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NUMERICAL SIMULATION OF SLUDGE INFLUENCE ON HORIZONTAL ELECTRIC IN METAL PAD OF ALUMINUM REDUCTION CELL

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The influences of sludge on horizontal electric current (HEC) in metal pad of cell were analyzed using a 3D model. The results show that the sludge located in the center has small influence on the HEC. And the sludge located in the side has great effect on the HEC. As the length of sludge increases, the negative peak move from the side to the middle. Moreover, it produces a large positive peak close to the side. The sludge located in side has small influence on the cathode voltage drop than that of the sludge located in center.

Keyword: aluminum reduction cell, sludge, numerical simulation, ANSYS

INTRODUCTION

In an aluminum reduction cell, addition of excess alumina to the cryolite bath leads to the formation of a sludge containing Al_2O_3 [1]. The mixture, which is heavier than liquid aluminum, can be described as loosely packed alumina where the voids are filled with bath. The undissolved alumina can be deposited at on the bottom of the cathode carbon, forming sludge (Figure 1).

Other events like metal tapping, anode changing and anode effect also generate sludge [2]. During metal tapping, the anode beam goes down a few centimeters in order to maintain the anode cathode distance. This important movement breaks the side channel crust, which falls in. And during the termination procedure of an anode effect, sludge is formed by both the overfeeding and through the crust collapsing in some areas of the pot.

On one hand, the high currents passing through the cell produce powerful magnetic fields. The horizontal components of the flow of electric current interact with the vertical component of the magnetic field, adversely affecting efficient cell operation [3]. Furman [4] noted the horizontal electric currents are not "pathological" but a logical result of the cell circuit topology. On the other hand, the electrical resistivity of sludge is far greater than that of the metal and the carbon, so the sludge will introduces a resistance to the current flow path. However, little attention has been paid to study the sludge effect on horizontal electric in metal pad of aluminum reduction cell. With the computer and software development, in this paper, we use a FEM model to analysis the influences of sludge on HEC in metal pad of aluminum reduction cell.

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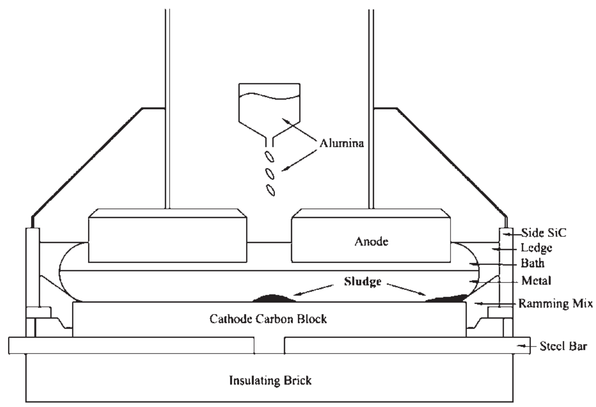

Figure 1 Schematic of the sludge in aluminum reduction cell

MODEL AND SPECIFICATIONS

All models presented in this paper were created using the ANSYS software. The governing equations and the boundary conditions are in accordance with the literature [5]. All the calculations are on 300 kA aluminum reduction cell. The 300 kA cell technological parameters list in Table 1.

Table 1 **Technological parameters of 300 kA aluminum reduction cell**

Parameter	Value
Current / kA	300
Number of cathode carbon block	26
Number of collector bar	104
Metal level / mm	200
Electrolyte Level / mm	190
Anode cathode distance / mm	40

Sludge typically contains about 40 % alumina, 2 % AlF_3 and 3 % CaF_2. Soft sludge electrical conductivity

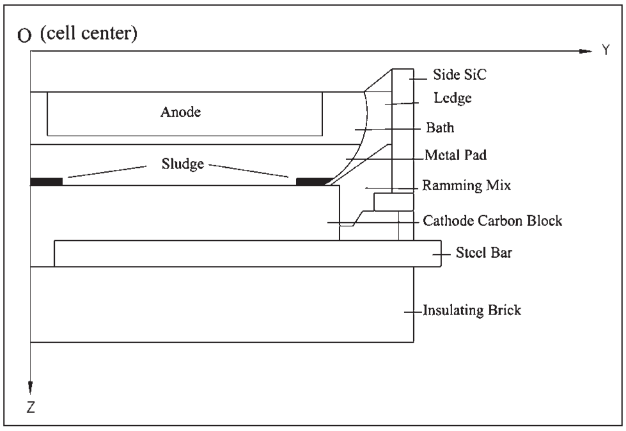

Figure 2 The coordinate system and the sludge location

is show in equation 1[6]. Soft sludge electrical conductivity is typically half that of a classic electrolyte.

$$k_{sludge} = 1S / cm \pm 0,2 \tag{1}$$

Sludge electrical resistivity is about 0.01Ω·m, which is far greater than metal electrical resistivity ($2,4\times10^{-7}$Ω·m), so the sludge could be seen as an insulator. Sludge in different locations will generate the different influence on the electric current distribution in the metal pad. The coordinate system and the sludge location are shown in Figure 2. Y direction is in accordance with the horizontal electric current. The sign for the horizontal electric current is that current flowing toward center of the cell is positive (PC) while current flowing toward the side of the cell is negative (NC). Parameters of the sludge and No of test list in the Table 2.

Table 2 **Parameters of the sludge and No of test**

No of test	Location	*a*/cm	*b*/cm
0	-	-	-
1	center	12,5	2
2	center	25	2
3	center	25	4
4	side	12,5	2
5	side	25	2
6	side	25	4

No 0 is the blank test (without sludge)
a is the length of sludge
b is the height of sludge

RESULTS AND DISCUSSION

Electric current distribution in the metal pad, especially the HEC, has great influence on the cell stability and current efficiency. Contours of HEC density in the metal pad of aluminum reduction cell are shown in Figure 3. The max PC and NC density in metal pad of aluminum reduction cell list in Table 3.

From the Figure 3 and Table 3, we can see that sludge in the cell will increase the value of HEC (positive and negative). To examine these current distributions more closely, The HEC density distributions in the bath/metal interface along the Y direction are shown in Figure 4.

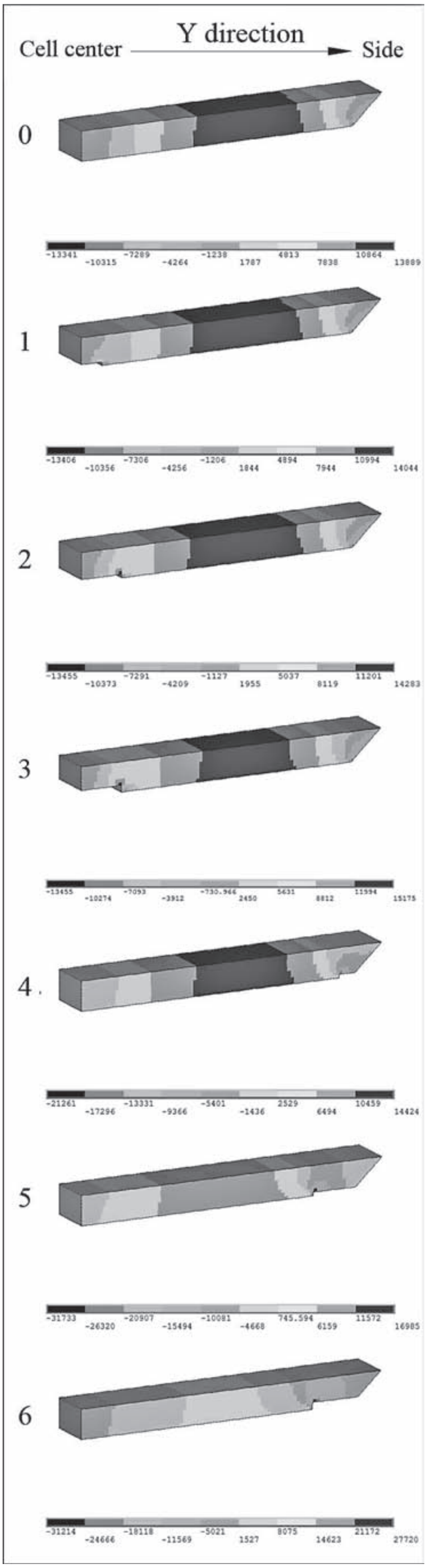

Figure 3 Contours of HEC density in the metal pad of aluminum reduction cell

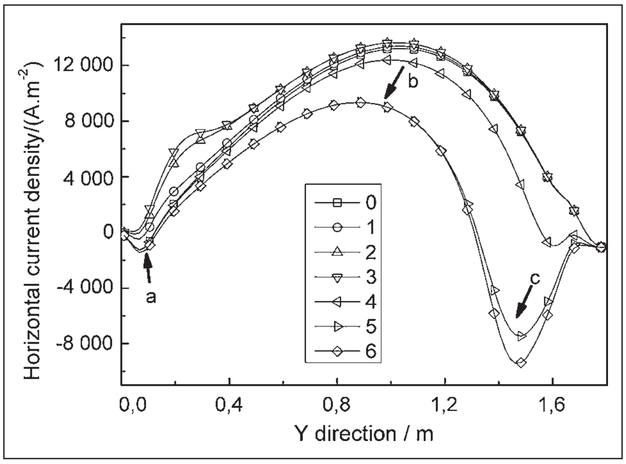

Figure 4 The HEC density distributions in the bath/metal interface

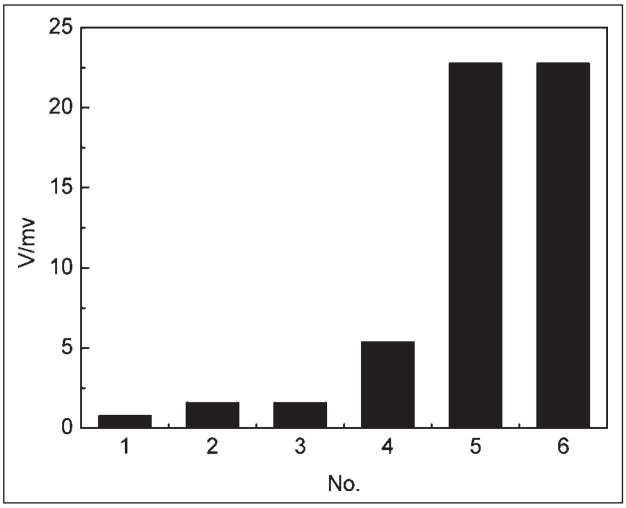

Figure 5 Comparison simulated cathode voltage difference (V_i-V_0, i=1,2…6)

Table 3 **HEC density in metal pad of aluminum reduction cell**

No of test	The Max NC / A·m^{-2}	The Max PC / A·m^{-2}
0	13,889	13,341
1	14,044	13,406
2	14,283	13,455
3	15,175	13,455
4	14,424	21,261
5	16,985	31,733
6	27,720	31,214

It can be seen from Figure 4 that the horizontal current curves are very different. Sludge located in the center channel has small influence on the HEC in metal pad. As the length of sludge increases, the positive peak located in the center disappears (arrow a). But the sludge located in the side has great effect on the HEC density. As the length of sludge increases, the negative peak move from the side to the middle (arrow b). Moreover, in the side channel, it produces a large positive peak (arrow c). That is to say, the sludge located in the side will generate the large metal turbulence, which is harmful for the cell operation.

Cell voltage is an important parameter for cell power consumption. Sludge electrical resistivity is quite large, so it must increase the cell voltage. The voltage difference (V_i-V_0, i = 1,2…6) are shown in Figure 5.

From Figure 5, we can see that the sludge located in side has a greater influence on the cathode voltage drop than that of the sludge located in the center. The voltage difference reaches up to 23 mv. Moreover, as the length of sludge located in side increases, the voltage difference increases rapidly.

CONCLUSIONS

Sludge located in different positions will produce different effects on the cell voltage and horizontal electric current in the metal pad. The sludge located in the center has small influence on the HEC density. As the sludge increases, the positive peak located in the center disappears. The sludge located in the side has great effect on the HEC density. As the length of sludge increases, the negative peak move from the side to the middle. Moreover, it produces a large positive peak close to the side. The sludge located in side has greater influence on the cathode voltage drop than that of the sludge located in center.

Acknowledgements

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Note: For English language is responsible the lecturer from Northeastern University, Shenyang, China