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Study on Cathode Structure Optimization of Aluminum Reduction Cell

Ban Yungang, Mao Yu, Mao Jihong, Liu Jing,Yang Xiaoling

Northeastern University Engineering & Research Institute Co., Ltd.
No.73, Xiaoxi Road, Shenhe Dist., Shenyang, Liaoning, China 110013

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Abstract

The authors of this paper using the thermo-electric field simulation software secondary development based on ANSYS studied the difference of horizontal current, cathode voltage drop, steel bar maximum current density when adopting different techniques, such as slotted steel bar, partial insulation steel bar, and low resistivity steel bar technologies. The results showed that the partial insulation steel bar technology to reduce the horizontal current of liquid aluminum pad is most obvious, and current distribution uniformity is also the best. The effect of reducing horizontal current is limited when adopting slotted steel bar technology. The using of low resistivity bar is more conducive to reducing the cathode voltage drop.

1. Introduction

In recent years, many new energy-saving technologies are emerging. As we know, the core physical field of reduction cell is MHD stability, namely the cell busbar arrangement optimization. So the aluminum reduction cell technology development focused on how to improve their physical field simulation and design optimization level.

It is quite difficult to optimize busbar arrangement under cell operating condition. Therefore, in order to further enhance the aluminum cell MHD stability, improve the effective polar distance, the technical personnel focus betting on how to reduce horizontal current in liquid aluminum and cathode voltage and so on. Therefore, in recent years, the aluminum industry have developed such as profiled cathode, slotted collection steel bar, shaped steel bar, steel bar with partial insulation and low resistivity steel bar technologies.

In fact, for any kind of cell, its cathode assembly design should be based on cathode material grade to select suitable structure, size and assembly methods. On the one hand, it is necessary to achieve a lower cathode drop and lower horizontal current. On the other hand, should consider the thermal balance and investment economy and so on. Through structure optimization of the cathode to achieve energy saving.

The authors of this paper using the thermo-electric field simulation software secondary development based on ANSYS studied the difference of horizontal current, cathode voltage drop, steel bar maximum current density when adopting different techniques, such as slotted steel bar, partial insulation steel bar, and low resistivity steel bar technologies etc..

2. Simulation Results and Analysis

2.1 Electric field of normal cathode

The normal cathode mentioned here refers to its assembly did not adopt slotted bars, partial insulation and other measures. Graphitic bottom block, traditional steel bar, graphite and paste connecting material were used in the normal cathode assembly. Typical results of the cathode were shown in fig. 1 and 2. The calculation results as reference for other energy-saving technology.

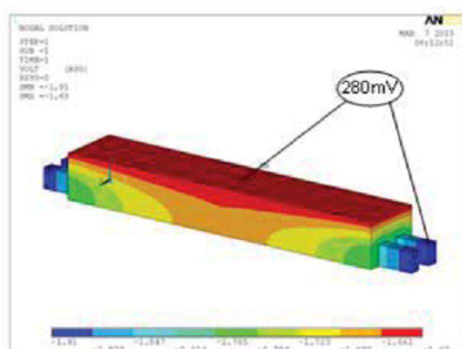

Fig. 1 Voltage of normal cathode

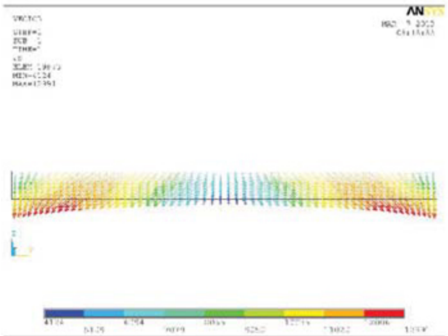

Fig. 2 Current density vector in liquid aluminum pad (adopting normal cathode)

The simulation result known that voltage drop of normal cathode is 280mV. The average and maximum value of horizontal current from Y-direction in the liquid aluminum pad is 5886A/m^2 and 9020A/m^2 respectively. The maximum current density of the steel bars is 211582A/m^2.

2.2 Slotted Steel Bar Technology

The position and size of the slotted bars can have a variety of options. Three different slot position and three different lengths were selected here during the simulation. The results were shown in fig. 3 and 4.

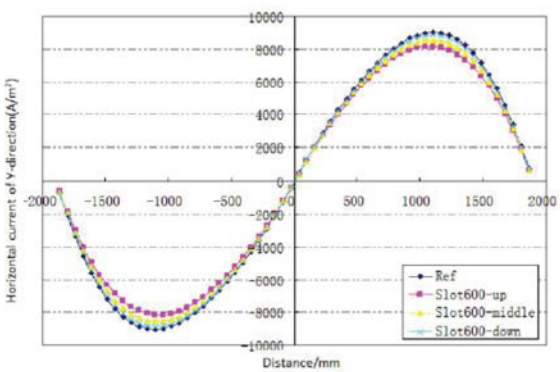

Fig. 3 Horizontal current distribution with different slot position

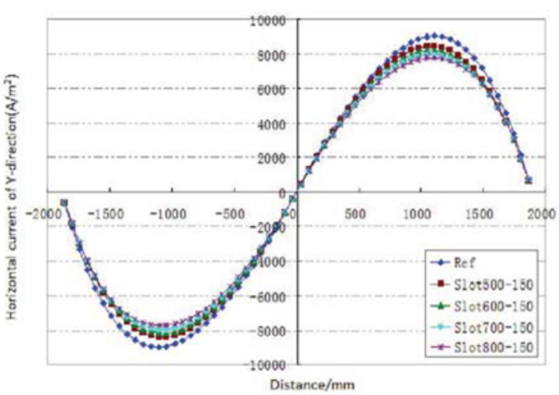

Fig. 4 Horizontal current distribution with different slot lengths

From the comparison results we can know that the more up slot position, the longer slotted length, and the reduction of horizontal current is more significant. However, the reduction of horizontal current is only about 10% when only using slotted bar technique.

Typical simulation results of the electric field with a particular position and size slot were shown in fig. 5 and 6.

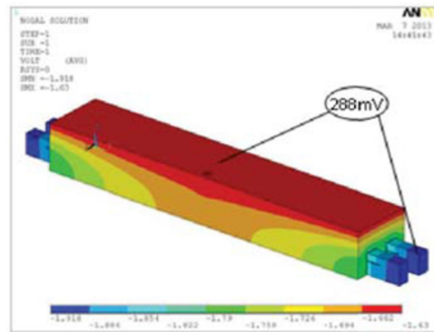

Fig. 5 Cathode voltage drop with slotted steel bar

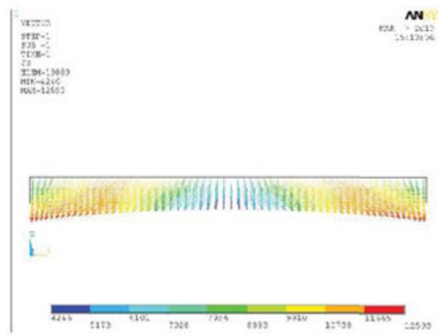

Fig. 6 Current density vector in liquid aluminum pad (adopting slotted steel bar)

From the simulation result we can know that cathode voltage drop with slotted bar is 288mV. The average and maximum value of horizontal current from Y-direction in the liquid aluminum pad is 5378A/m^2 and 8184A/m^2 respectively. The maximum current density of the steel bars is 281836A/m^2.

2.3 Partial Insulation Steel Bar

Partially insulated bars are also having a variety of forms and sizes. The typical simulation results of the electric field with a particular partial insulation and size were shown in fig. 7 and 8.

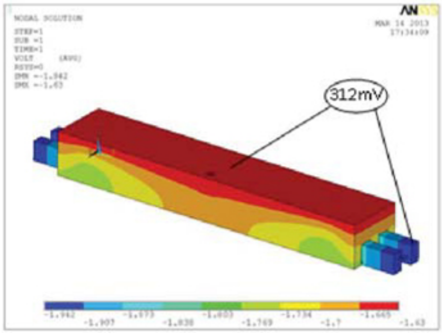

Fig. 7 Cathode voltage with partial insulation steel bar

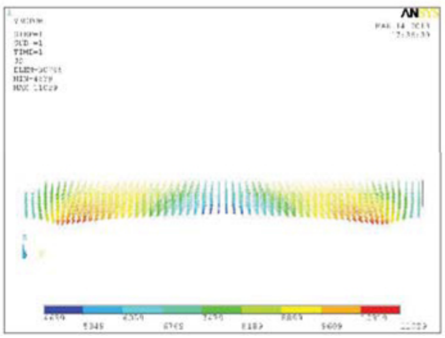

Fig. 8 Current density vector in liquid aluminum pad (adopting partial insulation steel bar)

From the simulation result we can know that cathode voltage drop with partial insulation bar is 312mV. The average and maximum value of horizontal current from Y-direction in the liquid aluminum pad is 3293A/m^2 and 5821A/m^2 respectively. The maximum current density of the steel bars is 244709A/m^2.

2.4 Slotted Combined with Partial Insulation Steel Bar

From 2.2 and 2.3 simulation results we can know that the horizontal current reduction is limited when only adopting slotted steel bar. However, the effect is more obvious when adopting partial insulation technology. Therefore, to achieve a more significant reduction of horizontal current, partial insulation should be priority adopted, and also should combine with the slotted steel bar technology. Typical simulation results adopting the two technologies were shown in fig. 9 and 10.

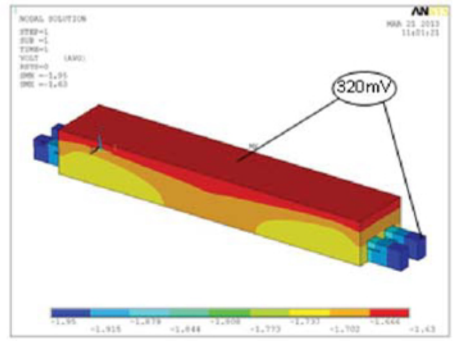

Fig. 9 Cathode voltage with slotted and partial insulation steel bar

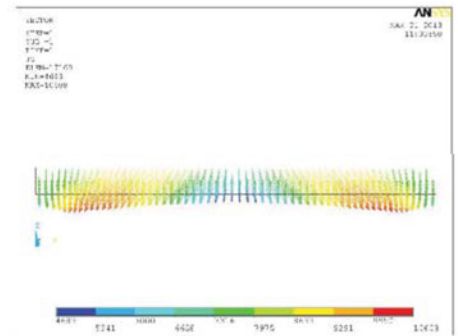

Fig. 10 Current density vector in liquid aluminum pad (adopting slotted and partial insulation steel bar)

From the simulation result we can know that cathode voltage drop with slot and partial insulation steel bar is 320mV. The average and maximum value of horizontal current from Y-direction in the liquid aluminum pad is 3262A/m^2 and 5628A/m^2 respectively. The value of horizontal current is significantly reduced and the uniformity of the current distribution has been significantly improved. The maximum current density of the steel bars is 263735A/m^2.

2.5 Low Resistivity Steel Bar

Low resistivity steel bar has better conductivity compared with ordinary steel bar. Therefore, lower horizontal current and voltage drop can obtain with the same bar section. Typical simulation results of the electric field with low resistivity steel bar were shown in fig. 11 and 12.

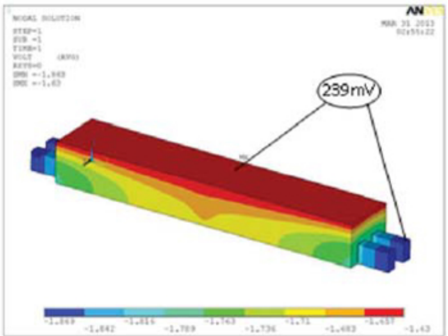

Fig. 11 Cathode voltage with low resistivity steel bar

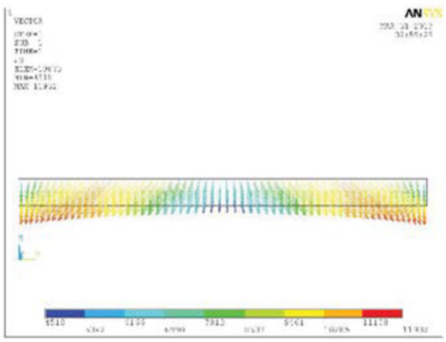

Fig. 12 Current density vector in liquid aluminum pad (adopting low resistivity steel bar)

From the simulation result we can know that cathode voltage drop with low resistivity bar is 312mV. The average and maximum value of horizontal current from Y-direction in the liquid aluminum pad is 4786A/m^2 and 7312A/m^2 respectively. The maximum current density of the steel bars is 205593A/m^2.

2.6 Comparative Analysis

Various forms of cathode mentioned above were calculated separately. Comparative analysis of different simulation results were carried out to further illustrate their impact on reducing horizontal current and cathode voltage drop as following.

- Reduction of Horizontal Current

The comparing of horizontal current when adopting different technology was shown in fig. 13 and tab. 1.

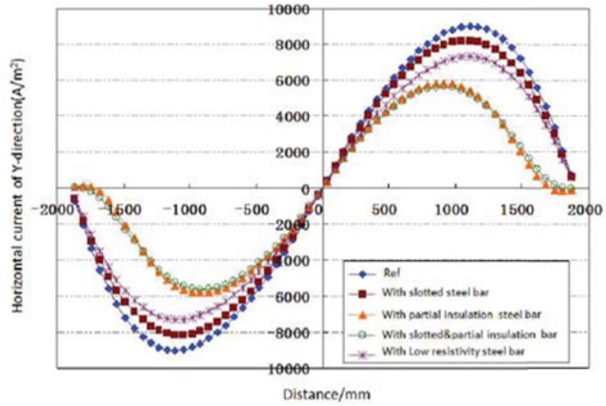

Fig. 13 Comparing of horizontal current from Y-direction when adopting different technologies

Tab.1 The simulation results of horizontal current from Y-direction

	Unit	Normal steel bar	Slotted steel bar	Partial insulation steel bar	Slotted combined with partial insulation Steel Bar	Low resistivity steel bar
|Jy| ave	A/m^2	5886	5378	3293	3262	4786
Jy max	A/m^2	9020	8184	5821	5628	7312

From the comparison we known that the reduction of horizontal current is most significant when adopting partial insulation steel bar or partial insulation combined slotted steel bar, the average value of Y-direction horizontal current has reduced 44.1% and 44.6% respectively, the maximum has reduced 35.5% and 37.6%. The value of average and maximum has reduced 18.7% and 18.9% respectively with the using of low resistivity steel bar. The average and maximum reduction of horizontal current is 8.6% and 9.3% when only adopting slotted steel bar.

- Cathode Voltage Drop

The comparison of cathode voltage drop adopting different technologies was shown in fig. 14.

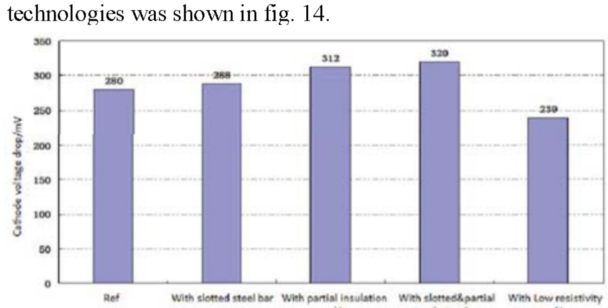

Fig. 14 The comparison of cathode voltage drop adopting different technologies

From the comparison in fig. 14 we known that cathode voltage drop will be increase obviously when adopting slotted or partial insulation steel bar because of the reduction of conductive area of the bars. The cathode voltage drop increase about 40mV with the using of the partial insulation bar. This also showed the using of the partial insulation bar should be combined with the reduction of horizontal current and the impact on the cathode voltage drop. Too much insulation area will increase the cathode voltage significantly. The use of low resistivity steel bar can reduce the cathode drop obviously; the voltage can reduce 41mV as compared with the using of ordinary steel bar, which coincide with the application results in some smelter in China.

- Maximum Current Density in Steel Bar

The comparison of maximum current density in steel bar adopting different technologies was shown in fig. 15.

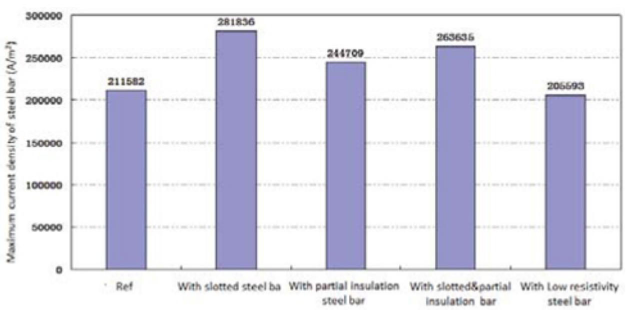

Fig. 15 The comparison of maximum current density in steel bar adopting different technologies

The maximum current density in steel bar increased due to changes of current flow and the conductive area reduction when adopting slotted bars and partial insulation bars. But the value is still lower than conventional permissible value and will not appear current overload.

3. Conclusions

The main conclusions are obtained as follows through a variety of energy-saving technologies and comparative simulation analysis.

The different energy-saving technologies can reduce the horizontal current to some extent. The reduction of horizontal current is most effective when adopting partial insulation measures. At the same time, more attention should pay on increasing of the cathode voltage drop. Therefore, the using of technology should be combined with its horizontal current reduction effectiveness and impact of the cathode voltage drop.

The Energy-saving techniques not only reduce the horizontal current in liquid aluminum, but also increase the current distribution uniformity in the liquid aluminum and carbon blocks, which will slowing the electrochemical corrosion of cathode block.

The low resistivity steel bar has lower resistivity. The energy saving effect is more significant under the same conditions.

A variety of energy-saving technology should give full consideration to the design features of the cell itself, should select the matching structure and size, and should consider cell lining and thermal field design.

Acknowledgement

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