Depth Analysis and Potentiality Exploitation on Energy-Saving and Consumption-Reduction of Aluminum Reduction Pot

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Dr. Marc Dupuis has been appointed Technical Consultant of GAMI

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LETTER OF APPOINTMENT

Herein to appoint Dr. Marc Dupuis as the technical consultant of Guiyang Aluminum-Magnesium Design & Research Institute

聘 书

兹聘 Dr. Marc Dupuis 为贵阳铝镁设计研究院技术顾问。

贵 阳 铝 镁 设 计 研 究 院

President of Guiyang Aluminum-Magnesium Design & Research Institute

At the New Year Celebration in Guiyang

中铝国际贵阳分公司 / 贵阳铝镁设计研究院

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Plan of the Presentation

- Introduction
- Analysis of mechanism and nature of pot work voltage reduction based on energy balance principle
- Heat dissipation at pot top
- Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot
- Conclusions

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- Introduction
- Analysis of mechanism and nature of pot work voltage reduction based on energy balance principle
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- Heat dissipation at pot side and pot bottom
- Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot
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Introduction

The key technologies in aluminum reduction are studied and developed, which raises Chinese aluminum reduction technology to the world advanced level soon.

Moreover, the consumption of energy and raw material for aluminum reduction production is very high in recent years, especially power consumption. With the energy crisis, the aluminum reduction production costs must be reduced without delay.

For this, the most efficient method is to reduce the DC consumption by increasing current efficiency (CE) and reducing cell voltage.

Analysis of Mechanism and Nature of Pot Work Voltage Reduction based on Energy Balance Principle

The pot energy balance was summarized by Warren Haupin in [1].
The heat input and output may be divided into the followings:

Heat input

1. Current (variable)

2. Voltage

2.1 Anode (constant)

2.2 Cathode (constant)

2.3 ACD

2.3.1 Bubble voltage drop (variable)

2.3.2 Bath voltage drop—ACD, bath ratio (variable)

2.3.3 Back-EMF (constant)

Analysis of Mechanism and Nature of Pot Work Voltage Reduction based on Energy Balance Principle

Heat output

1. Heat dissipation at pot top (internal cause: Topr)
   (External cause: material and thickness of anode covering materials, flue gas velocity and sealing degree of pot hood)
2. Heat dissipation at pot side (internal cause: Tsuper)
   (External cause: bath level, metal level, pot lining design)
3. Heat dissipation at pot bottom (internal cause: Topr)
   (External cause: material and thickness of cathode lining)

The object of voltage reduction is the voltage combination in the heat input, the majority of which is voltage drop of ACD (anode cathode distance).

Therefore, the energy balance of pot is maintained by reducing the heat dissipation in heat output combination as well as the voltage in heat input combination so as to reduce the voltage.

Heat Dissipation at Pot Top

The material composition of the covering materials is relevant to the alumina content and the bath crushing size in the covering materials

Covering materials sample with above 93% Al_2O_3 left, covering materials sample with below 13% Al_2O_3 and 0.5-8mm bath crushing size right

Heat Dissipation at Pot Top

Area	Heat dissipation area		Heat dissipation (kW)	Heat dissipation (V)	%
Anode area	Pot hood	Pot side cover plate	112.8	0.346	18.4
		Pot rim plate	15.5	0.047	2.5
		Pot end cover plate	15.0	0.046	2.4
		Sub-total	143.2	0.439	23.4
	Pot superstructure	Pot top	43.4	0.133	7.1
		Anode guide bar	7.4	0.023	1.2
		Fume	181.5	0.557	29.7
		Sub-total	232.3	0.713	38.0
	Total		375.5	1.152	61.4

Heat dissipation distribution (anode area) for a Type A 320 kA pot

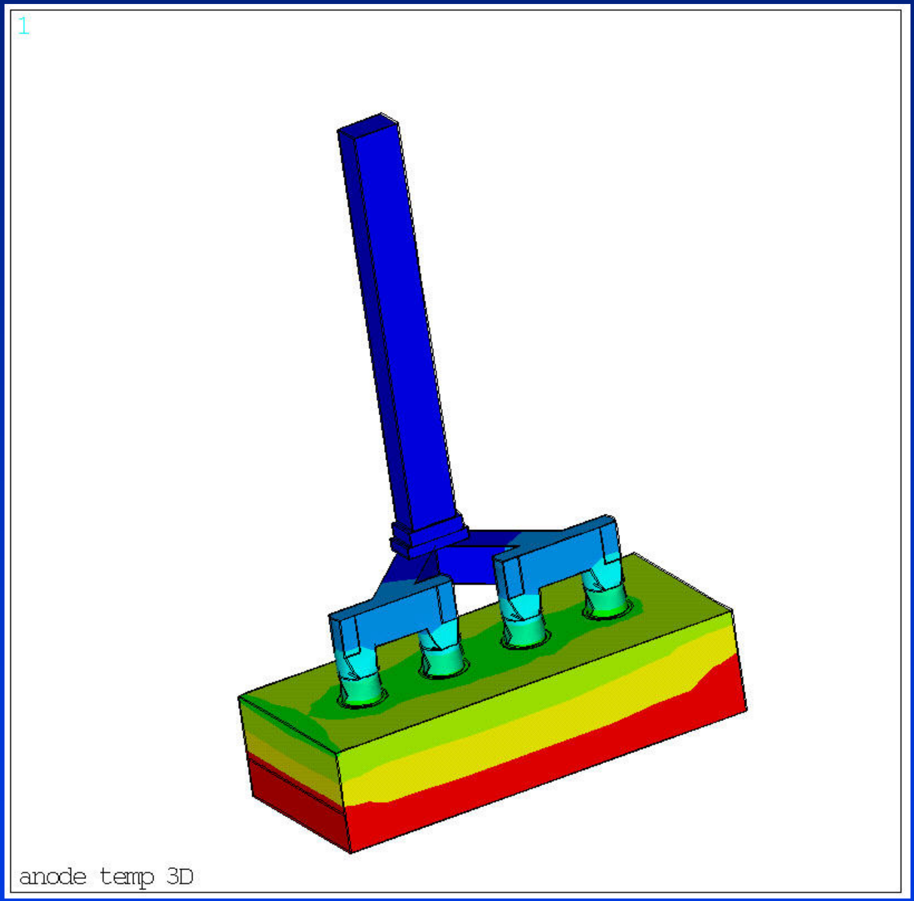
Heat Dissipation at Pot Top

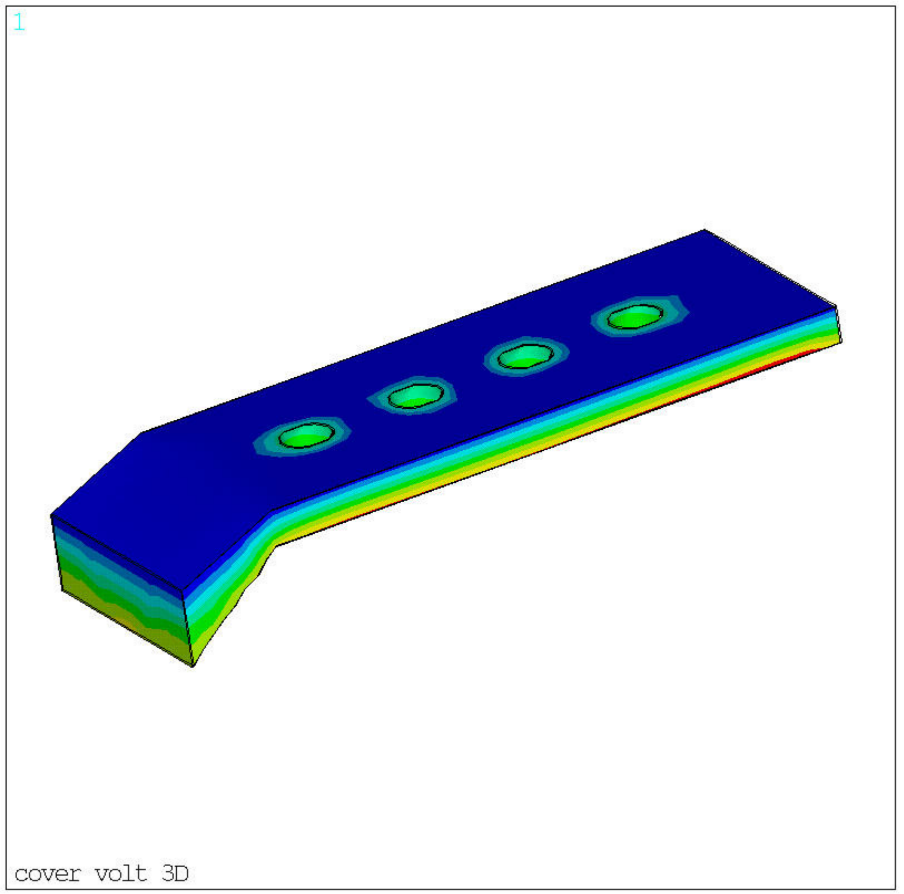
Area	Heat dissipation area		Heat dissipation (kW)	Heat dissipation (V)	%
Anode area	Pot hood	Pot side cover plate	97.1	0.298	16.1
		Pot rim plate	21.0	0.064	3.5
		Pot end cover plate	16.3	0.050	2.7
		Sub-total	134.4	0.412	22.2
	Pot superstructure	Pot top	67.1	0.206	11.1
		Anode guide bar	6.9	0.021	1.1
		Fume	111.5	0.342	18.5
		Sub-total	185.5	0.569	30.7
	Total		319.8	0.981	52.9

Heat dissipation distribution (anode area) for a Type B 320 kA pot

Heat Dissipation at Pot Top

The thickness of covering materials has a major impact on the heat dissipation at the top of the pot.





350 kA, covering materials with a thickness of 10 cm

Heat Dissipation at Pot Top

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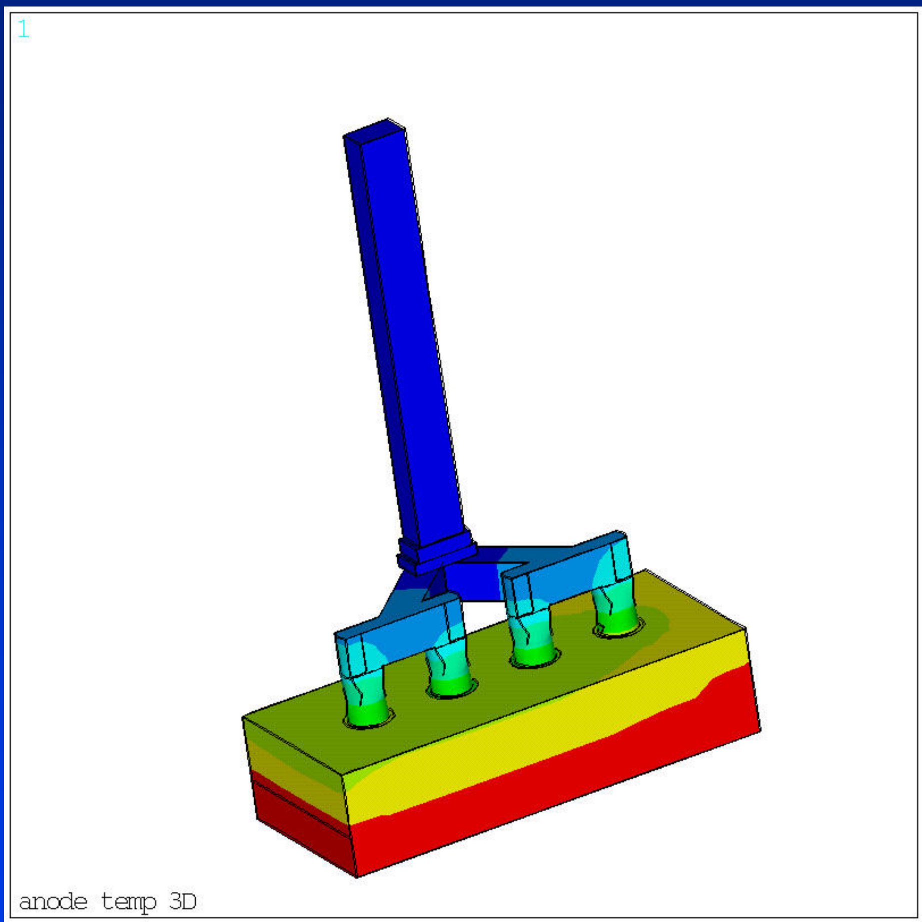
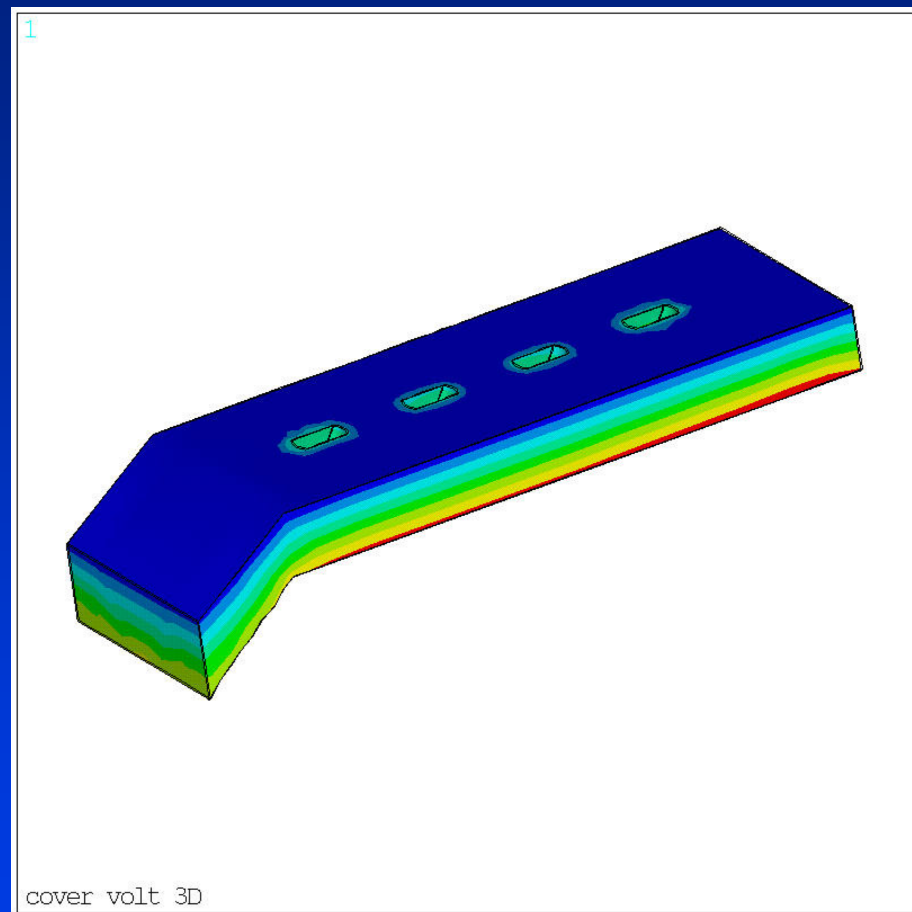




350 kA, covering materials with a thickness of 18 cm

Heat Dissipation at Pot Top

Covering materials with 10 cm thickness

	kW/V	%
Heat dissipation of aluminum guide bar :	20.480/0.059	2.75
Heat dissipation of anode stub:	150.976/0.431	20.31
Heat dissipation of horizontal covering layer:	169.116/0.483	22.75
Heat dissipation of slope covering layer:	23.869/0.068	3.21
Heat dissipation of inner rim plate at pot side:	0.492/0.001	0.07
Heat dissipation of inner rim plate at pot end:	1.089/0.003	0.15
Heat dissipation of anode area:	366.022/1.046	49.23

Covering materials with 18 cm thickness

Heat dissipation of aluminum guide bar:	22.759/0.065	3.31
Heat dissipation of anode stub:	136.407/0.390	19.87
Heat dissipation of horizontal covering layer:	124.906/0.357	18.19
Heat dissipation of slope covering layer:	23.505/0.067	3.42
Heat dissipation of inner rim plate at pot side:	0.492/0.001	0.07
Heat dissipation of inner rim plate at pot end:	1.089/0.003	0.16
Heat dissipation of anode area:	309.158/0.883	45.03

Impact of different thickness covering materials on voltage reduction

Heat dissipation at pot side and pot bottom

	Pot side ledge thickness (cm)	Pot side bottom ledge length(cm)	Pot end ledge thickness (cm)	Pot end bottom length(cm)
Flat-bottom cathode	8-15	5-15	12-18	8-18
Irregular-bottom cathode	10-18	20-25 (inside groove)	13-20	10-20

Relationship of optimal ledge thickness and bottom ledge length

Pot voltage	3.7 to 3.9 V	3.9-4.1 V	4.1-4.2 V
Superheat	Below 7 °C	8-10 °C	Above 10 °C
Thermal insulation area	Thermal insulation of side, lower side and bottom	Thermal insulation of side and bottom	Thermal insulation of bottom

Relationship among voltage, superheat and lining thermal insulation

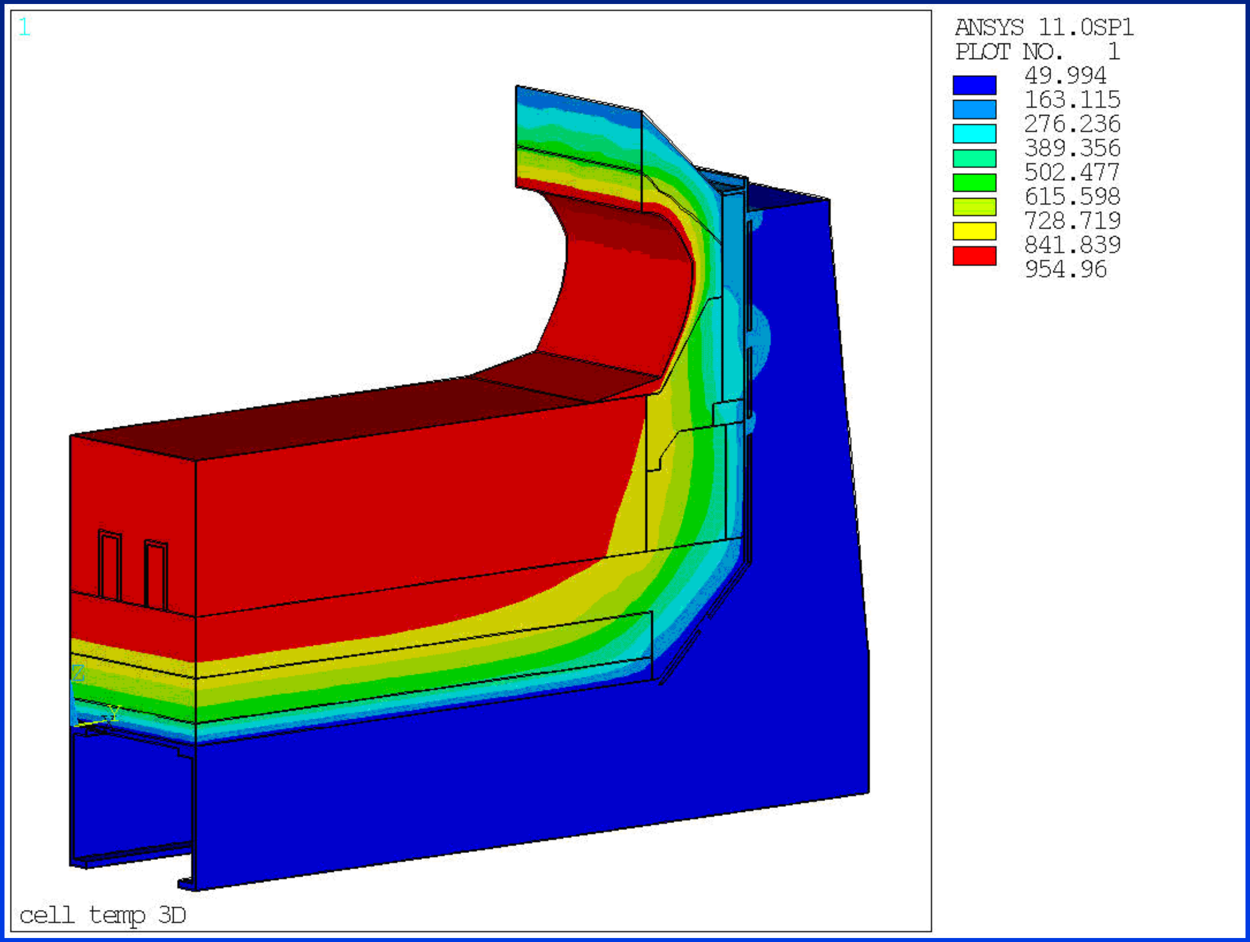
Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot

Conventional lining structure

Current density:	350000	(A)
Metal level:	22.0	(cm)
Bath level:	18.0	(cm)
ACD (anode cathode distance):	5.4	(cm)
Covering material thickness:	18	(cm)
Al2O3:	2.5	(%)
AlF3:	10	(%)
LiF:	1	(%)
MgF2:	0.4	(%)
CaF2:	5.6	(%)
Liquidus temperature:	945.32	(°C)
Superheat:	8.0	(°C)

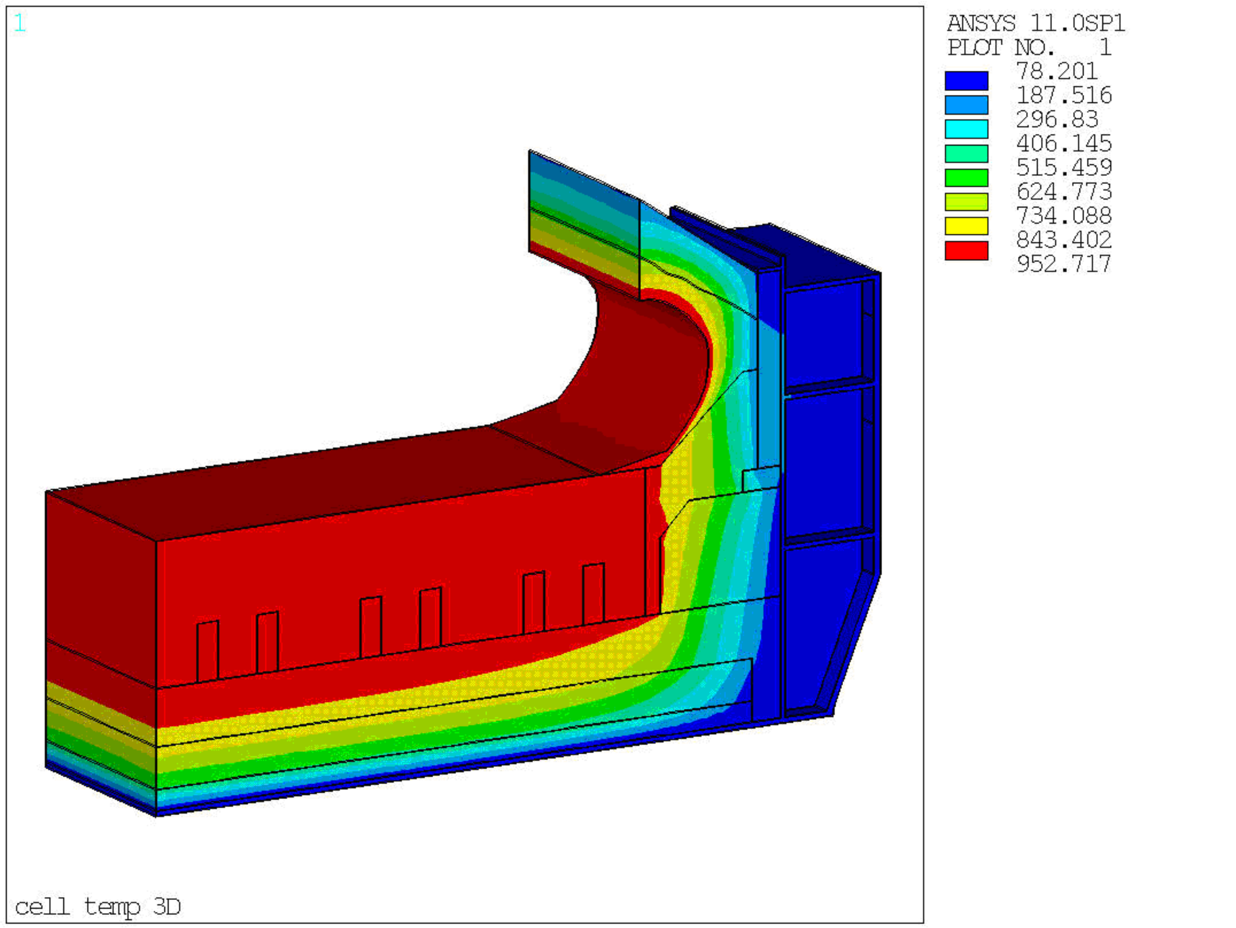
Process control parameters

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot



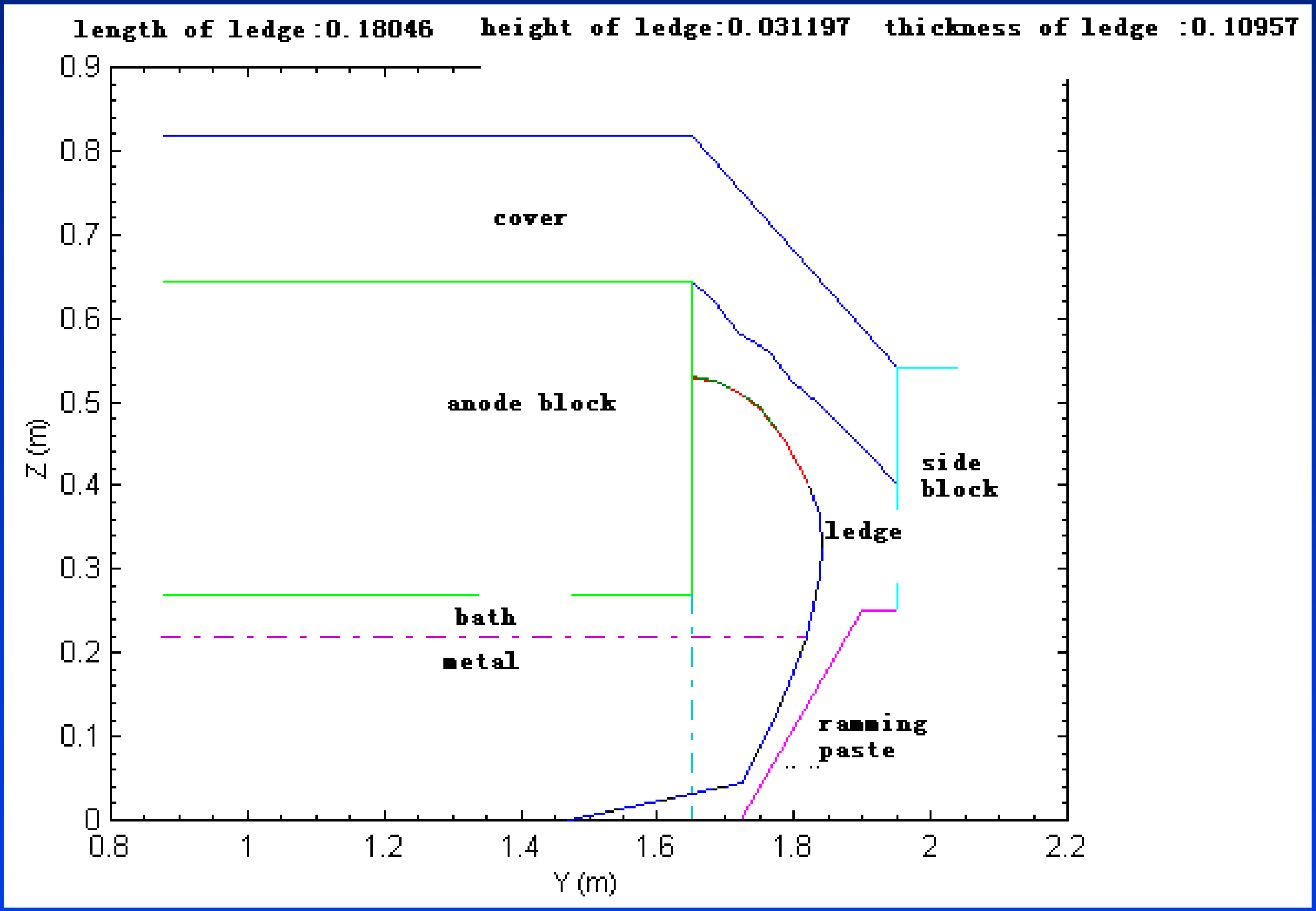
Conventional lining structure, pot side temperature

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot



Conventional lining structure, pot end temperature

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot



Conventional lining structure, profile of pot side ledge

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot

Conventional lining structure

Anode voltage drop:	346	(mv)
Clamp voltage drop:	15	(mv)
Guide rod voltage drop:	26	(mv)
Explosive welding voltage drop:	8	(mv)
Anode stub voltage drop:	42	(mv)
Voltage drop of iron/carbon joint:	105	(mv)
Carbon block voltage drop:	150	(mv)
Bath layer voltage drop:	1502	(mv)
Bubble layer voltage drop:	170	(mv)
Cathode voltage drop:	284	(mv)
Cathode steel bar voltage drop:	109	(mv)
Cathode joint voltage drop:	106	(mv)
Cathode carbon block voltage drop:	69	(mv)
Counteraction electric potential:	1672	(mv)
Voltage drop for busbar around pot:	200	(mv)
Pot working voltage:	4.174	(V)

Voltage break down

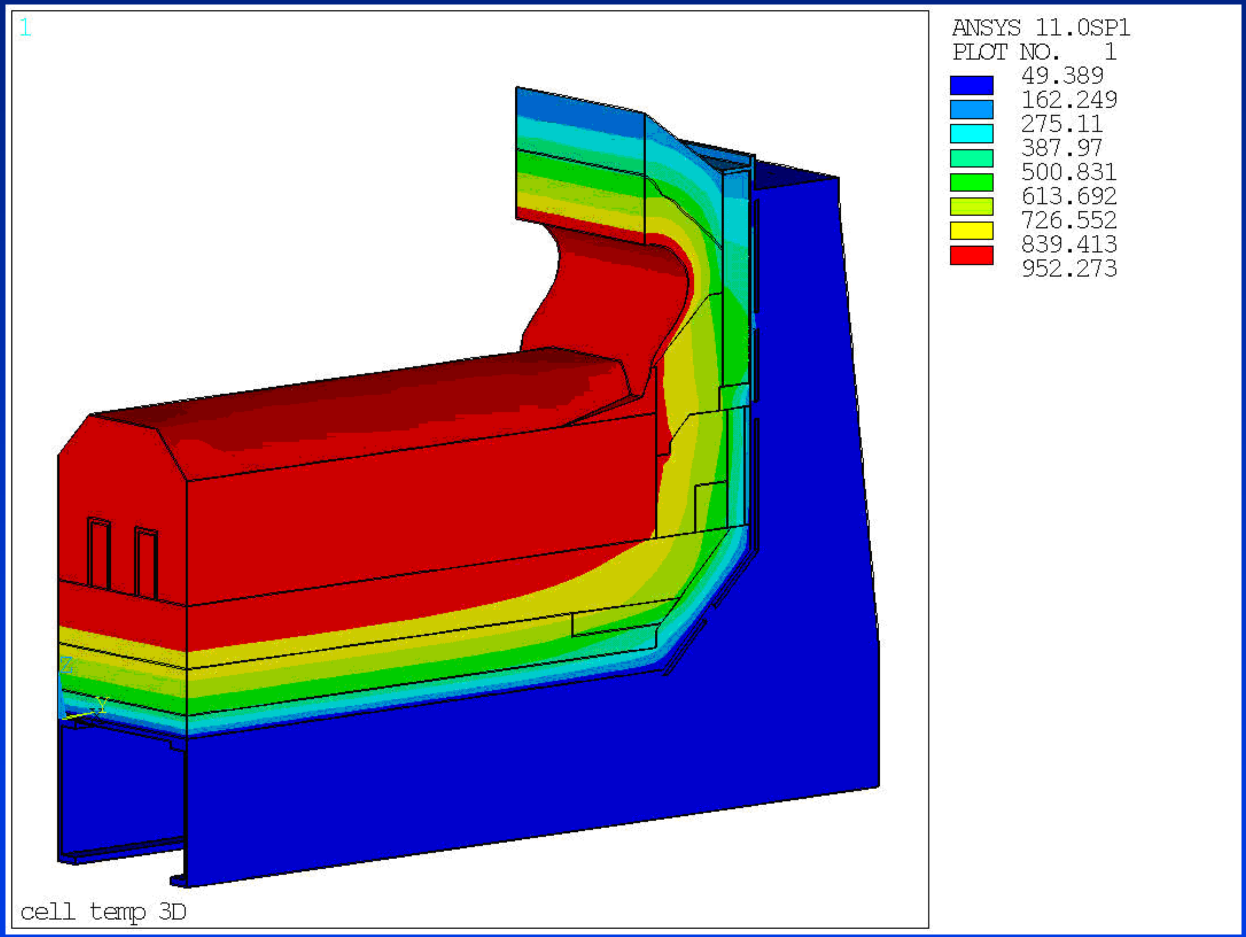
Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot

New thermal insulation lining structure

Current density:	350000	(A)
Metal level:	12.0	(cm)
Bath level:	18.0	(cm)
ACD (anode cathode distance):	4.5	(cm)
Covering material thickness:	18	(cm)
Al2O3:	2.5	(%)
AlF3:	10	(%)
LiF:	1	(%)
MgF2:	0.4	(%)
CaF2:	5.6	(%)
Liquidus temperature:	945.32	(°C)
Superheat:	7.0	(°C)

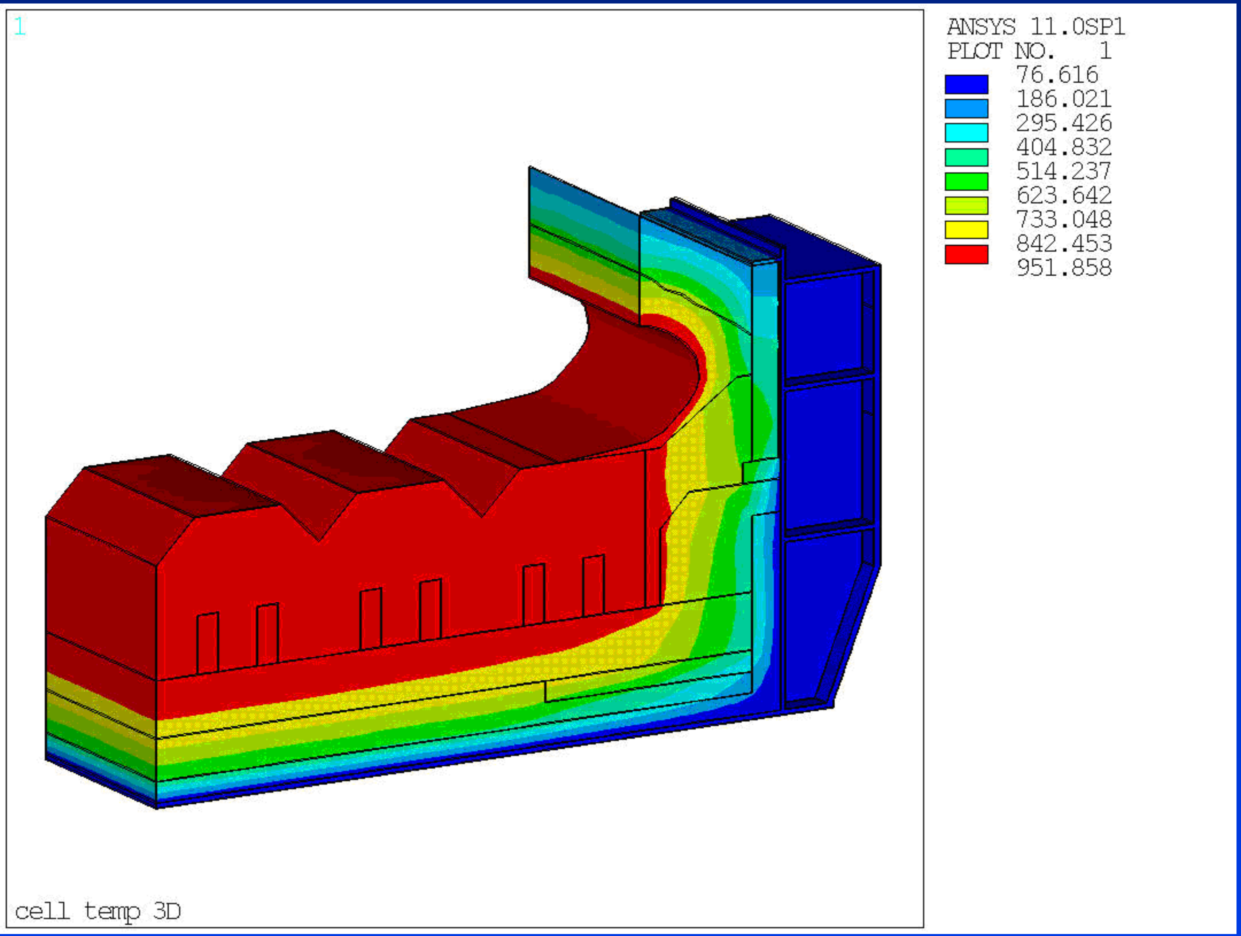
Process control parameters

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot



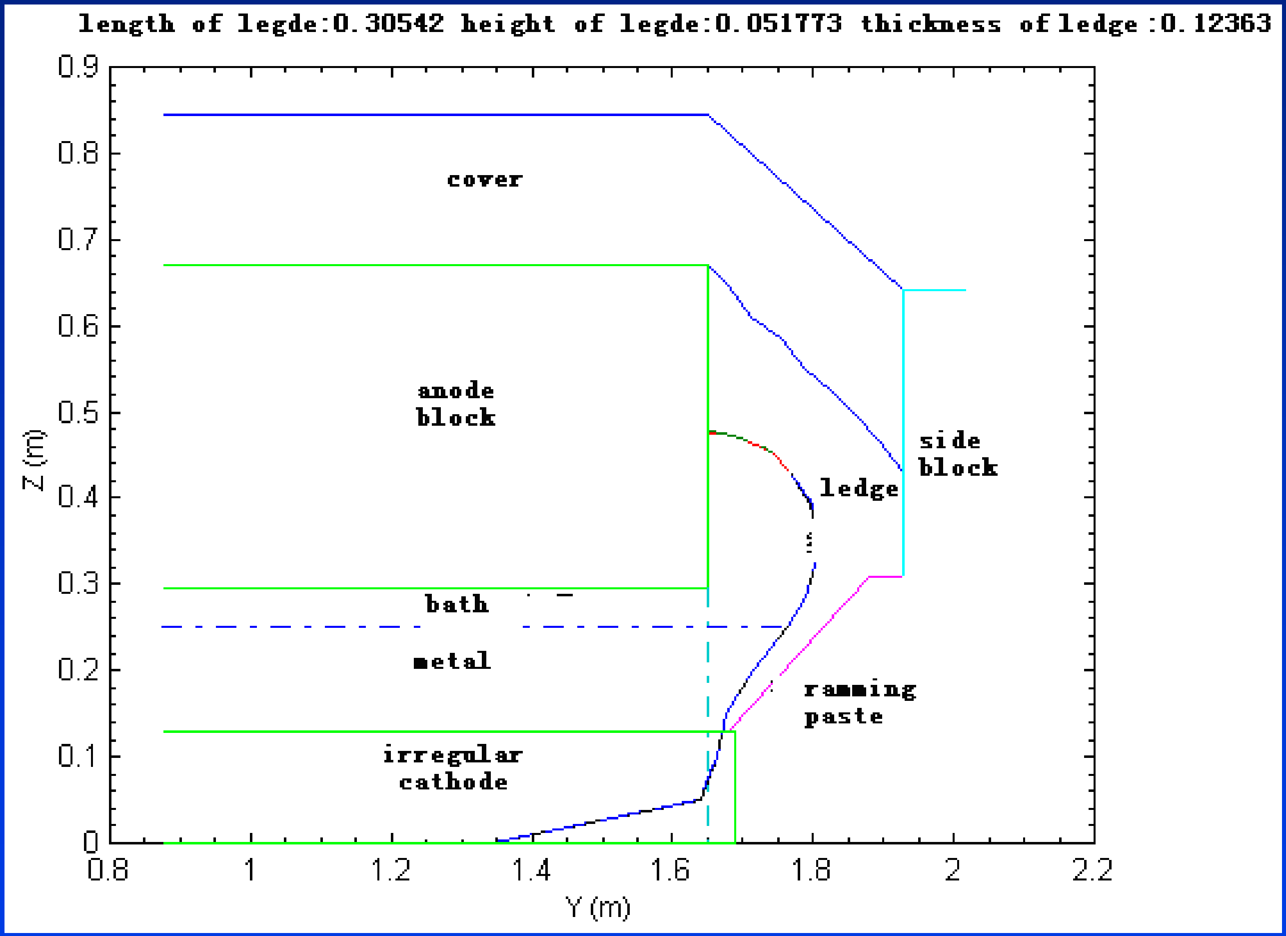
New thermal insulation lining structure, pot side temperature

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot



New thermal insulation lining structure, pot end temperature

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot



New thermal insulation lining structure, profile of pot side ledge

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot

New thermal insulation lining structure

Anode voltage drop:	347	(mv)
Clamp voltage drop:	15	(mv)
Guide rod voltage drop:	26	(mv)
Explosive welding voltage drop:	8	(mv)
Anode stub voltage drop:	42	(mv)
Voltage drop of iron/carbon joint:	104	(mv)
Carbon block voltage drop:	151	(mv)
Bath layer voltage drop:	1228	(mv)
Bubble layer voltage drop:	170	(mv)
Cathode voltage drop:	229	(mv)
Cathode steel bar voltage drop:	106	(mv)
Cathode joint voltage drop:	64	(mv)
Cathode carbon block voltage drop:	59	(mv)
Counteraction electric potential:	1672	(mv)
Voltage drop for busbar around pot:	200	(mv)
Pot working voltage:	3.846	(V)

Voltage break down

Heat dissipation distribution calculation and actual measurement comparison between conventional lining and new thermal insulation lining in 350 kA pot

Conventional lining structure

Current efficiency:	94 %
Daily aluminum production:	2650 kg
Direct current consumption:	13231 kWh/T

New thermal insulation lining structure

Current efficiency:	93 %
Daily aluminum production:	2622 kg
Direct current consumption:	12323 kWh/T

Comparison of economic benefit

Conclusions

Throught industrialized experiments, testing at the site, computer simulation and comparisons, the ways and the methods to decrease energy consumption through pot voltage reduction with respect to heat dissipation are as follows:

- **material and thickness of anode covering material**
- **new-type thermal insulating lining material**
- **new-type thermal insulating lining and cathode design**

Comparing with the conventional pot, the reduced cell voltage is around 200-450 mV. The reduced energy consumption per ton aluminum is around 640-1440 kWh/T based on the calculation of 93% current efficiency.

The annual reduced energy consumption of the pot line is around 32*107-72*107 kWh per year based on the calculation of an annual capacity of 500 thousand tons.

The operation cost savings are in the range of 160 to 360 million Yuan per year as per 0.5 Yuan per kWh conversion for the power price.