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Editorial

Aluminium Production Process: Challenges and Opportunities

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Aluminium, with more than 50 Mt annual production in 2016, is an essential material in modern engineering designs of lightweight structures. To obtain aluminium ingots from bauxite, three main processes are involved: the Bayer process to produce alumina from bauxite; the anode manufacturing process to produce electrodes, and the smelting process using the Hall-Héroult technology. The Hall-Héroult process, involves the electrolysis of alumina, dissolved in molten cryolite to produce liquid aluminium that should be casted to produce ingots of different types of alloys. The technology is now about 130 years old and the aluminium production experienced a phenomenal growth during the past two decades—the highest growth rate for a commodity metal. The aluminium electrolysis cell is made of a steel shell, the internal surfaces of which are covered with a series of insulating linings made of refractory materials. The top lining, made of carbon, is in direct contact with the molten metal and acts as the cathode. The anode is also made of carbon, suspended in the electrolyte and consumed during electrolysis. According to the International Aluminium Institute [1] the energy required to produce one ton of aluminium varies between 12.8 and 16 MWh, depending on the technology used and the age of the smelters. Carbon consumption of the process—roughly about 400 kg of carbon for tone of aluminium—is also significant, contributing to the generation of about 1.5 tons of CO_2 per ton of aluminium. Thus energy efficiency and the environmental footprint of the process are the top concerns of this industry.

Major aluminium producers and scientists gather once a year during ICSOBA "The International Committee for Study of Bauxite, Alumina and Aluminium" [2] in order to share the challenges of the industry and the latest technological and scientific progresses. The scope of the event covers the whole Al production chain, from bauxite refining to aluminium electrolysis, including electrode manufacturing and aluminium smelting processes. This Special Issue was launched to publish selected works presented at this event, in order to disseminate the recent progress and new achievements in this emerging field with broader scientific and industrial communities. The submitted papers mostly focus on carbon technology for aluminium smelting, dealing with different issues related with carbon consumption and its environmental impact.

Allard et al. [3] presented a new generation of eco-friendly ramming paste. In an electrolysis cell, ramming paste, composed of calcined anthracite and coal-tar-pitch binder, is used to seal the seams between cathode blocks and the joints between the cathode lining and the cell walls. Installation of ramming paste is always challenging, implying special precautions for health and environmental issues, basically due to the polycyclic aromatic hydrocarbons (PAH) and volatile organic compounds (VOC) emissions. The authors extensively characterized 5 eco-friendly ramming pastes and reported their physico-chemical properties. They presented different characteristics of the samples in laboratory scale, i.e., green density, flexural strength, volume expansion, VOC and PAH emissions. The authors also report some field data, including cell performance and preheating data, obtained from Emirate Global Aluminium plant.

Khaji and Al Qassemi [4] published extensive plant data, aiming at finding possible correlations between anode manufacturing parameters and the net carbon consumption in smelting process. The manufacturing parameters, i.e., pitch content, metallic impurities and baking temperature were first correlated with baked anode properties such as air and CO_2 reactivity and air permeability. The plant net carbon consumption was then correlated with anode properties. A clear and quasi-linear correlation was reported between net carbon consumption and air and CO_2 reactivity residues, while anode desulfurization was found to increase net carbon consumption.

Ben Boubaker et al. [5] reported a work, exploring the potential of the acousto-ultrasonic (AU) technique as a non-destructive inspection method for prebaked anodes. Fast, reliable and non-destructive testing methods are of high importance in Al smelting process, making it possible to detect and discard the low-quality anodes before being set in the electrolysis cell. The authors used acoustic-ultrasonic signals to excite the anode block on one end, while measuring the attenuated signals at the other ends. The anodes were also subjected to destructive tests, i.e., X-ray computed tomography (CT-scan). Principal Component Analysis (PCA) [6] was performed on the attenuated signal features and the data were correlated with the CT-scan data. The authors reported that AU signals are sensitive to the presence of cracks as well as the density of baked carbon anode, thus exhibiting a good potential for anode non-destructive inspection.

Picard et al. [7] investigated the possibility of application of X-ray computed tomography, as a non-destructive testing method, for detecting cracks in baked anodes. Cracks may be initiated during the anode-forming step, due to the release of induced stresses, or during the baking step, due to the pitch devolatilisation and gas generation [8]. They could result in increasing the anode electrical resistivity or in early failure of the anode due to the thermal shock while introducing it in hot cells. The authors developed an algorithm, based on the percolation process, capable of quantifying certain types of cracks. The algorithm was applied on CT images, obtained from samples with quite large cross-sectional area of 30×27 cm^2.

The initial versions of all contributions were published in the ICSOBA proceedings (Travaux) [2]. The selected contributions in this Special Issue are good examples of the efforts the industry is making to mitigate the environmental footprint of the process and to apply new methods and tools for better control of the anode quality.

I would like to thank all the authors for their contributions in this Special Issue. The priceless contribution of the reviewers is also highly appreciated; their constructive comments and suggestions significantly increased the quality of the published papers. Finally a special thanks goes to the *Metals* Editorial Office for the opportunity they gave to the authors to disseminate their work through this Special Issue.

References

1. World-Aluminium: Primary Aluminium Production. Available online: http://www.world-aluminium.org/statistics/#linegraph (accessed on 6 April 2017).
2. The International Committee for Study of Bauxite, Alumina & Aluminium. Available online: http://www.icsoba.org (accessed on 6 April 2017).
3. Allard, B.; Tawfik, M.; Kumar, A. Performances of Green and Eco-Friendly Ramming Pastes in EGA Pots. *Metals* **2016**, *6*, 112. [CrossRef]
4. Khaji, K.; Al Qassemi, M. The Role of Anode Manufacturing Processes in Net Carbon Consumption. *Metals* **2016**, *6*, 128. [CrossRef]
5. Ben Boubaker, M.; Picard, D.; Duchesne, C.; Tessier, J.; Alamdari, H.; Fafard, M. The potential of acousto-ultrasonic techniques for inspection of baked carbon anodes. *Metals* **2016**, *6*, 151. [CrossRef]
6. Johnson, M. Waveform based clustering and classification of AE transients in composite laminates using principal component analysis. *NDT E Int.* **2002**, *35*, 367–376. [CrossRef]

7. Picard, D.; Lauzon-Gauthier, J.; Duchesne, C.; Alamdari, H.; Fafard, M.; Ziegler, D.P. Crack Detection Method Applied to 3D Computed Tomography Images of Baked Carbon Anodes. *Metals* **2016**, *6*, 272. [CrossRef]
8. Meier, M.W. *Cracking Behaviour of Anodes*; R & D Carbon Ltd.: Sierre, Switzerland, 1996.