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A NEW MATERIAL FOR COLLECTOR BAR SEALING – LRM2

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Abstract

The collector bar sealing is an important procedure for cathode construction. The material selection and the installation techniques have to be very well managed in order to obtain a high performance pot with low cathode voltage drop and long lifetime.

A new cathode block-to collector bar sealing material has been developed in Novelis Ouro Preto, southern of Brazil, aiming to achieve better electrical resistance and handling during application. This material, so-called LRM2, contains iron powder instead of traditional carbonaceous paste.

In this paper, a comprehensive study comparing the traditional carbonaceous with iron-powder gluing is presented. The collector bar-to cathode sealing showed that iron powder techniques do not show meaningful difference on pot voltage when compared with cast iron and can improve the handling procedures during operation.

Company Information

The Novelis Ouro Preto plant is located in the southern part of Brazil. In this facility, there are currently two HS Soderberg potlines, a Carbon Plant, a Casthouse and Hydroelectric Power Plants.

Introduction

The cathode design and construction play an important role in pot performance. The cathode is a critical point of discussion to predict the life, the stability and the electrical efficiency of the pot. It is assembled using several materials, such as cathode carbon blocks, collector bar, ramming pastes, glues, refractories, etc. This paper describes the gluing of the collector bar into the slot of the block (Figure 1) as one important activity to achieve good electrical contact.

The cast iron is one of the well-known methods to provide collector bar and carbon block connection. This material replaces the use of carbonaceous paste and can improve the electrical contacts mainly for high amperage pots. The application of the cast iron requires special installations in order to melt the material and pour it onto the cathode. This process must be extremely controlled to avoid crack formation on the blocks and imperfections on the connection. The operational costs of the cast iron technique make the cathode construction cost 50% higher when compared with paste techniques[1].

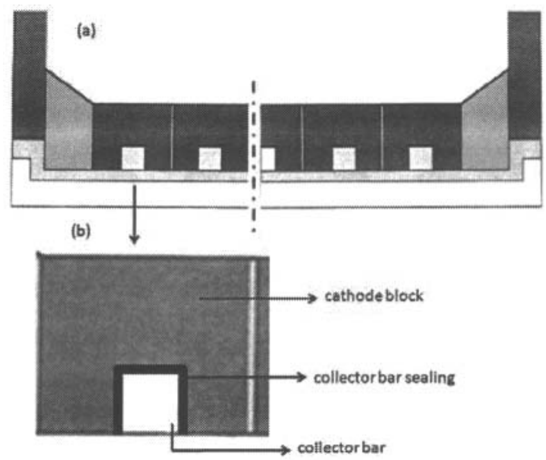

Figure 1. (a) Cathode overview. (b) Schematic representation of sealing the collector bar onto cathode block.

Investment on special facilities, operational costs and technical knowledge to control the cast iron application process are some reasons that have made some smelters to keep using the carbonaceous paste or to develop special techniques to improve the connection.
One of the developments was the use of the "glue and graphite" installed with rammers. Another technique tried was the "Solid Glued Bar Pots" that used a special glue on the cathode block and the bar was forced against block[2]. Results of both these techniques were measured and showed improvements comparing to standard carbon mixtures.

Another proposed material was a paste to replace the anthracite of the carbon mix with the iron powder. The results showed a very good alternative material to be used as bar/block sealant[3] which will be discussed with numbers in the next sections.

Novelis has worked over the past years to improve the pot performance. One of the initiatives was to develop a new material for the bar/block connection. The material was conceptually designed to use powder iron mixed with a special binder.

LRM2 A New Material for Collector Bar Sealing

In recent years the Novelis team has made efforts to develop a new material to improve the collector bar sealing. Since the beginning of this project the team has adopted some premises as follow:

- It should be a internal development;
- The pot technology would not be changed;
- There should be no implementation cost;
- Investments on new installations would not be approved;
- The pots pre-heating technology would not be changed;
- The proposed material should result in improvements on energy efficiency of the pots;
- No investment cost and high return.

A great quantity of the mixtures was tested varying the components such as graphite, aluminum and iron in different granulometry distributions. The selection of the binder was another big challenge because the perfect viscosity of the material to flow in the slot of the carbon block should be achieved. Still regarding the binder, it was also necessary to achieve a good gluing resistance that would fix the bar onto the block during the cathode installation.

The first proposed material achieved 40 $\Omega.mm^2/m$ in the electrical resistivity. Nevertheless, the plans were to achieve at least 20 $\Omega.mm^2/m$. Thus, another development phase was required.

The second phase of the project gave to the team an amazing result, even better than expected and the material produced was named as LRM2. The result is shown in table 1.

Table 1. LRM2 Physical Analysis

characteristic	unit	result
Green apparent density	g/cm^3	4,5
Electrical resistivity	$Ohm.mm^2/m$	0,7
Coefficient of thermal expansion (20, 1000 °C)	$(\Delta L/L_0).10^{-6}$	5,5
Thermal condutivity	W/mK	11,6
Real density	g/cm^3	7.32
Baked apparent density	g/cm^3	4,61
Compressive strenght	Kg/cm^2	867
Loss at baking	%	4,5

LRM2 Volumetric Expansion

Volumetric expansion tests were carried out, in which 38 mm Ø x 75 mm L green specimens are heated up until 1000 °C (3 °C per min) in inert atmosphere.

As seen in Figure 2, the volumetric expansion pattern is similar to that found for carbon materials expanding until 525 °C. Beyond this temperature, a light shrinkage is observed until 800 °C when the shrinkage becomes sharp. After 850 °C the behavior changes and a metallic pattern expansion is observed.

The behavior of the LRM2 during heating results in perfect connection between bar and block without excessive stress on the block.

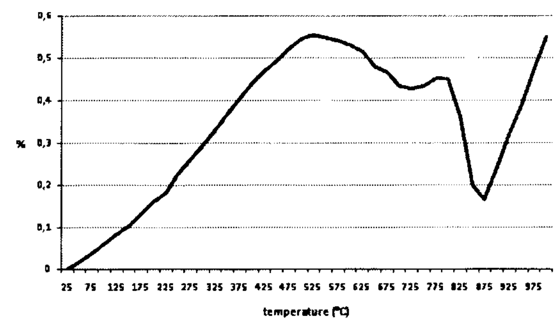

Figure 2. Volumetric expansion and shrinking pattern of the LRM2.

LRM2 on Potline

Since 2008 Novelis Ouro Preto Smelter has used this new material for cathode bar sealing instead of using a carbon paste based on amorphous anthracite and coal tar pitch. This initiative successfully achieved the objectives, the pot voltage and the resistance variation decreased, making the pots more efficient in energy consumption.

A comparison with pots using the LRM2 and pots using carbonaceous paste (Reference pots) is presented in Figures 3 to 5 where it is possible to observe the cathode voltage drop, the pot voltage (including anode effect voltage), pot noise (standard deviation of 12 measurements of pot electrical resistance taken every 4 seconds), respectively.

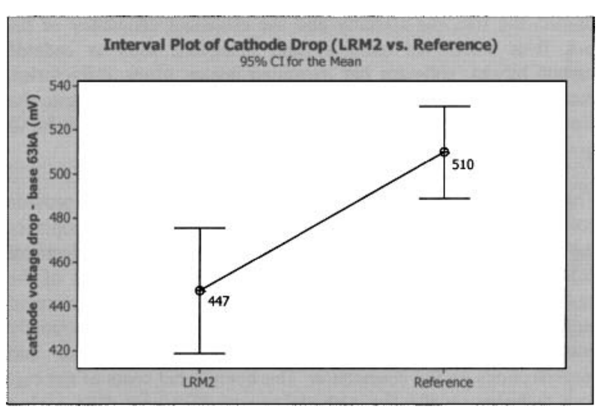

Figure 3. Cathode drop comparison.

The measurements in the potline showed a reduction in cathode voltage drop of 60 mV for pots using LRM2.

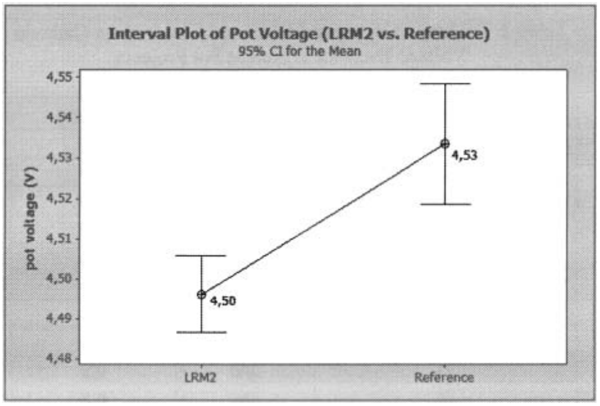

Figure 4. Pot voltage comparison.

Looking at the pot voltage, the test pots achieved 30mV lower voltage when compared to reference pots.

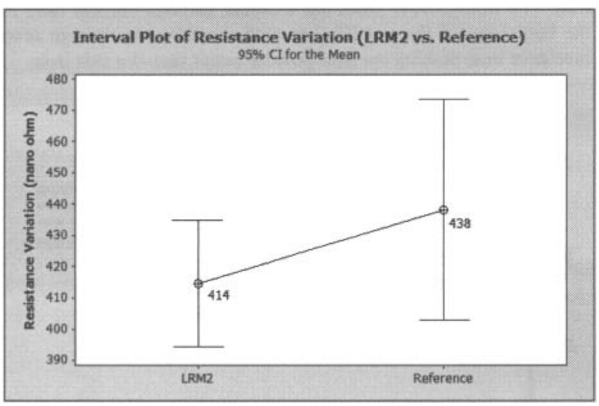

Figure 5. Resistance variation comparison.

It was also observed a reduction on the pot noise representing a gain in pot stability and consequently in current efficiency.

LRM2 versus Cast Iron on Electrical Resistance

With the purpose to understand the electrical differences between cast iron and iron powder sealant the Novelis team measured the electrical resistance of each material in different temperatures (from 25°C to 1000°C).

Two specimens were used in this measurement: one made with cast iron and another calcined made with iron powder and pitch. A specimen of each material was connected on its extremities with metallic wires and they were connected to an energy source that produced 5A. A voltmeter with 0.001V resolution was used to read the voltage of the specimen and a muffle with controlled atmosphere was used to heat the material during the tests. Readings were done every 100°C. The results are shown in Figure 6.

According to the presented measurement the iron powder paste showed a significant improvement comparing with the anthracite paste. The electrical resistivity reduced from 60 $\Omega.mm^2/m$ to less than 10 Ω.mm2/m.

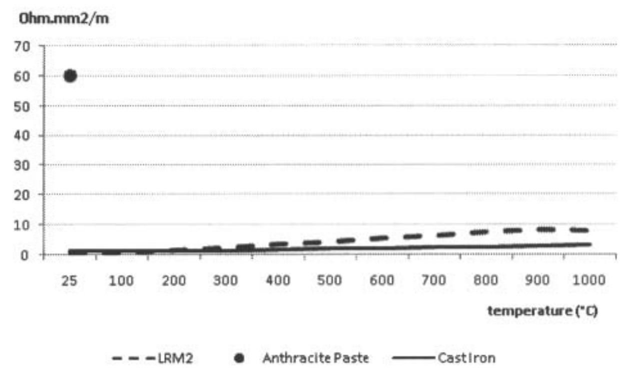

Figure 6. Electrical resistance comparison between cast iron and iron powder paste

When comparing with cast iron the resistivity is lightly above 300 °C. At work temperature the difference is around 5 $\Omega.mm^2/m$.

The comparison of benefits between LRM2 and anthracite paste is easy to understand, LRM2 is even better taking into account Figure 6, whereas the comparison between LRM2 and cast iron requests more elements to verify which material is the best.

The view of resistivity does not supply the better view for a good comparison but it is the raw material for a calculation that is possible to estimate the difference of voltage drop in connection when applied on the pots. The equation 1, used in the analysis, follows hereunder:

$$\Delta V = (\rho^{LRM2} - \rho^{cast\text{-}iron}) . L . I . A^{-1} \qquad \text{equation 1}$$

Where,

ΔV = (Voltage LRM2 – Voltage Cast Iron): voltage drop difference in connection
ρ^{LRM2}: LRM2 electrical resistivity
$\rho^{cast\text{-}iron}$: Cast Iron electrical resistivity
L: sealant thickness (considering 5 cm)
I: line amperage
A: cross-sectional area

Following this logic is possible to simulate the electrical variation with LRM2 and with Cast Iron. Two simulations were carried out: one changing the cross-sectional area, Figure 7, and the other changing the line amperage, Figure 8.

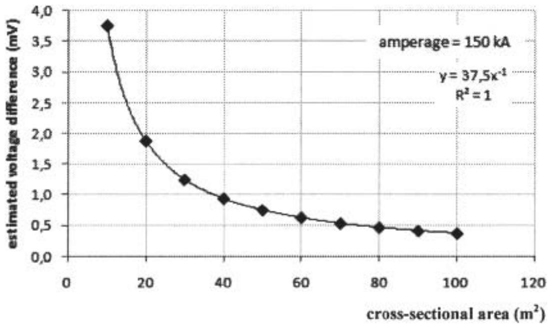

Figure 7. Estimated voltage difference vs. cross-sectional area considering fixed amperage (150 kA)

Figure 7 shows that increasing the cross-sectional area, or the pot size, the difference between LRM2 and cast iron is reduced. In practical terms it is possible to affirm that the cathode drop in large pots will be the same (1 mV or less) and in small pots it will be at most 3 mV.

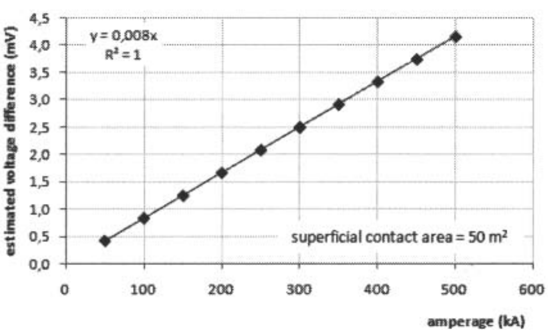

Figure 8. Estimated voltage difference vs. line amperage considering fixed cross-sectional area, $50m^2$

In the second analysis, Figure 8, it is possible to observe an increase of the difference between the two sealants but the difference even with high amperage is little, less than 4 mV.

A third analysis could be done mixing the information from Figure 7 and Figure 8. By increasing the amperage it is required to increase the pot size so that the influence of both parameters is neutralized. Upon simulation of several pot projects it was possible to observe that the worst scenario for difference between LRM2 and cast iron on cathode voltage drop would be around 1.0 mV (small pots), see table 2.

Table 2. Difference Between LRM2 and Cast Iron on Cathode Voltage Drop for Different Pot Projects

cross-sectional area (m^2)	amperage (kA)	ΔV (mV)
15	60	1,0
22	80	0,9
29	100	0,9
36	120	0,8
43	140	0,8
50	160	0,8
57	180	0,8
64	200	0,8
71	220	0,8
78	240	0,8

Some other papers have already published studies comparing iron powder pastes and cast iron. Figure 9 shows a very good performance of an iron powder material when compared with cast iron. The iron powder paste has a higher cathode voltage drop in the beginning of the pot life but with the time the voltage drop increases less, making the iron powder better than the cast iron.

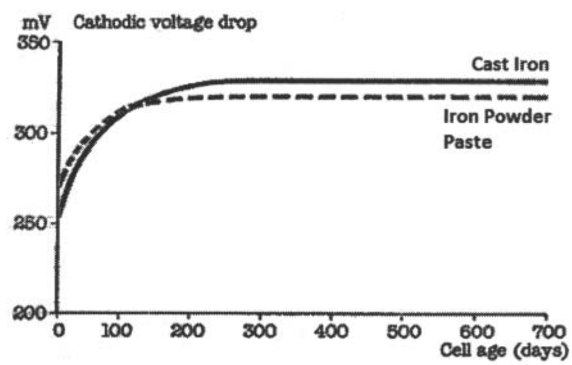

Figure 9. Cathodic voltage drop comparison between iron powder paste (BVM 51) and cast iron[4]

The reason for this behavior is the fact that the collector bar reacts with sodium and aluminum, promoting a volumetric expansion and increasing the resistance on the cathode. This fact is stimulated by the presence of air at 900°C that increases the reactions[5].

One of the critical points when cast iron is used is in the operation to seal the bar on cathode block. The expansion of the bar at operation temperature is four times higher than the expansion of the slot. The wrong control of the temperature during the collector bar application can result, during pot start-up, in a volumetric expansion higher than critical value, resulting in crack formation on cathode block. These cracks can break the cathode, increase voltage drops or promote metal penetration reaching the bar where expansion reactions happen[6]. Typical cracks due to wrong cast iron installation are shown in figure 10.

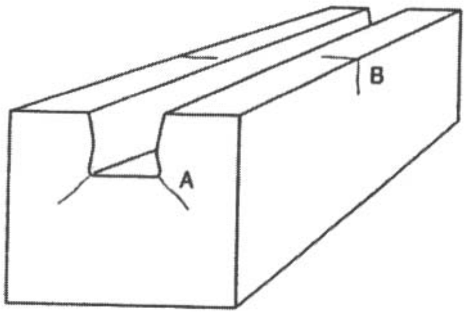

Figure 10. Typical cracks that may form during cast iron sealing of collector bar. (A) Wing crack and (B) Corner crack[1].

The iron powder mixture is plastic during calcination, until 550°C. Therefore, the expansion after carbonization is not enough to create cracks on the carbon blocks.

How to make the connection bar/block using LRM2?

The installation of the bar on the block using LRM2 is extremely easy when compared to some other processes such as using cast iron. The procedure is written below:

- The components must be heated up to 100°C;
- Set the cathode block with the slot side up on an operation table that is prepared to avoid movements of the block;
- Cover the bottom of the slot with LRM2 and ram it;
- Set the collector bar inside the slot, over the paste bed with low pressure;
- Set the bar on the right position and use stop fillets to block bar movements;
- Apply the LRM2 between block and bar in layers with maximum 70 mm using pneumatic rammers with pressure 6.0 kg/cm^2.
- After application the components have to be kept 24 hours in repose. After 24 hours the LRM2 viscosity will be enough to keep the collector bar fixed to the cathode block.

Figure 11 illustrates the collector bar installations on cathode blocks using LRM2.

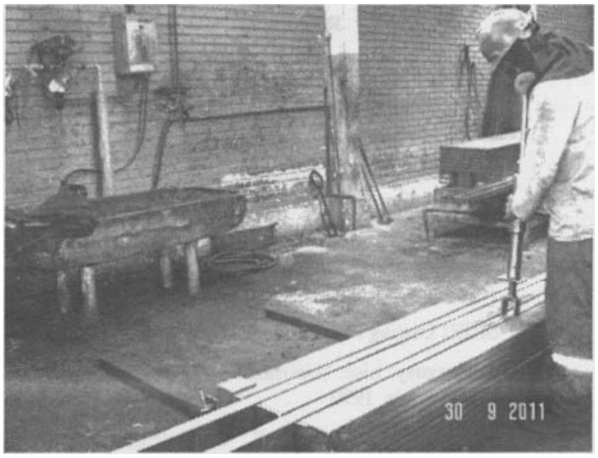

Figure 11. Collector bar installation on cathode blocks using LRM2

Conclusion

The cathode construction is an issue of discussion in all smelters around the world. Part of this procedure was explained in the present paper with discussions about the techniques of connecting the collector bar onto the cathode block. The summary of discussions follows hereunder:

- Cast iron technology (the most used technique) and LRM2 (the new proposed material) give better results than the mixtures based on anthracite. More than 50 ohm.mm^2/m can be reduced using cast iron or LRM2 instead of carbon mix;
- Cast iron techniques require special installations and have high operational cost (50% more than other techniques);
- Cast iron techniques require an advanced process control to avoid imperfection in connection and cracks on the blocks;
- The cathode voltage drops using cast iron and LRM2 were simulated and discussed. It showed that LRM2, when compared with a good cast iron process, does not have meaningful differences.

It was also shown the field results of the LRM2 in the Novelis Ouro Preto smelter. It was shown that 30 mV were saved in the pot voltage and improvements on pot stability were observed.

Ouro Preto smelter developed the LRM2 sealant material even without investments on industrial installations and created a very simple operational practice to connect the collector bar onto the cathode block.

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