Contribution of ICSOBA in setting development trends in global bauxite, alumina and aluminium industry

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The modern aluminium industry was born with the invention of the Hall-Héroult process in 1886, and for more than 130 years the technology development has never stopped. Equipment development has been the most spectacular. However, during the second part of the 20th century, automation, PLC and computers as well as lean organizations further transformed the aluminium industry, in line with the 3rd industrial revolution. For the last few years, a new revolution, Industrie 4.0, born in manufacturing industries, has gained momentum. The aluminium industry, like most process industries, is somewhat lagging behind in this journey. However, numerous signals show the ball is now rolling. Icsoba, which was founded in 1963, has since supported technology developments by increasing the shared knowledge in the field of bauxite and encouraging exchange of ideas and cooperation between the alumina and aluminium professionals. Those considerations are as important today as ever, and Icsoba is transforming itself to support the aluminium industry in its journey towards Industrie 4.0.

The participants of the Hamburg Conference in 2017

1. Introduction

In 2018 we celebrated Icsoba's 55 years of activity. More than half a century of vocation for an organization such as Icsoba is quite an achievement by all means. Many entities created around the same time no longer exist today, but Icsoba is alive and doing better than ever.

In order to understand the success of Icsoba over the years, one has to look at the reasons and motivation behind bringing it to life[1]. The first Icsoba symposium was organized by the Yugoslav Academy of Sciences and Arts in Zagreb in October 1963. The Academy took the leadership role by realigning its scientific activity for solving economic and technical problems. By giving scientists and scientific institutions of various countries an opportunity to remain in direct contact, the Academy contributed to establishing solid links for international collaboration in the interest of progress in science. After the Congress, a very successful visit was arranged to the bauxite deposits of Dalmatia. During the concluding session, the Hungarian and French participants made the proposal that the Yugoslav Academy contemplate the possibility of establishing a permanent international working community. The Yugoslav Academy accepted this proposal and elaborated the Statute of the International Committee for the Study of Bauxite, Alumina and Aluminium. Icsoba was established.

2. Icsoba contribution to industry development trend

Since Icsoba was founded, the industry size has increased over ten times. All the time, Icsoba has unwaveringly supported technology developments by increasing the shared knowledge in the fields of bauxite, alumina and aluminium and encouraging the exchange of ideas and cooperation between the professionals in these fields, and in this way more often than not set the development trend of our industry.

a. Bauxite resources and mining

Icsoba's role is significant in knowledge sharing in the field of geological research, analyses, data interpretation and exploration of alumina bearing raw materials in the last 55 years – mainly bauxites but also non-bauxitic ores[2]:

- Exploration techniques developed: double/triple walled bits, air-core drillings, bucket auger, etc.
- Development in material testing and new methods introduced: DTG, X-ray diffraction, scanning electron microscopy, mass spectrometry, infrared spectroscopy, atomic absorption, Mösbauer method, RD/Rietveld method, Al, Si concentrations determined in situ, etc.
- Geomathematical methods: geo-statistics, kriging, semi-variogram, fuzzy function, etc. resulted in reducing the errors in the resource estimate and risks in mining
- New huge resources have been identified and new mines established in Australia, China, India (Eastern Ghats), Vietnam, Indonesia, Guinea and Brazil
- Bauxite beneficiation at Weipa (Australia), Bao Lok (Vietnam), Zhengzhou (China), Trombetas and Paragominas (Brazil) became a common, routine procedure
- Conveyor belt system (Australia, India) and slurry pipeline (Brazil) are applied for the first time in bauxite supply to refineries.

b. Alumina refining

In the last 40 to 45 years, a very intensive development of the Bayer process took place with the support of Icsoba, whose publications captured the following most important tendencies[3]:

- The conversion from batch to continuous tank reactors in the early days. The development of the tube digestion technology increased the production capacity of a single line and reduced operation cost[4]
- Red mud thickening and washing technol-

ogy and equipment have been significantly improved, resulting in low soda loss with residue and high throughput of the units[5]

- The transition from pond-type bauxite residue storage areas to dry stacking after paste thickeners and then after press filters allowed to significantly reduce the required surface area and capital cost. The development and proposal of best practices of bauxite residue disposal[6] and utilization[7,8] was explored as well
- The change from floury to sandy alumina quality is a significant tendency taken by the industry. On equipment side, using of larger units, better mechanical performances, higher liquor productivities at precipitation allowed to save electrical energy and steam, and to reduce capital cost for building new lines/plants[9].
- The shift from rotary to stationary alumina calcination units was overwhelming. Continuous evolvement of Fluid Bed[10] and Cas Suspension[11] calciners equipment allowed not only to improve product quality in terms of alpha phase content and particle size distribution but also to achieve energy consumption close to theoretically possible level.

Along with the Bayer process, the details of alternative technologies to process low grade bauxite, nepheline, alunite and clays including sintering, Bayer-Sintering, acidic processes have been presented and discussed giving insights on development and industrial implementation of those technologies[12,13].

c. Aluminium smelting

Icsoba accompanied the rapid development of the aluminium reduction technology in the last 30 years, most notably:

1. The fast cell amperage increase in many existing potlines by as much as 20 to 40%[14]. At the same time new potlines increased the current from 300 kA to more than 600 kA. The fastest development of new cell technology took place in China[15].
2. The development of the pneumatic transport of alumina to the cells[16], the development of cell point feeding technology and control to operate the cells without sludge and anode effects, which enabled very low PFC emissions.
3. The increasing anode quality in spite of deteriorating raw materials[17] and the introduction of slotted anodes, which resulted in better cell performance by decreasing bubble voltage drop[18].
4. The development of potroom service equipment such as pot tending machines (PTMs), allowing easy anode changing and cavity cleaning as well as laser marking for accurate anode positioning. The safety of crane operations increased by the automatic monitoring of crane insulation resistance[19].

These examples of the development of process technology and equipment illustrate the huge progress our industry made in the second half of the 20th century. However, during the same period, automation, PLC and computers as well as lean organizations further transformed the aluminium industry in line with the 3rd industrial revolution.

3. New industry development trends

Most refineries and smelters have reached a competitiveness plateau today and future gains cannot come from a new wave of headcount and cost reduction but from a significant improvement in process performance. In recent years, new solutions that have emerged in the manufacturing industry have gained momentum: automation and digitalization in the overall framework of Industrie 4.0. The aluminium industry, like most processing industries, is somewhat lagging behind in this journey to 4.0. However, numerous signals show that the ball is now rolling.

a. Automation

Driverless trucks in bauxite mining, developed by the major mining companies (20% of Rio Tinto's existing fleet of almost 400 trucks in the Pilbara, Australia, drive autonomously today)[20], are currently contemplated for new projects, for example at the new Rio Tinto Amrun bauxite mine in Cape York, Australia[21]. Driverless trucks mean that more material can be moved efficiently and safely, creating a direct increase in productivity. They use predefined GPS courses to automatically navigate haul roads and intersections and to know actual locations, speeds and directions of other vehicles at all times.

Prof. Dr. S. S. Augusthithis, Prof. Dr. Olga Lahodny-Sarč, and Prof. Dr. J. Nicolas

A group of participants on the Plenary Session of the Congress

The Icsoba Congress in 1978

Unmanned vehicles are also making their way into aluminium smelters as anode and/or metal hauler[22,23]. Those vehicles are aimed to be associated with autonomous devices for tapping, measurements and sampling.

Automation has also progressed in the smelter area. As an example, mechanized reduction cell hood handling[24,25] has been deployed as an intermediate step on the journey towards automated anode change, for which several tests have already been made during the last decade.

Other examples are automated equipment aimed at supplying additional information for quality control and process enhancement. There are numerous illustrations around the concept of predictive anode quality: online electrical resistivity measurement (Fives ECL Mirea)[26], automated butt characterization (Stas Abis)[27], etc. This type of equipment, used as 'soft sensors', is integrated in an overall end-to-end anode tracking system, which perfectly illustrates the transition to our next point: factory digitalization.

One cannot forget about a tremendous progress in chemical characterization of the aluminium industry materials. Automatic bauxite sample preparation and analysis systems, on-line crushing, grinding, pressing and briquette handling of electrolytic bath specimen or fully automatic metal analysers – all aided by LIMS (Laboratory Information and Management System) have deeply transformed current laboratory operations.

b. Digitalization

Considerations regarding 'Refinery of the Future' and 'Smelter of the Future' have been around for some years now[28,29]. Industrial implementations of the digitalization approach, as illustrated by such 'predictive anode quality', based on processing (advanced analytics) large numbers of real time and historical process data, are rapidly spreading. Machine learning has been recently presented in the field of anode quality interaction with reduction cell performance[30]. Digitalization is moving a step further with experimentation of cell process control via 'digital twin' as pioneered by Aluminium of Greece[31].

Many digitalization examples are also found in the upstream part of our industry. An illustration is the approach taken by Emirates Global Aluminium (EGA) when preparing the start-up of the first Middle East alumina refinery at Al Taweelah in Abu Dhabi. Taking the

opportunity of being a greenfield project, the authors claimed to have developed "one of the most modern Process Information Management Systems (PIMS), applying the latest of the Industrie 4.0 elements as a first step towards the Smart Refinery"[32]. The concept of the whole refinery digital transformation has been also discussed by Honeywell: it includes elements of big data analysis, the connected worker and the connected plant. It is rightly said that it takes a big step to implement the emerging and most challenging technologies in the field including smart sensors and autonomous machines[33].

Other illustrations are given, for example, with the development of a digital twin to achieve predictive analysis of wear mechanisms in the refinery digestion plant facility, supplementing the non-destructive monitoring[34]. On the white side, the construction of process simulation models and detailed equipment model allowed further significant optimization of the alumina calcination plant[35]. It is worth mentioning a concluding remark from the authors: "A comprehensive digital system will not be able to achieve the desired level of performance without the inclusion of process understanding."

Finally, we should also mention the application of 4.0 quality concepts of digitalization, data acquisition, scalability, analytics and connectivity to elevate traditional management system tools to the Industrie 4.0 standard in the context of bauxite mining[36].

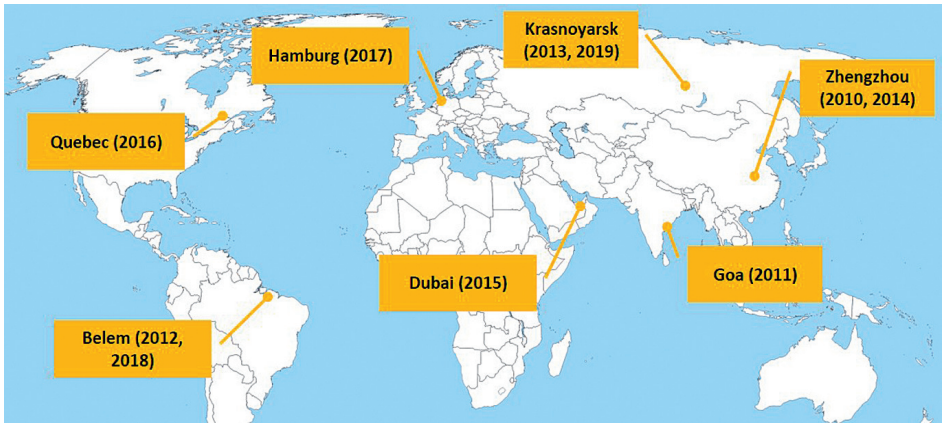
4. Icsoba evolution to support industry transformation

As shown above, multiple examples demonstrate that the aluminium industry has entered the era of digitalization. This transformation is unlocking new opportunities along the whole value chain and all the players have either started or are about to start the journey. Transforming our industry is requiring and will require for several years to look at our processes with different lenses from different angles. It will require different skills, knowledge and probably people whilst, at the same time, the fundamentals principles will remain. How can a technology conference support such a transformation? This is the challenge Icsoba is presently facing and aiming to meet successfully!

a. Build on Icsoba DNA which proved so successful during the last 55 years

i. Multiculturalism of its board of directors

Icsoba is an international association of members, which elect the board of directors. The board is responsible for managing and supervising the activities and affairs of the corporation and is accountable to the members. The directors have legal responsibility for Icsoba and are registered with Canadian authorities. The present composition of the board confirms not only its international status but also reflects its multicultural character. Among the board directors are two Canadians (with Polish and Iranian backgrounds), two French, a Swiss, a Russian and an Indian. Such board composition promotes universal understanding and vastly facilitates global communication.



Location map of Icsoba Conferences since 2010

ii. High quality of publication and scientific content

A key element of Icsoba's reputation is the high quality of publications and scientific content. The Technical Committee oversees maintaining and enhancing the reputation of Icsoba publications through the rigorous selection of high-quality papers and of the practical organization/running of the sessions during the annual conference. The Technical Committee (TC) is composed of the programme director (a member of the board of directors) as its chairperson and of three to five subject organizers. The TC members jointly represent the technical areas: bauxite, alumina, bauxite residue, carbon and aluminium.

The author guidelines and template for Icsoba abstracts, papers and presentations provide a uniform standard and appearance of each contribution. Approximately 100 papers and corresponding presentations are selected each year for the conference and the papers are included in the Travaux volume of the conference proceedings, which have reached more than 1,000 pages in recent years.

iii. Travelling around the world

Icsoba's international success is based on the practice of rotating the venue of international conferences to countries that play an important role in the global aluminium industry. Unlike many other organizations that are stationary, Icsoba moves from place to place around the globe and the delegates attending the annual conference travel with it. Visitors often bring expertise and solutions that locals may not have, and the opposite is also true. Icsoba provides a unique forum for discussions and plant visits, allowing its members to see the aluminium world, to learn and share know-how from research and current practices.

Over the years Icsoba has been travelling the world visiting major bauxite and aluminium production centres: Goa (India, 2011), Belem (Brazil, 2012), Krasnoyarsk (Russia, 2013), Zhengzhou (China, 2014), Dubai (UAE, 2015), Quebec (Canada, 2016), Hamburg (Germany, 2017) and Belem again in 2018. In the last two decades China, Middle East and India had an extraordinary growth of activity in alumina and aluminium production thanks to available energy. To put emphasis on these countries, Icsoba has plans to stage conferences there again in the near future.

iv. Proposing field trips associated with each conference

Field trips (plant visits) organized at the end of each Icsoba conference are highly instructive and appreciated by the delegates. For example, at the end of the 2018 conference in Belem, the delegates enjoyed visiting three different Hydro plants: the Albras aluminium smelter, the Alunorte alumina refinery and the Paragominas bauxite mine. A year before (in Hamburg) visits were organized to the DadCo alumina refinery and the Trimet aluminium smelter. The field trips offer the delegates a unique opportunity to see the production facilities, meet local personnel and discuss selected technical issues.

v. Offering grants to students

The student grants originate from the Icsoba funds and mark our presence in a specific country. The grants are offered to two to three students who present papers at the conference

and who are nominated as grant recipients by a local academia representative. Two student grants were offered in 2018 to the students from the Universidade Federal do Este do Para, Brazil. In addition, the elected students obtain free access to the conference.

b. Enhancing collaboration within the aluminium industry

i. Integrating industry input: the Icsoba Corporate Members Council

The vision of Icsoba to become 'The Technology Conference of the Aluminium Industry, for the Aluminium Industry' translates our view that the future of our organization lies in the high engagement of the aluminium industry.

The industry engagement requires participation from companies to orient Icsoba conferences to industry issues and challenges, pragmatically. To this aim, Icsoba revisited its corporate membership status and set up a Corporate Members Council in order to get direct feedback on industry needs and to ensure that all industry players from major producers, engineering firms, equipment suppliers to service providers get the opportunity to influence the Icsoba strategy and its deployment.

The Corporate Member Council meets once a year, during the annual conference. Icsoba's activity report is presented as well as the progress report on developments associated with the current strategic plan. The Corporate Members input is collected and further discussed during the board meeting for integration in its development plan.

ii. Partnering with aluminium associations

Icsoba undertakes to play the role of the industry's leading voice, providing global standards, business intelligence, sustainability research and industry technical expertise to member companies, policymakers and the general public. In the spirit of equality, mutual benefit and friendly co-operation, Icsoba has identified a framework within the aluminium sector. The objectives of this framework are to contribute to the industrial knowledge base and to stimulate economic activities along the aluminium value chain.

Several organizations have signed Memorandum of Understandings (MoUs) for cooperation with Icsoba, which is beneficial for both sides. For example, over the years the MoUs were signed with the Aluminum Association of Canada, China Nonferrous Metals Industry Association, The Aluminium Association of India and Associação Brasiliera do Alumínio (Abal). Icsoba highly values these partnerships and intends to further extend their number in the coming years.

iii. Partnering with other conference organizers

As already discussed, digitalization implies different knowledge. As a consequence, different players, namely automation and IT companies, are taking up more space in the process industry landscape. However, as the fundamental principles remain, it is of prime importance to ensure a close connection between the data and cooperation among systems experts and process experts. The mission of 'The Technology Conference of Aluminium Industry, for the Aluminium Industry' is to provide a platform for such connection.

This is why Icsoba signed an MoU with Quartz Business Media to organize an Icsoba session within the framework of the next 'Future Aluminium Forum'[37], which was held on 22 and 23 May 2019 in Warsaw, Poland. The Icsoba session dealt with 'Aluminium 4.0: when process approach meets data-driven approach in mining, refining and smelting' and saw representatives from aluminium companies willing to share their developments and success in their journey toward Industrie 4.0.

With this initiative, Icsoba aims to encourage and facilitate cross fertilization between process and data approach of our industry.

c. Enhancing knowledge dissemination

Dissemination of knowledge is the key factor to promote the collective effort of people acting in the whole aluminium value chain, from mine to metal. Therefore, beyond the organization of its annual conference and exhibition, which enhances the generation and exchange of ideas during the four-day event, Icsoba has a proactive strategy for knowledge dissemination and deploys all efforts to maximize the impact of the knowledge and know-how developed and shared by its members:

- A particular attention is made to invite influential keynote speakers with different backgrounds; i.e. technology, science, market, environment, etc. Dissemination of such a broad spectrum of keynote talks enhances the development of all facets of the industry.
- Icsoba has an agreement with MDPI to publish some selected papers in the open-source journal 'Metals' to further disseminate the knowledge to a broader audience.
- The Icsoba Platform for Industry-University Collaboration for Innovation is another example where our members share their valuable knowledge about the R&D infrastructure and available resources worldwide.
- Several thousand technical papers have been published in the Travaux volumes over more than half a century. All submitted papers are subject to a rigorous peer-review and edition process, performed by experienced Icsoba members from industry and academia. The value of this documentation for building a collective knowledge is better understood if one assumes that each paper addresses a hurdle of the industry, which is usually determined by the industry. All published documents have been electronically scanned and Icsoba will soon launch a user-friendly interface for access to this documentation.

5. Conclusion

Icsoba, who celebrates 55 years of activity, has unwaveringly supported the aluminium industry and, in many respects, contributed to set its development trends. This resulted in the impressive developments experienced during the decades of Icsoba history in the bauxite, alumina and aluminium industries that have grown 10-fold and reached what it is today.

Now, the aluminium industry is starting its journey towards digitalization. Icsoba considers that sharing knowledge and encouraging exchange of ideas and cooperation between the alumina and aluminium professionals is as important as ever. Icsoba is therefore acting to

Travaux books with conference proceedings

transform itself to support this new development trend. This transformation is based on three pillars, namely:

- Building on Icsoba DNA which proved successful for the last 55 years (multi-culturalism of its board members, high quality of publications, travelling around the globe, proposing field trips and grants to students)
- Enhancing collaboration within the aluminium industry (widen its corporate members base and integrating their input through the Corporate Members Council, partner with aluminium associations and other conference organizers)
- Enhancing knowledge dissemination (inviting influential keynote speakers, proposing a platform for industry-university cooperation and a user-friendly interface to access to the 2,000 technical papers of the Icsoba library).

With those actions in place, and with an open mind regarding input and suggestions from all of its members and partners, Icsoba aims at its vision of being 'The Technology Conference of the Aluminium Industry, for the Aluminium Industry'.

6. References

1. F.R. Feret, 50 Years of Icsoba, – in Proceedings of the 31st Intl Icsoba Conference, Krasnoyarsk, Russia, Sept. 4-6, 2013, Travaux 42, 49-54 (2013)
2. György Komlossy, History of the Icsoba. 50 years activity in the field of bauxite geology and mining (from localism to globalism), in Proceedings of the 31st Intl Icsoba Conference, Krasnoyarsk, Russia, Sept. 4-6, 2013, Travaux 42, 61-94. (2013)
3. György Bánvölgyi, Fifty years history of Icsoba: the alumina production, in Proceedings of the 31st Intl Icsoba Conference, Krasnoyarsk, Russia, Sept. 4-6, 2013, Travaux 42, 96-115 (2013)
4. Brady Haneman, Evolution of Tube Digestion for Alumina Refining, in Proceedings of the 34th Intl Icsoba Conference, Quebec, Canada, Oct. 3-6, 2016, Travaux 45, 73-82 (2016)
5. R.D. Paradis, Application of Alcan's deep bed thickener technology in the Bayer process, in Proceedings of the 8th Intl Congress of Icsoba Energy and Environment in Aluminium Industry (Part I), Milan, Italy, April 16-18 1997, Travaux 28, 230-234 (1997)
6. Roelof Den Hond and Marja Brouwer, Design Aspects of Bauxite Residue Storage Areas, in Proceedings of the Intl Icsoba Seminar on Bauxite Residue (Red Mud), Goa, India, Oct. 17-19, 2011, Travaux 40, 66-74 (2011)
7. Craig Klauber, Markus Grafe, Greg Power, Bauxite Residue Utilization and the Lack Thereof, in Proceedings of the Intl Icsoba Seminar on Bauxite Residue (Red Mud), Goa, India, October 17-19, 2011, Travaux 40, 188-195 (2011)
8. Andrey Panov and Gennadiy Klimentenok, Directions for Large Scale Utilization of Bauxite Residue, in Proceedings of the Intl Icsoba Seminar on Bauxite Residue (Red Mud), Goa, India, Oct. 17-19, 2011, Travaux 40, 297-311 (2011)
9. J-L. Theron, Latest plant experiences in the application of the Alusuisse precipitation process, in Proceedings of the 7th Intl Congress of Icsoba (Part II), Balatonalmádi, Hungary, June 22-26, 1992, Travaux 25, 95-108 (1992)
10. Michael Missalla, Andreas Koschnick, Linus Perande, Hans Werner Schmidt, Energy efficiency in alumina refineries – Combining hydrate filtration with alumina calciner, in Proceedings of 33rd Icsoba Conference, Dubai, UAE, 29 Nov. – 1 Dec. 2015, Travaux 44, 88-92, (2015)
11. Benny Erik Raahauge, Thermal Energy Consumption in Gas Suspension Calciners, in Proceedings of 36th Icsoba Conference, Hamburg, Germany, 2-5 Oct. 2017, Travaux 46, 333-346, (2017)
12. M. N. Smirnov, Physical-Chemical Fundamentals of Alumina Production from Nepheline, in Proceedings of the 2nd Intl Congress of Icsoba (Vol III), Budapest, Hungary, October 6-10, 1969, Travaux 28, 337-348 (1969)
13. Alexander Senyuta, Andrey Panov, Alexander Suss, Yuri Layner, Comparison of acidic and alkaline technologies for producing alumina from low grade ores, in Proceedings of the 19th Intl Symposium of Icsoba, Belem, Brazil, Oct. 29 – Dec. 2, 2012, Travaux 41, (2012)
14. Vinod Nair et al, Amperage Increase from 340 kA to 425 kA in EGA DX Technology, in Proceedings of the 36th Intl Icsoba Conference, Belem, Brazil, 29 Oct. - 1 Nov. 2018, Paper AL07, Travaux 47, 663-674 (2018)
15. Bingliang Gao et al., History and Recent Developments in Aluminum Smelting in China, in Proceedings of 35th Intl Icsoba Conference, Hamburg, Germany, 2 – 5 October 2017, Paper KN05, Travaux 46, 53-68 (2017)
16. Jens Garbe, Arne Hilck and Andreas Wolf, Pneumatic Conveying of Alumina – Comparison of Technologies, in Proceedings of 33rd Intl Icsoba Conference, Dubai, UAE, 29 Nov. – 1 Dec. 2015, Paper AL08, Travaux 44, 567-572 (2015)
17. Tapan K. Sahu et al., Strategy for Sustaining Anode Quality Amidst Deteriorating Coke Quality, in Proceedings of 33rd Intl Icsoba Conference, Dubai, UAE, 29 Nov. – 1 Dec. 2015, Paper CB03, Travaux 44, 425-434 (2015)
18. E. Jensen, The Effects of Slotted Anodes on Aluminium Reduction Cell Performance, in 18th Intl Symposium Icsoba, Zhengzhou, China, November 2010, Travaux 39, 531–538 (2010).
19. Etienne Tezenas du Montcel, Crane Electrical Insulation Monitoring in Potlines: New CANDITM 4.0 Performance, in Proceedings of 35th Intl Icsoba Conference, Hamburg, Germany, 2 – 5 Oct. 2017, Paper AL16, Travaux 46, 939-944 (2017)
20. www.mining.com/rio-tinto-autonomous-trucks-now-hauling-quarter-pilbara-material/
21. www.alcircle.com/news/bauxite/detail/29639/rio-tintos-amrun-bauxite-project-expected-to-support-further-capacity-expansion-and-technological-innovation
22. https://informeaffaires.com/regional/aluminium/mecfor-realise-une-premiere-en-amerique-du-nord
23. www.ecagroup.com/en/business/eca-group-provide-unmanned-logistic-vehicles-rio-tinto-aluminium
24. www.qatalum.com/Media/News/Pages/Innovations-in-Pot-Tending-at-the-Qatalum-Smelter.aspx
25. M. Trideau, Embedded Service Robot: Towards an Automated, Efficient and Green Smelter, in Proceedings of 33rd Intl Icsoba Conference, Dubai, UAE, 29 Nov. – 1 Dec. 2015, Paper AL09, Travaux 44, 573-577 (2015)
26. G. Leonard, A. Bernard, Y. El Ghaoui, M. Gagnon, P. Coulombe, G. Bourque and S. Gourmaud, MIREA – An On-line Real Time Solution to Check the Electrical Quality of Anodes, in Proceedings of 33rd Intl Icsoba Conference, Dubai, UAE, 29 Nov. - 1 Dec. 2015, Paper CB06, Travaux 44, 455-466 (2015)
27. www.stas.com/en/products/carbon/abis-anode-butt-inspection-system/
28. C. Vanvoren, Towards the Smelter of the Future, in Proceedings of 33rd Icsoba Conference, Dubai, UAE, 29 Nov. – 1 Dec. 2015, Presentation KN03, Travaux 44, 45 (2015)
29. R. Costa, Mining and Refining 4.0, in Proceedings of 36th Intl Icsoba Conference, Hamburg, Germany, 2-5 Oct. 2017, Presentation KN04, Travaux 46, 35 (2017)
30. P. Côté and S. Guérard, A Machine Learning Approach to Early Detection of Incorrect Anode Positioning in an Aluminium Electrolysis Cell, in Proceedings of 37th Intl Icsoba Conference, Belem, Brazil, 29 Oct. - 1 Nov. 2018, Paper AL02, Travaux 47, 607-618 (2018)
31. www.genewsroom.com/press-releases/aluminium-greece-collaborates-ge-drive-efficiency-using-predix-based-first-their-kind
32. J. Rüster, E Pai, K. Sitaraman and R. Farzanah, Development of the Technical Operating Strategy at Al Taweelah Alumina Refinery: Application of Industry 4.0, 11th Alumina Quality Workshop, Gladstone, Australia, pp. 21-27 (2018)
33. R. K. Johas, Digital Transformation in Alumina Refining , 147th TMS annual Meeting, Phoenix, AZ, March 11-15, pp. 79-87 (2018).
34. M. Barnes, D. Koffler and C. Bowels, Digital Maturity in Alumina Refining, in Proceedings of 37th Intl Icsoba Conference, Belem, Brazil, 29 Oct. – 1 Nov. 2018, Paper AA04, Travaux 47, 241-254 (2018)
35. S. Haus, T. Hensler, C. Binder, A. Scarsella and M. Missalla, Outotec Pretium Calciner Optimizer – Integrating Process Know-How into Daily Operation, in Proceedings of 37th Intl Icsoba Conference, Belem, Brazil, 29 Oct. – 1 Nov. 2018, Paper AA17, Travaux 47, 369-380, (2018)
36. J.S. de Sousa, I.O. Rocha and R.M. de Castro, Digital transformation Applied to Bauxite and Alumina Business System – BABS 4.0, in Proceedings of 37th Intl Icsoba Conference, Belem, Brazil, 29 Oct. – 1 Nov., 2018, Paper BX09, Travaux 47, 119-132, (2018)
37. https://futurealuminiumforum.com/

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