Light Metals 2014
Edited by: John Grandfield
TMS (The Minerals, Metals & Materials Society), 2014

Study on the Anode and Cathode Configuration of Aluminum Reduction Cell

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Keywords: Aluminum reduction cell; Anode and cathode configuration; horizontal current

Abstract

The authors of this paper using the thermo-electric field simulation software secondary development based on ANSYS studied the horizontal current distribution in liquid aluminum pad of two cases, namely the cathode and anode configuration adopting "correspondence" and "non-correspondence". The results showed that the effect of reducing horizontal current is not obvious when anode and cathode using "correspondence" configuration, especially during the actual production cannot eliminate the uneven distribution of anode current, and also can not eliminate the horizontal current caused by anode change. The structure of modern reduction cell determined the horizontal current in the liquid aluminum pad mainly derived from cell width direction, namely the direction of current in and out. Therefore, the reducing of horizontal current should also be more considerate on the cell width direction. The number of cathode should not be previously determined during the bus configuration around the cell.

1. Introduction

As we know, during the design of aluminum cell, the number of anodes is determined by the following major factors: the selected anode current density, the selected anode section size, favor the reduction of anode overvoltage, and favor the configuration of upper structure etc.; The number of cathodes is mainly determined by optimization busbar arrangement around the cell, which help to get better MHD stability design results. Therefore, during the structural design of the aluminum reduction cell, the numbers of anode and cathode are not necessarily equal, namely the configuration of anode and cathode is not necessarily adopt "correspondence" mode. There are also some technical staff believe the design of equal number of anode and cathode favor to reduce horizontal current in liquid aluminum pad.

The authors of this paper studied the horizontal current distribution in liquid aluminum pad in the two cases of NEUI400 aluminum reduction cell which adopted graphitized cathode, and researched the effect of the two cases on the horizontal current distribution through simulation.

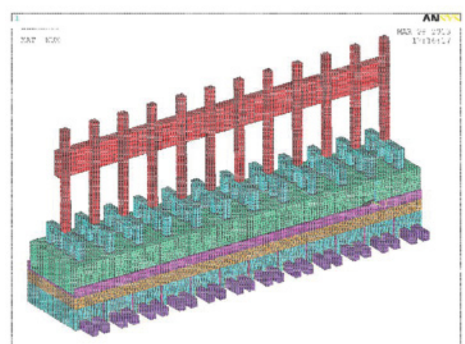
2. Simulation Results and Analysis

Two finite element models were established which the anode and cathode configuration adopting "correspondence" and "non-correspondence" mode. For each model, two conditions of normal and anode change were considered separately in the simulation. Normal condition mentioned here refers to all anodes are in complete and uniform conducting state, and anode change condition refers to one anode at the state of non-conductive.

2.1 Simulation Results under Normal Condition

2.1.1 Simulation Model

The follow 1/4 cell finite element model with "correspondence" and "non-correspondence" anode and cathode configuration were established respectively under the normal condition, as shown in fig. 1.



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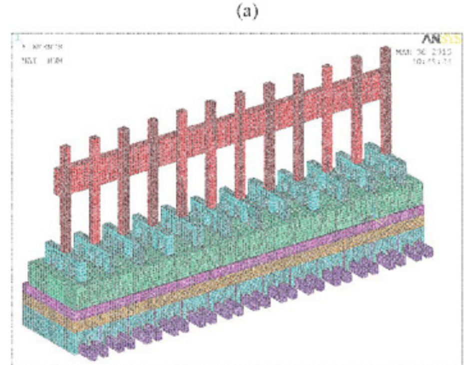
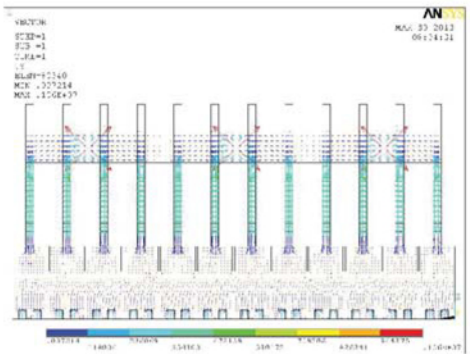


(b)

Fig. 1 1/4 cell finite element model under normal condition
(a) Anode and cathode adopting "correspondence" configuration; (b) Anode and cathode adopting "non-correspondence" configuration (The following is also the same)

2.1.2 Simulation Results and Analysis

Typical simulation results of the two different configurations of 1/4 cell are shown in fig. 2 to 5. The value of average and maximum horizontal current in the aluminum pad was shown in tab. 1.



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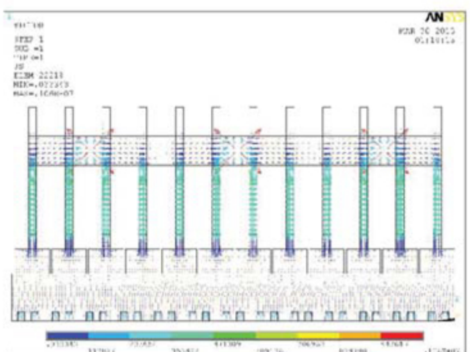

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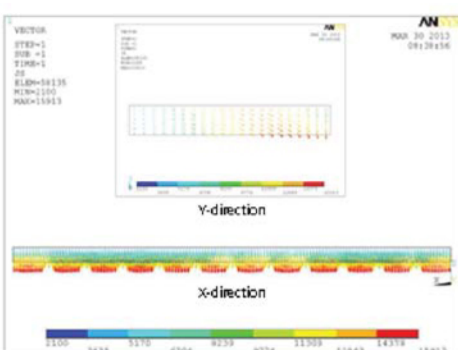
Fig. 2 Current density vector of the conductor part under normal condition



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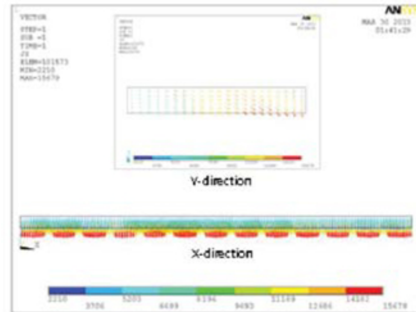
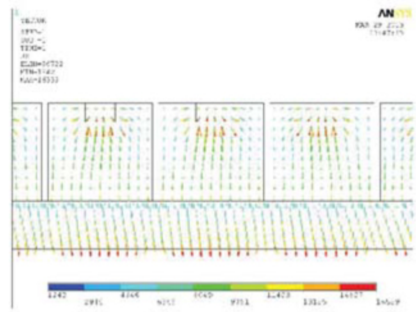


(b)
Fig. 3 Current density vector of the aluminum pad under normal condition



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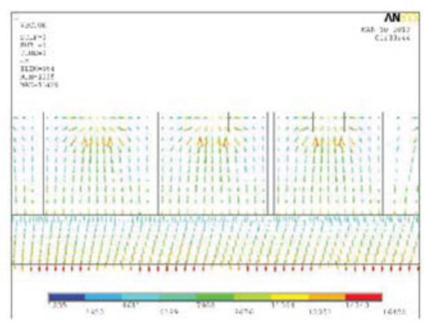

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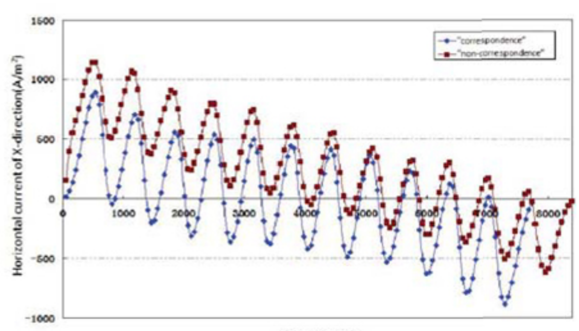
Fig. 4 Current density vector of the anode carbon, electrolyte and aluminum pad under normal condition



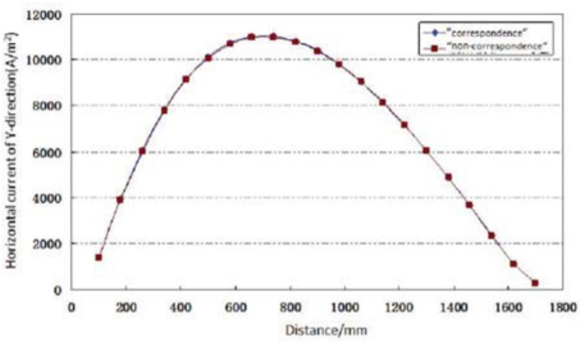


Fig. 5 Horizontal current distributions in aluminum pad at typical position under normal condition

Tab. 1 The value of average and maximum horizontal current in the aluminum pad under normal condition

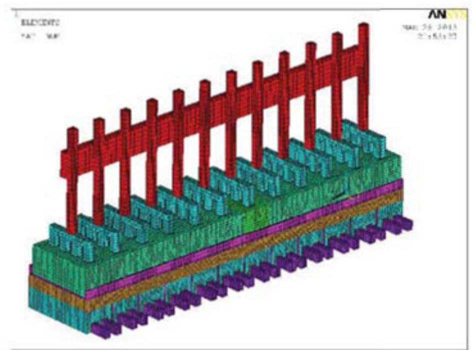
	Unit	Cathode and anode with "correspondence" configuration	Cathode and anode with "non-correspondence" configuration
$\mid J_X \mid$ ave	A/m^2	277	367
J_X max	A/m^2	1271	1416
$\mid J_Y \mid$ ave	A/m^2	6872	6881
J_Y max	A/m^2	11279	11232

From the above results we can know that no matter which configuration ("correspondence" or "non-correspondence" configuration), the horizontal current in liquid aluminum pad are mainly come from Y-direction (namely the current in and out direction), and the horizontal current from X-direction (i.e. the longitudinal direction of the cell) is relatively much smaller. This is due to the structural characteristics of the aluminum reduction cell. The horizontal current in liquid aluminum pad from X-direction is only about 5% of Y-direction no matter adopting which anode and cathode configuration. Although adopt "correspondence" configuration can slightly reduce the horizontal current of X-direction in the liquid aluminum pad. However, due to the good conductivity of molten aluminum, the reduction of horizontal current is not obvious. Therefore, the contribution to improve the MHD stability will be very small too, and this is without considering the case of anode change. As we know, during the industrial reduction, there is anode change that leaving the anode cannot conductive for a long time almost every day. Even with the anode and cathode "correspondence" configuration, still cannot eliminate horizontal current from X -direction in the aluminum pad caused by the different consumption of anode and replacement of anode. Further analysis has been carried out under the condition of anode change as following.

2.2 Simulation Results under Anode Change Condition

2.2.1 Simulation Model

The follow 1/4 cell finite element models with "correspondence" and "non-correspondence" anode and cathode configuration were established respectively under anode change condition, shown in figure 6. Both models are set to one anode (both the same location) in the non-conductive state. The anode number is 48 groups (single anode) and cathode number is 24 in anode and cathode "correspondence" model mentioned here. In the "non-correspondence" model, the anode number is 48(single anode) and cathode number is 26.



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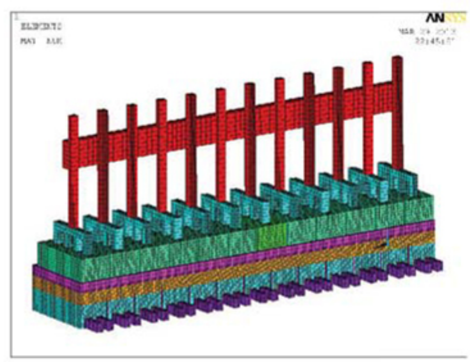

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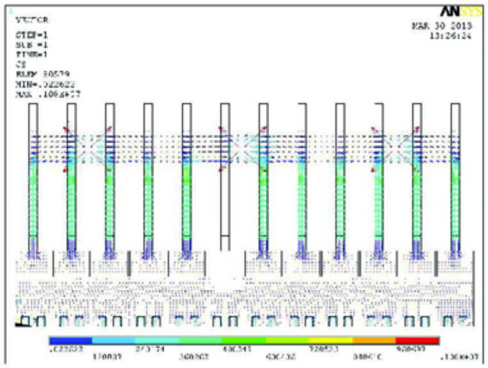
Fig. 6 1/4 cell finite element model under anode change condition

(a) Anode and cathode adopting "correspondence" configuration; (b) Anode and cathode adopting "non-correspondence" configuration (The following is also the same)

2.2.2 Simulation Results and Analysis

Typical simulation results of the two different configurations of 1/4 cell under anode change condition are shown in fig. 7 to 10. The value of average and maximum horizontal current in the aluminum pad under the condition was shown in tab. 2.



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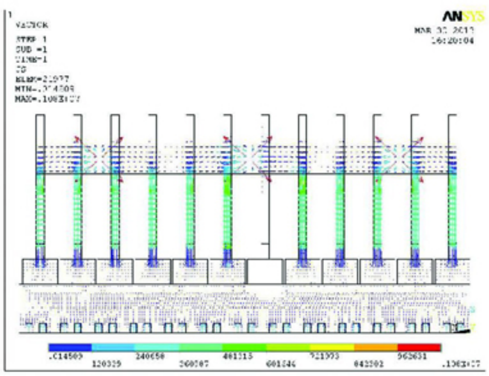

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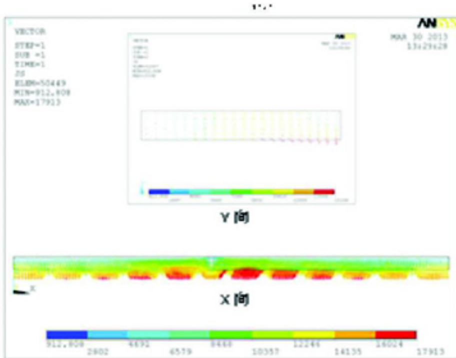
Fig. 7 Current density vector of the conductor part under anode change



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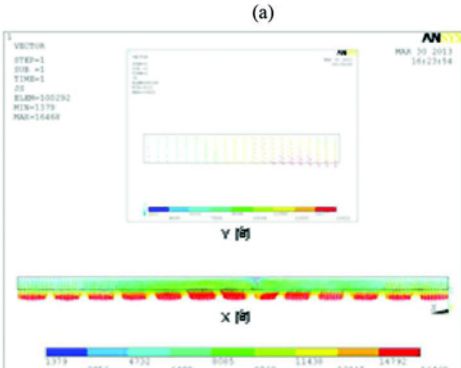

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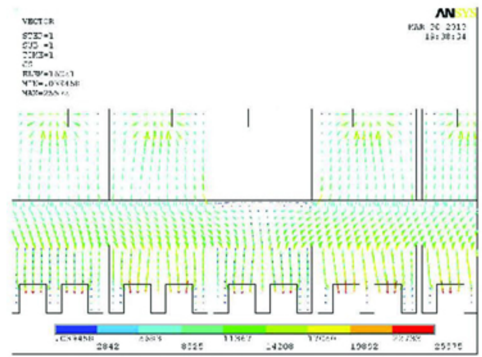
Fig. 8 Current density vector of the aluminum pad under anode change condition



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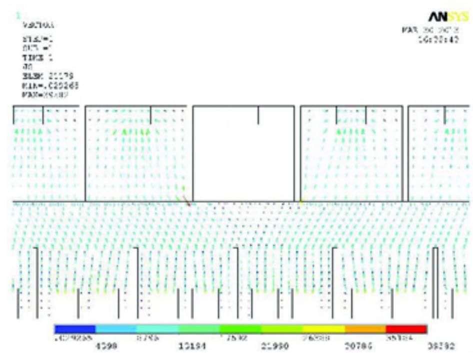

(b)

Fig. 9 Current density vector of the anode carbon, electrolyte and aluminum pad under anode change condition

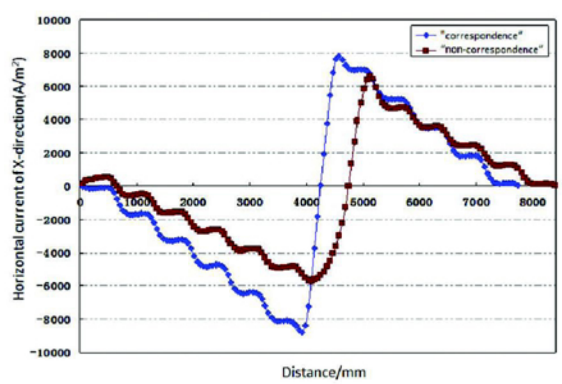

Fig. 10 Horizontal current distributions in aluminum pad at typical position under anode change condition

Tab. 2 The value of average and maximum horizontal current in the aluminum pad under anode change condition

	Unit	Cathode and anode with "correspondence" configuration	Cathode and anode with "non-correspondence" configuration
$\lvert Jx \rvert$ ave	A/m^2	3957	2697
Jx max	A/m^2	8789	6616
$\lvert J_Y \rvert$ ave	A/m^2	6874	6874
J_Y max	A/m^2	11291	11247

From the above simulation results we can know that the horizontal current from X-direction increased significantly under the anode change condition. While has almost no effect on the Y direction horizontal current. Replace the anode when compared with the normal conditions, the horizontal current increased about ten times in the liquid aluminum pad. Take the cathode and anode "correspondence" configuration, for example, the value of average and maximum horizontal current is respectively 277A/m^2 and 1271A/m^2 under normal condition, In the anode change condition, the value of average and maximum horizontal current increased significantly to 3957 A/m^2 and 8789 A/m^2, which further illustrate the anode and cathode "correspondence" configuration has no help to eliminate horizontal current caused by the different anode consumption and anode change.

The horizontal current form X-direction of "non-correspondence" configuration is lower than "correspondence" configuration compare with the tab. 1 and 2. This is mainly due to the cathode number of "non-correspondence" is more than "correspondence" configuration, which means the effect is smaller caused by anode change. That is, under the same conditions, the more the cathode groups, the horizontal current from X-direction produced by anode replacement is smaller.

The horizontal current mainly comes from Y-direction determined by the structural characteristics of the reduction cell. Therefore, to achieve a substantial reduction of horizontal current in the liquid aluminum pad should be more consider on the Y-direction. The number of cathode (or cathode width) should be chosen which will be benefiting the busbar arrangement around the cell (ie, optimized magnetic design).

3. Conclusions

Through the comparative simulation and analysis, the main conclusions are as follows:

The anode and cathode "correspondence" configuration nearly has no help to reduce the horizontal current in the liquid aluminum pad, especially under the condition of anode change;

The horizontal current in the liquid aluminum pad mainly from the Y-direction, so the reduction of horizontal current should be more consider on the Y-direction to further improve the MHD stability.

The number of cathode should be selected to favor busbar arrangement around the cell (that is, optimize design field) point of view, the cathode number should not be limited before the busbar design.

Acknowledgement

The project is jointly completed by NEUI's aluminum reduction technology R&D team. The project is organized by Mr. Lu Dingxiong, Mrs. Mao Jihong, Mr. Qi Xiquan and Mr. Yang Qingchen, etc.