VERTICAL STUD SØDERBERG TECHNOLOGY DEVELOPMENT BY UC RUSAL IN 2004 – 2010 (PART 2 – ECO-SØDERBERG TECHNOLOGY)

Vladimir Frizorger[1], Victor Mann[2], Evgeniy Chichuk[1], Victor Buzunov[1], Elena Marakushina[1], Nikolay Pitercev [2], Igor Cherskikh[1], Eduard Gilderbrandt[3]

[1] RUSAL ETC, Pogranichnikov st. 37/ 1, Krasnoyarsk, 660111, Russia
[2] RUSAL, Technical Direction, Nikoloyamskay St. 13 – 1, Moscow, 109240, Russia
[3] Siberian Federal University, Krasnoyarsk, Russia

Keywords: VSS, VSS Modernization, Eco- Søderberg, Colloid Anode

The Second Phase of Søderberg Modernization in Krasnoyarsk Smelter

Within the framework of the second modernization stage (since 2005), UC RUSAL began an "Environmentally friendly Søderberg" project. The strategic goal was to create a competitive cell.

The 'Environmentally friendly or Eco-Søderberg' project has included:

- Anode production equipment and technology.
- Cathode design and cathode production method.
- Anode and cell technology with an automated process control system.
- Activities aimed at gases afterburning and their removal from cells.
- Automated raw materials transport and feeding systems.

Within the project, special designed mechanisms and devices continue to be developed for decreasing manual labor. The goal is to mechanize and automate all cell tending operations.

Since 2010 the 'Environmentally friendly Søderberg' has been implemented in 4 potrooms of RUSAL Krasnoyarsk.

Parameters of the 'Environmentally friendly Søderberg' technology are given in the Tables 1, 2 and 3. Almost all cell operations are conducted without crust breaking – through special peepholes in the gas collection skirts in the gas removal system (see figure 1).

Table 1. Parameters reached by Søderberg S8BM-E (Eco-Søderberg) pilot cells in comparison with conventional VSS S8BM

Parameters	S8BM	S8BM-E July 2010	Delta
Amperage, kA	174.7	174.7	0
Current Efficiency, %	87.7	91.5	3.8
Power Consumption DC, kWh/t Al	16,102	15,500	602
Anode Paste Consumption, kg/t Al	520	490	30
Pitch Consumption, kg/t Anode Paste	297	246	51
Metal Height, cm	51	25	26
Cell Metal Inventory, t	28	16	12

Table 2. Industrial parameters of the S8BM-E (Eco- Søderberg) technology in comparison with foreign VSS smelters [2]

Process and Economical Parameters	Environmentally Søderberg	Alcoa Aluminium, Lista, Norway	Aratu-Alcan, Brazil
Amperage, kA	174	123	117.6
Current Efficiency, %	91.5	91.5	89.0
Production, kg Al/day	1,320	850	837
Power Consumption DC, kWh/t Al	15,500	16,900	15,700
Anode Paste Consumption, kg/t Al	490	495	516
AlF_3 Consumption, kg/t Al	15-17	15	

Table 3. Environmental parameters of the S8BM-E (Eco- Søderberg) technology in comparison with foreign VSS smelters [2]

Environmental Parameters	**Environmental Søderberg, RUSAL**	**Alcoa Aluminium Lista, Farsund, Norway***	**OSPAR 2010**
F total, kg/t	0.6	<0.5	<0.6
PAH (benzo(a)pyren)	0.0085	0.008	0.01

*Additional roof scrubbing with seawater

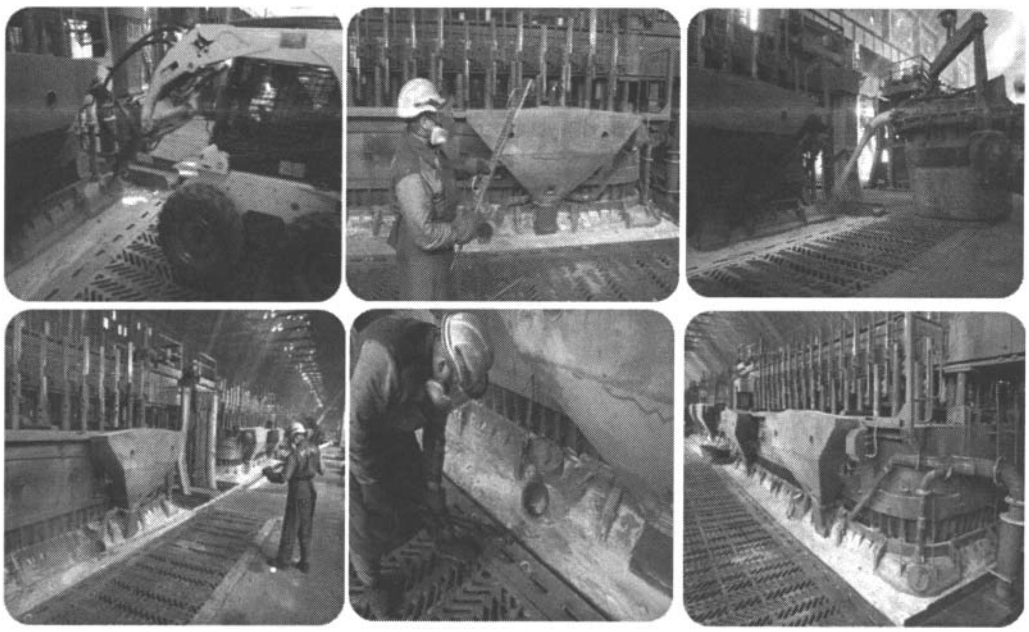


Figure 1. S8BM-E pot tending without crust breaking

One of the main parts that have been modernized is the anode. The 'Environmentally friendly Søderberg' concept requires less content of binder material (in comparison with a dry anode) without influence on anode operational characteristics. Such global and large-scale work aimed at improving the Søderberg anode technology has not been done in the world since 1972.

In order to improve effectiveness of mixing fines with pitch, the process of mixing became a separate operation. Anode paste production is conducted in 2 stages. The first stage includes mixing of pitch with fines. For this, equipment that works on the basis of mechanical activation is used (see figure 2).

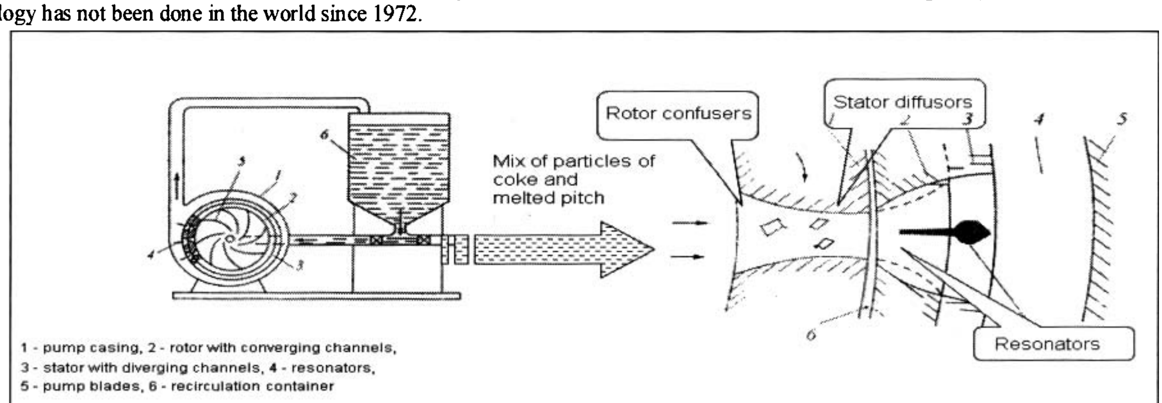


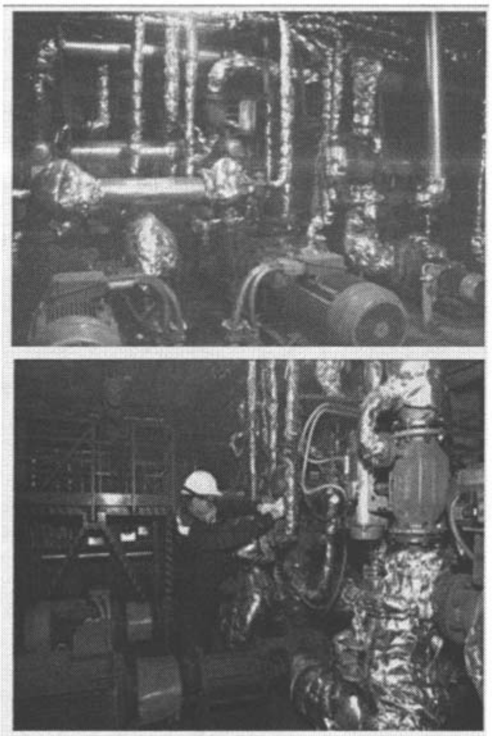
Figure 2. Hydropercussion-cavitation method of modification, dispersion and homogenization of carbon-carbon compositions

A mechanical activator is a machine comprising of a stator and a rotor along the circle of which holes (confusers) are located. The stator and rotor holes coincide with a frequency of 1500 to 1600 pulses per second. Due to high intensity of the process of mechanical activation, a pitch and fines composition becomes very homogeneous.

According to the above-stated, almost new, by its properties, binder has been received – a pitch and fines composition that does not exfoliate for several hours. Anode paste produced by mixing a mechanically activated pitch and fines composition with coke coarse fractions is called colloid anode paste to signify colloidal properties of the suspended coke fines in the pitch.

Initially, the coke-fines-pitch mixing process was developed through numerous experiments within the carbon laboratory where the parameters of composition production and parameters of compositions, and parameters of initial components of compositions before and after mechanical activation were studied.

New technology was tested in a pilot area at RUSAL Krasnoyarsk (see figure 3).



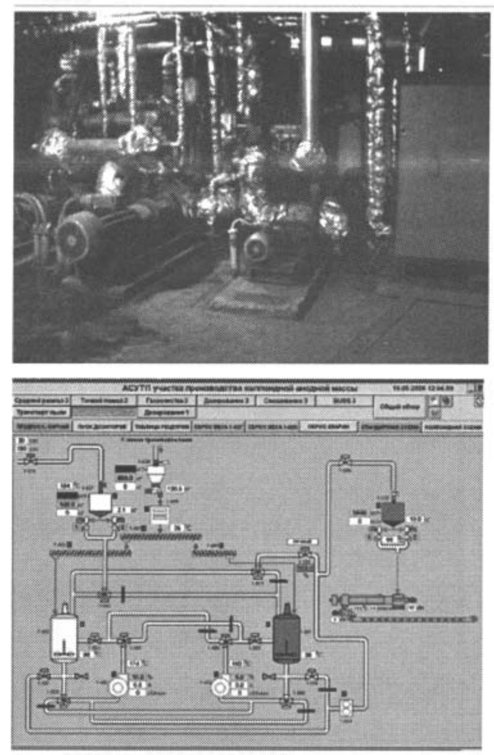


Figure 3. Colloidal anode paste production area (pilot)

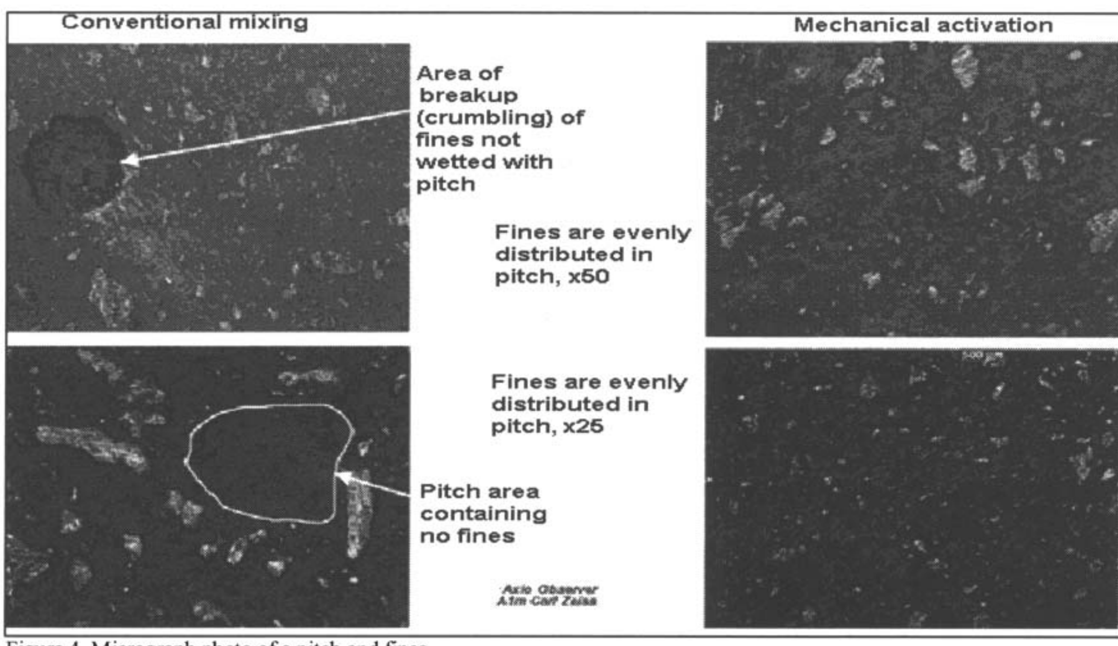


Figure 4. Micrograph photo of a pitch and fines

During mechanical activation at least three processes occur:

- pitch modification, at which a pitch softening point increases by 10 to 12 degrees; light resins are removed, and:
- dispersion, where the agglomerated fine coke that is formed with the initial contact or mixing with pitch is broken up into smaller agglomerates or individual coke particles that become wetted;
- As a result, new surfaces are formed and the newly formed surfaces and the entrapped air within the larger agglomerates are released with reduction of agglomerate size by the blending frequency. This creates brand new conditions for wettability of the surface of particles of coke fines with pitch. As a result, a new product, and a modified binder are close in characteristics to colloidal a suspensions. Therefore, the technology was called 'colloidal anode paste production technology', and the anode itself – 'colloidal anode',
- homogenization, the purpose of which is uniform (even) distribution of hard particles of coke in liquid pitch.

Figure 4 shows micrograph photos of a pitch and fines composition (x 50).

Since the end of 2010, stud hole paste (SHP) has been produced based on the principle of mechanical activation.
Improved wettability of coke with pitch allowed decreasing the content of coal tar pitch from 40% to 36%. Secondary anode formed from colloidal SHP is denser (see figure 5), has a less number of pores and cracks, and low air permeability. This helps to decrease the voltage drop at the stud–secondary anode border.

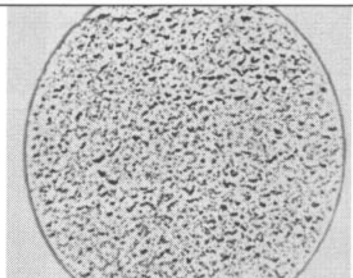
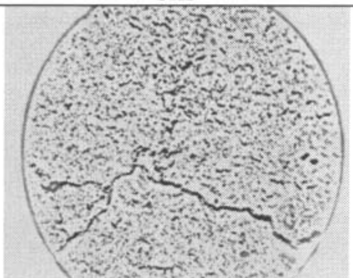
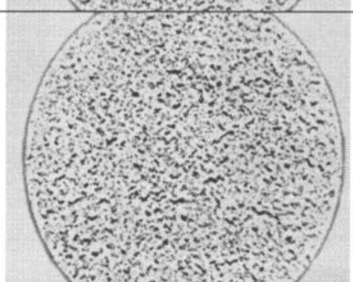
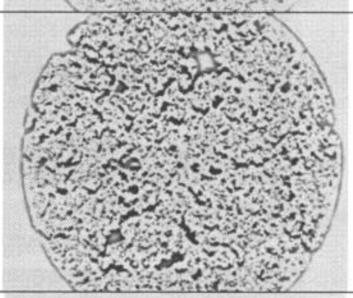
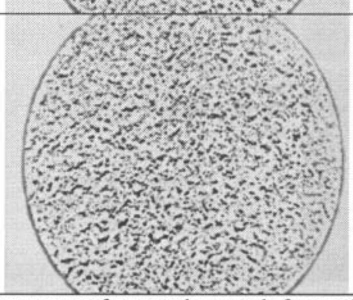
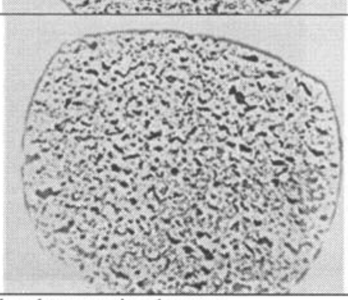
Height from anode face, mm	Secondary anode from colloidal SHP	Secondary anode from conventional SHP
300		
180		
20		

Figure 5. Photograph of the structure of a secondary anode from colloidal and conventional pastes

A secondary anode sample taken from colloidal SHP is homogeneous along its height, and there is no border between different portions of SHP. A sample taken from conventional SHP has clear borders at which it can be easily broken.

Physical and mechanical parameters of a secondary anode from colloidal and conventional pastes are compared in Table 4. Lower porosity and air permeability of a colloidal anode decrease reactivity, dust generation and anode consumption per tonne Al.

Table 4. Physical and mechanical parameters of a secondary anode from colloidal and conventional pastes

Parameters	Unit	Dry Anode		RUSAL Colloidal Anode			Pre-bake
		average	AD	lab	industrial	AD	
Apparent density	**kg/cm^3**	1.49	+/– 0.02	1.63	1.54	+/– 0.02	typical 1.58
Specific electrical resistance	**μΩ*m**	66	+/– 4	54	61	+/– 2	typical 58
Air permeability	**nPm**	3.8	+/– 1.7	0.2	1.5	+/– 0.4	< 2.5
CO2 reactivity	**mg/cm^2/h**	17	+/– 2	15.0	17	+/– 2	< 10

Table 5. Physical properties of colloidal and dry pastes

Parameters	Height from anode face 180 to 300 mm		Height from anode face 20 to 170 mm	
	Colloidal anode	Conventional anode	Colloidal anode	Conventional anode
Apparent density, g/cm^3	1.44	1.29	1.40	1.33
Specific electrical resistivity, μΩ*m	90	112	108	198
Open porosity, %	31	33	31	33
Air permeability, nPm	80	-	63	136

Table 5 shows some parameters of colloidal and dry pastes. At present, colloidal paste parameters produced on site are slightly worse than in the laboratory, but much better than conventional paste parameters. Colloidal paste is not just better in terms of density, specific electric resistivity, and air permeability, it is also better because the above-stated parameters are more stable, which evidences less sensitivity to raw materials. This is proven by data on average deviation of parameters of colloidal and dry pastes.

Anode paste produced on the basis of mechanical activation of a coke and pitch mix helped to receive a product with parameters are close to baked anode parameters (see Table 4).

Conclusions

A new technology of aluminum production, "Ecological Søderberg" with colloidal anode was developed as a basis of the second phase of VSS smelters modernization. The new technology compared with PB has lower total cost and close environmental characteristics. Conversion of the existing VSS technology to Eco-Søderberg is much cheaper and cost-effective than conversion to the PB, especially taking into account the scale of the Company's VSS production.

Acknowledgements

The authors recognize that the results were achieved thanks to the work of hundreds of RUSAL specialists, who supported the project in different directions. So we express our deep gratitude to them.

Special thanks go to our advisors John Johnson and Doug Hewgill for assistance in the preparation and processing of the material.

References

1. Adolf Karsten Syrdal, "The Søderberg Technology", The 20th International Course on Process Metallurgy of Aluminium, Trondheim, Norway, 2001, pp. 155-181.

2. Primary Aluminium Smelters and Producers of the World, compiled by R.P. Pawlek, Beuth Verlag GmbH, №9/2011

3. http:// www.genisim.com/ aluminium /smelters/ smelters.htm

4. Technical Inquiry, The 1, 2nd, 3rd VSS conferences. Calgary – Canada, 1998, Haugesund – Norway, 2000, and Krasnoyarsk – Russia, 2005.