot equipment. It will be obvious that the invention can equally well be performed using other parameter values with this reducing the scope of the invention.

During anode rocking, it has proved that the lowest part of the anode carries a considerably higher current than normal, 100 % or more, but, surprisingly enough, in the method according to the invention, this has not proved to have any harmful effect. Neither has it been found that anode rocking has had any adverse mechanical consequences or operational complications.

It is pointed out that the desired effect, the quenching of anode effect is probably due to two aspects of anode rocking: 1) On the occurence of the anode effect the bath is set in motion in a manner which will lead to the mixing in of bath with a higher alumina content under the anode. 2) When the anode is placed into an inclined position, it is easier for gas bubbles and film under the anode to escape.

Temporary movement of the bath will also be favourable to promote the escape of gas film and bubbles. To achieve the desired effect, the wearing face of the anode must adopt an angle of between 0.1 - 20° from the horizontal.during such a movement.

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Claims:

1. A method of quenching anode effect when producing aluminium by electrolytic reduction, characterized in that the anode, when anode effect has started, for a short period is placed into an inclined position, so that the wearing surface forms an angle of 0.1 - 20° with the horizontal, and is then placed back into its normal position.

2. A method according to claim 1, characterized in that the wearing surface of the anode is held stationary in the inclined position during the lasting of the anode effect plus a preset period of about 1-120 sec.

3. A method according to claim 1, characterized in that the anode is moved up and down in the inclined position for a predetermined period of a few seconds to about 3 minutes.

4. A method according to claim 1, characterized in that the anode is moved so that the angle formed by its wearing surface with the horizontal varies for a

predetermined period of a few seconds to about 3 minutes.

5. A method according to claims 1 to 4, characterized in that the anode, when anode effect has started, is rocked for a period of about 1 to 80 seconds, whilst the anode is in an inclined position followed by a resting period of about 60 sec, whereafter in case that the anode effect does not reoccur, the anode is placed back into its normal position.

6. A method according to claims 1 to 4, characterized in that the anode, when anode effect has started, is rocked for a period of about 1 to 80 seconds, whilst the anode is in an inclined position, followed by a resting period of about 60 sec, whereafter in case that the anode effect does reoccur, the inclined anode is lowered for about 10 mm for a short time and is then placed back into its normal position.

7. A method according to claims 1 to 6, characterized in that the order to start or stop and also the duration and scope of anode rocking are given by a control device which measures operational characteristics and organizes the other operating manoevres for the pot line.

8. A method according to claim 7, characterized in that anode rocking is initiated by the voltage across the cell when this voltage exceeds a certain preset value.

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EUROPEAN SEARCH REPORT

Application number
EP 79 10 1144

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
A	US - A - 2 061 146 (L. FERRAND)		C 25 C 3/06
A	FR - A - 2 083 362 (G. FACSKO)		

TECHNICAL FIELDS SEARCHED (Int.Cl. 3)

C 25 C 3/06
3/20

CATEGORY OF CITED DOCUMENTS

- X: particularly relevant
- A: technological background
- O: non-written disclosure
- P: intermediate document
- T: theory or principle underlying the invention
- E: conflicting application
- D: document cited in the application
- L: citation for other reasons

&: member of the same patent family, corresponding document

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	13-12-1979	GROSEILLER