Proceedings of Iran International Aluminium Conference (IIAC2018)
April 24-25, 2018, Tehran, I.R. Iran

A Brief Analysis of the Effect of Aluminium Reduction Pot Power Outage and the Treatment Measure

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Abstract: A stable and continues supply of direct current electricity is a prerequisite for the operation of aluminium reduction pots. Occurrence of power outage poses a significant impact on both the aluminium reduction pots and operation of the entire potline. For this reason, corresponding treatment measures shall be taken both prior to and after power outage in order to ensure that the potline can achieve an orderly pot shutdown and secondary baking to resume production.

Keywords: Aluminum Reduction Pot; Effect of power outage; Treatment Measures

1. Foreword

Aluminum reduction production is a continuous process, which is extremely demanding in regard to power supply system. It not only requires a basically constant direct current, but also an extremely high stability and reliability of the power supply system. Due to a lack of power supply in some parts of Iran, and also because of national policies, extreme climate and geological conditions, etc., possibility of aluminum reduction pot power outage exists. Therefore, knowledge of effect of power outage on aluminum reduction pots and establishment of relevant treatment measures is of significant importance to the risk prevention in the aluminum smelters in Iran. In this work, an analysis of the change of aluminum reduction pots during power outage has been made, with relevant treatment measures established in order to provide experience and references for protection measures of aluminum reduction pot shutdown.

2. Power Supply Requirements of Aluminum Reduction Process

DC current is a prerequisite for normal operation of aluminum reduction pots and the sole source of energy of aluminum reduction pots. With its unique characteristics, aluminum reduction process is a typical electrochemical process featuring high amperage and low voltage. It requires the power supply system to provide constant DC electricity with extremely high stability and reliability. As a result, rectifier units with high amperage become the core equipment in the power supply system of aluminum smelters.

In order to guarantee the continuity of DC electricity supply, high reliability of power supply is required. For the rectifier substation in an aluminum smelter, 2 loops of separate power supply of 100% spared of each other are required. And those 2 loops of power supply are required preferably to be connected to 2 different substations in the power grid or different bus bar sections of the same “hub grade” substation so as to ensure the 2 loops of power supply are separate from each other. In addition, it is required that in the event that any one of those 2 loops stops normal power supply, the other one must be able to supply the total current that is required by the normal operation of the aluminum smelter.

3. Effect of Power Outage on Aluminum Reduction Pot System

Aluminum reduction is a process of molten salt is electrolysis. The bath that is utilzied, i.e., NaF and AlF, have an initial crystallization temperature of 800℃, and efficient aluminum reduction production requires the bath temperature to be kept within the range of 940℃～960℃ so as to ensure the bath can have sufficient Al2O3 solubility, with suitable flow and diffusion.

Power outage will pose an adverse impact on potlines, depriving aluminum reduction pots of heat source and severely breaking thermal balance. The longer the duration of power outage is, the bigger the impact will be.

3.1 Effect on Aluminum Reduction Pots

In prebaked aluminum reduction process, alumina concentration is generally controlled to be within 2%~3%, and the bath molecular ratio within 2.1~2.3. It can be seen from the Na3AlF6-Al2O3 binary system melting diagram and NaF-AlF3 binary system phase diagram that in this region cryolite will precipitate from the bath melt as temperature drops. Sampling and testing of the cryolite precipitates and the liquid bath inside pots show that solid cryolite that has big molecular ratio with low CaF2 content gradually precipitate from the bath melt inside the pots as temperature drops after occurrence of power outage, resulting in increased AlF3 and CaF2 content of the bath melt inside the pots and thus reducing alumina solubility inside the bath. At the same time, as cryolite flux precipitates and temperature drops, the alumina inside the bath gradually reaches hyper-saturated state, precipitates and settles at the bottom of the pots, with sediments formed. As power outage continues, temperature drops further and sediments increase and gradually turn hard, with pot bottom crusts or excessive side ridges formed, which can result in large area of rough and uneven pot bottom surface, enormous shrinkage of pot cavity, connection of pot bottom crusts to side ridges, and increase in the height of pot bottom, thus significantly increasing pot bottom voltage drop, pot working voltage, and electrical energy consumption.

As power outage continues, temperature drops and the bath shrinks significantly, hot anodes are greatly exposed outside the bath, oxidize and peel due to contact with air. A large quantity of carbon slag floats on the bath surface, posing a significant impact on subsequent operation of aluminum reduction pots.

3.2 Effect on Operation of Aluminum Reduction Potlines

3.2.1 Adverse Effect on Production Stability

After power supply resumes, the bath that settles at pot bottom due to increase in density as a result of cooling and shrinkage caused by power outage will increase the ratio of horizontal current inside the liquid aluminum, breaking the stability of magnetic field. The magnetic field can only return to normal after a period of time when the bath that settles at the pot bottom completely melts and floats again above the liquid aluminum.

3.2.2 More Likely to Result in an Increase in Anode Effects with Longer Duration

Power outage can also cause extremely unstable operation aluminum reduction pot operation, dramatic increase in voltage noise value, increase in anode effects that have longer duration and are hard to suppress, slow resumption of potline current, more likely severe impact on the rectifier power supply system after aluminum reduction pot power supply is resumed.

3.2.3 Adverse Effect on Current Efficiency

Aluminum reduction pots have low current efficiency during the resumption period, with the entire potline in a poor state of increased energy consumption and decreased output, bringing significant economic costs to the smelter.

3.2.4 Adverse Effect on Pot Life

Dramatic temperature change during power outage exerts destructive thermal stress on the internal structures of aluminum reduction pots, resulting in varying degrees of damage to pot linings and pot shells, and thus reducing pot life.

3.2.5 More Likely to Result in Uneven Current Distribution in Anodes, Causing Potline Explosion Accidents.

Long duration of power outage or dramatic decrease in current will result in big heat energy loss of aluminum reduction pots, which in turn causes the bath inside aluminum reduction pots to cool, shrink and transform from liquid state to solid state. A large quantity of bath settles to the surfaces of cathodes, with high electrical resistance sediment barriers formed. The uneven distribution of the mixture of the solid bath and liquid aluminum inside the pot cavity is more likely to result in increase in current density of some anodes and decrease in current density of other anodes after power supply is resumed. Bath freezing will accelerate in the area with low current density, which further increases electrical resistance in that area, with the area with large current density bearing the burden of more current, and thus ultimately resulting in melting of such weak parts as the joints of anode aluminum rods and steel stubs and even the complete detachment of aluminum rods from stubs under electrothermal action due to high temperature. The detachment of aluminum rods from steel stubs is an accelerated process. So, it is self-evident that the detachment of the last aluminum rod from the steel stub will cause explosion accident, as extremely huge current of hundreds of thousands of amperage is forcibly cut off without any arc suppressing measures put in place.

Once the liquid bath begins freezing and settling, the aluminum reduction pots are on the verge of being “dead”. All the “dead” aluminum reduction pots or the ones that are about to be “dead” must be isolated from the potline so as to save other aluminum reduction pots and resume the normal operation of the potline. However, isolation of “dead” aluminum reduction pots or the ones that are about to be “dead” has to involve manual power outage or amperage reduction, which in turn will have an impact on the potline. Therefore, we believe that power outage has a severe impact on polines and this impact will continue to develop and are hard to control.

4. Treatment Measures Taken Both Prior to and After Power Outage

4.1 Preparation Prior to Power Outage

(1) Increase bath level and molecular ratio and properly increase pot voltage so as to increase the thermal capacity of the melt inside the aluminum reduction pots and prevent anodes from getting separated from bath due to severe bath shrinkage.

(2) Tap a proper amount of liquid aluminum prior to power outage to reduce heat dissipation at pot bottom.

(3) Enhance aluminum reduction pot thermal insulation works prior to power outage, increase covering material thickness, and use alumina, scraps or cryolite to cover all the feed points, aluminum tapping points and crust holes so as to reduce heat dissipation on pot surfaces.

(4) Properly increase potline amperage 8 hours prior to power outage and close the gas exhaust system of aluminum reduction pots to increase aluminum reduction pot temperature prior to power outage; stop anode change operation.

(5) Record the scale value which anode beam location corresponds to so as to provide references for power supply operation and post power supply operation.

(6) Prepare sufficient anode effect rods and cryolite so as suppress anode effects during power supply period and supplement bath.

4.2 Protection of Cathode Linings

Tap a proper amount of bath prior to pot shutdown so that the residual bath can form a protective film over the cathode surfaces so as to reduce the heat dissipation speed of cathode linings. Tap as much liquid aluminum as possible after pot shutdown and timely lift anodes off the liquid layer so as to prevent the anodes from sticking to the cathodes, avoid damage to the cathodes during anode lifting in the process of pot cleaning, and prevent thermal insulation from being weakened by side heat dissipation due to excessive aluminum present inside the aluminum reduction pots. In addition, prevent excessive liquid aluminum from seeping into the cathodes and avoid secondary damage to the cathodes during pot cleaning.

4.3 Thermal Insulation of Aluminum Reduction Pots

Implement good thermal insulation at the top part of anodes, e.g., add thermal insulating materials on anodes, close aluminum reduction pot gas exhaust duct valves, and make sure the pot cover plates are well closed. Implement good thermal insulation at pot shells. Enhance ambient thermal insulation and reduce air convection.

4.4 Adjustment of Cooling Speeding

Monitor the cooling speed of pot cavity through the means of thermocouples. In addition, with the low cooling speed during the later stage of thermal insulation and total shut down period taken into account, efforts shall be made to prevent the effect of excessive pot shutdown thermal insulation duration on subsequent production by such proper adjustment as weakening thermal insulation measures, etc.

4.5 Release of Aluminum Reduction Pot Stress

Tighten and loosen anode clamps 48 hours after pot shutdown so as to timely release the stress between anodes and linings and thus avoid pot superstructure deformation or damage due to excessive stress.

4.6 Anode Utilization after Aluminum Reduction Pot Shutdown

After the thermal insulation period is completed, match anodes together as per anode consumption conditions to achieve proper utilization so as to avoid anode waste.

5. Power Supply at Iran South Aluminum Corporation's Project Site

5.1 Overview of Iran South Aluminum Corporation

The Iranian South Aluminum Smelter project is located in the Lamard Energy Intensive Industrial Zone at about 3km of the city of Lamard in southern Iran. Iran's natural gas is concentrated mainly in south Iran. In order to transform its economic development mode of relying mainly on exporting raw materials, enhance the added value of natural gas, and create more jobs, the Iranian Government establishes two economic development zones in south Iran. Main projects planned in Lamard Economic Development Zone include: petrochemical projects, iron & steel projects, aluminum projects, magnesium projects, etc.

The Iranian Owner is responsible for design, supply and construction of all the 230kV feeders and their protective facilities, the communication facilities of upstream substation, and the terminal towers within 50m of the 230kV GIS located in the 230kV switch yard, and installation of the overhead lines from the terminal towers to the power receiving towers.

Iran South Aluminum Smelter utilizes the 430kA high amperage prebaked aluminum reduction pots designed by Northeastern University Engineering & Research Institute, Co., Ltd.

5.2 Power Supply Characteristics

In the initial stage, the electricity used by Iran South Aluminum Smelter is supplied by Iranian national power grid. And in the later stage, the smelter will utilize its own captive power plant that is to be constructed soon.

The 230kVGIS will adopt indoor configuration, with 2 loops of incoming power lines and 7 loops of power feeders installed. Those 7 loops of feeders adopt portal frames to supply power to 5 rectifiers and 2 power transformers via overhead lines.

6. Conclusion

Unpredictability in the power supply of Iranian national power grid and insufficient power supply in some regions are bound to have the potential of uncertain power supply, resulting in pot shutdown. In order to prevent the effect of pot shutdown on aluminum reduction potlines, such countermeasures as good preparation prior to pot shutdown, protection of cathode linings, pot thermal insulation, adjustment of cooling speeding, release of pot stress, utilization of anodes after pot shutdown, etc., shall be taken to strive to achieve a smooth secondary baking of aluminum reduction pots so as to resume production as soon as possible.