New Study and Application of Intelligent Breaking Control Device for Aluminium Reduction Pot in the MPPIC Technology

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Abstract

The first generation of the Multivariable Process Parameter Intelligence Control (MPPIC) technology of the CHALIECO GAMI had been developed over 10 years up to now. Every respect concerning this technology had been improved and upgraded considerably during these years. With this technology selected by the domestic and overseas aluminium smelters for all kinds of the larger and super large aluminium reduction pot technologies, substantial progress has been made of their combined technical performances and economic indexes [1]. Based on the third generation of the MPPIC technology, the intelligent alumina breaking and feeding device has been innovated as well. It will create better conditions and process fundamentals not only for alumina concentration distribution and anode effect intelligent control, but also for the stable operation and enhanced performance of the larger aluminium potline for production.

Keywords: Aluminium reduction pot, the MPPIC Technology, pot controller, intelligent breaking control device.

1. Technical Background

In the background of rapid development of Internet+ and intelligent industrial technologies, intelligent design and control technology in today's primary aluminium industry has stepped into a new stage. Since 2008, with popularization of larger and super large reduction cells in and beyond Chinese market, CHALIECO GAMI has advanced the first generation of MPPIC (multivariable process parameter intelligence control) [1] technology to its third generation. This means that GAMI is now ranked as one of the world leaders in intelligent manufacturing and control technologies for aluminium reduction cells.

CHALIECO GAMI focuses on the innovation and advancement of intelligent devices and products, committing itself to propel intelligent production and improve enterprises' intelligent level of research, production, management and service. The MPPIC technology realized integration of information technology and manufacturing technology from two aspects: process management technology and manufacturing and executing technology.

MPPIC technology is centered around the pot control system and deployed with an intelligent tapping system, an intelligent feeding system, online temperature measurement system, a pot condition analysis system and RDTS (remote data-diagnosis technology service). The detailed integration platform is presented in Figure 1 [2].

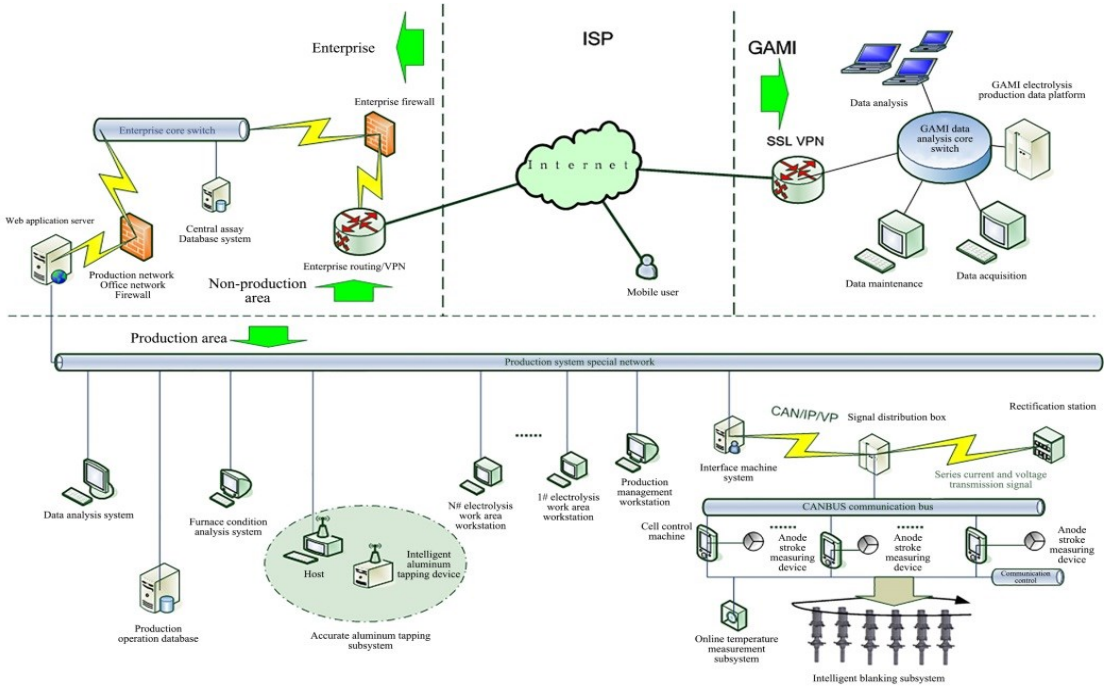


Figure 1. Integration Platform of MPPIC.

2. R&D content

During the production of aluminium, crust breaking and alumina feeding are two of the most essential working procedures that are intelligently controlled by computer; added to this, it is the most vital factor relating the normalization and stability of a pot. The traditional feeding method is a single breaking followed by a single dose of alumina, which is not as reliable and accurate as expected. The shortcomings of this method are:

- A breaker jam cannot be identified automatically: When a breaker jam occurs, it can only be observed from anode effects (AEs) or by manual inspections, which leads to increased manpower requirements as well as increased power consumption caused by AEs.
- Breaking continues when the feeding hole is unobstructed, which increases the wear of the breaker, shortens breaker life and wastes compressed air.
- Time spent for penetrating the feeding hole cannot be predicted, and the breaker cannot withdraw immediately after entering the bath, which increases the duration of breaker being soaked in the bath resulting in a real possibility of elephant leg formation with reduced breaking efficiencies.

With continuous improvement of the intelligent control technology in aluminium production, there is now a high demand for a new intelligent breaking method to solve all these problems. The device and technology being discussed in this paper, which based on CHALIACO GAMI's MPPIC technology, are served to meet such a demand.

3. Technical Description

The newly-developed intelligent breaking device consists of a breaking cylinder, a pressure sensor, a data-collection card and a pot controller. Every single part is interconnected and linked to the SCADA through the pot controller.

The control method can be summarized as follows: Firstly, the air pressure value detected by the pressure sensor is converted to approximately 4 to 20 mA signal and transmitted to the data-collection card that is installed inside the pot controller. Then, after being converted into digital signal by VFC module in the card, the signal is sent to the CPU of pot controller through which the digital signal is converted into corresponding pressure value. Meanwhile, the pot controller automatically analyzes breaker jam according to auxiliary analysis value and voltage change value, and deal with breaker jam by either increasing or decreasing breaking times. If there is any abnormal situation observed the SCADA system will give a voice alarm to call upon manual intervention by an operator.

The innovative features of the device are:

- Intelligently identify whether a feeding hole is obstructed and prolong breaking interval accordingly, so as to reduce compressed air consumption.
- A breaker withdraws rapidly with less bath stuck to it to prolong the lifespan of breaker and cylinder.
- Automatically breaking when a breaker jam is identified. If the feeding hole cannot be penetrated after several times of releasing the breaker, the system will automatically give a voice alarm.
- Intelligently identify unstable or low air pressure and air leakage in the compressed air system.

Figure 2 shows the structure of intelligent breaking device.

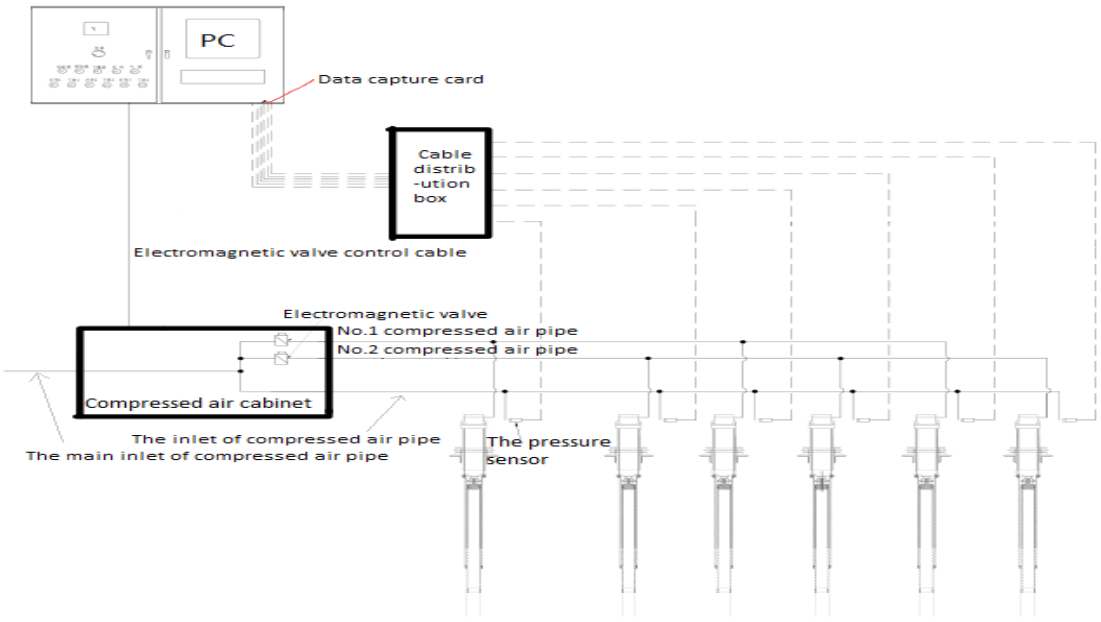


Figure 2. Schematic of the Intelligent Breaking Control Device.

4. Application and Effect

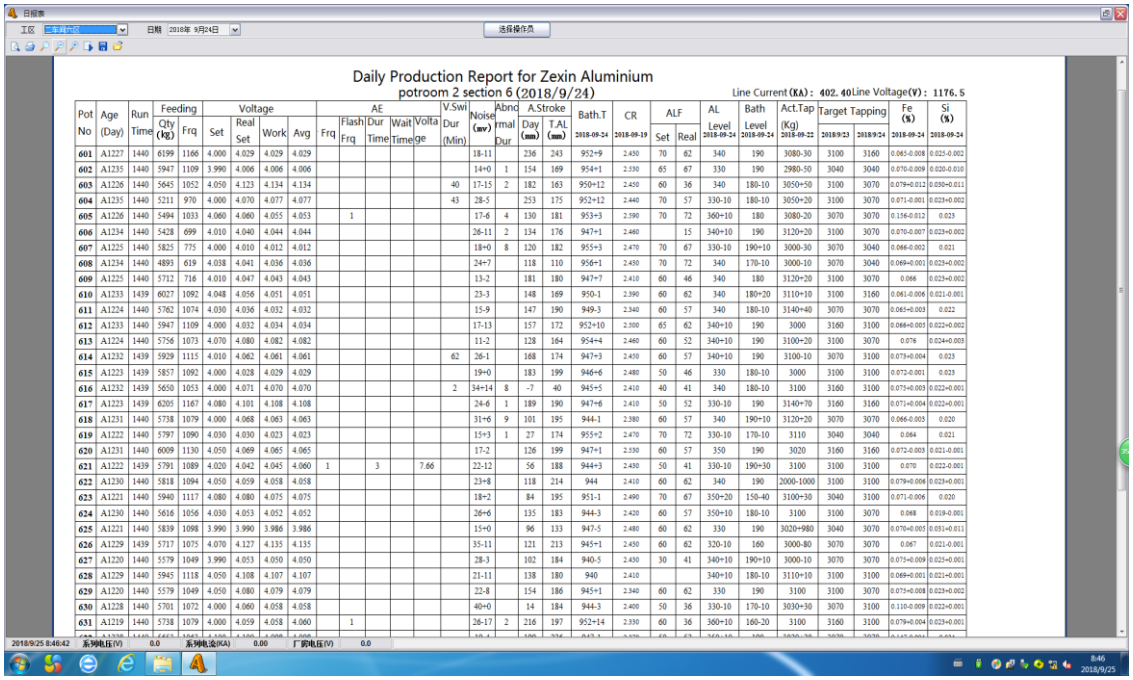
To present its use we take one 400-kA potlines in China that was provided with the intelligent breaking control device: At first, confirm the average air pressure of compressed air at potroom and then add the new parameter setting functions to the original interface of MPPIC-based intelligent breaking and feeding parameters, which has been already set by SCADA. These functions include intelligently extension of breaking interval and breaking time, breaker jam identification, breaking cylinder reset value and so on. When air pressure changes due to cylinder

overhaul or other abnormal situations, the SCADA system sends a signal to the command interface to call upon a reset of certain breaking points. The dialog box is set when the SCADA system uploads its command so there is no need for manually altering the parameters. This is is all done automatically.

The last parameters of the pot controller to be set are the air pressure values of selected cylinders, which can be checked by "digital readout+" and "digital readout-" in the operational panel. On an HMI or workstation one can check air pressure curves of every cylinder at data display menu.

If the compressed air pressure is stable in the potroom, the red curve of one cylinder rising to some certain value indicates breaker jam occurs at this point; significant fluctuation of the red curve indicates air leakage; overlap of a red curve and a blue curve indicates that the cylinder does not work; air pressure dropping to set minimum value and below or climbing to set maximum value and over indicates sensor default or line short.

From the chart in Figure 3, the impact of applying this device at several trial pots in one domestic 400-kA smelter is presented:



Daily Production Report for Zexin Aluminium
potroom 2 section 6 (2018/9/24)
Line Current(KA): 402.40 Line Voltage(V): 1176.5

Pot No	Age (Day)	Run Time	Feeding Qty (kg)	Feeding Frq	Voltage Set	Voltage Real Set	Voltage Work	Voltage Avg	AE Frq	AE Flash Frq	AE Dur Time	AE Wait Time	AE Volta Ge	AE V.Swi Dur (Min)	Noise (mv)	Abnormal Dur	A.Stroke Day (mm)	A.Stroke T.AL (mm)	Bath.T 2018-09-24	CR 2018-09-19	ALF Set	ALF Real	AL Level 2018-09-24	Bath Level 2018-09-24	Act.Tap (Kg) 2018-09-22	Target Tapping 2018/9/23	Target Tapping 2018/9/24	Fe (%) 2018-09-24	Si (%) 2018-09-24
601	A1227	1440	6199	1166	4.000	4.029	4.029	4.029							18-11		236	243	952+9	2.450	70	62	340	190	3080-30	3100	3160	0.065-0.008	0.025-0.002
602	A1235	1440	5947	1109	3.990	4.006	4.006	4.006							14+0	1	154	169	954+1	2.330	65	67	330	190	2980-50	3040	3040	0.070-0.009	0.020-0.010
603	A1226	1440	5645	1052	4.050	4.123	4.134	4.134						40	17-15	2	182	163	950+12	2.450	60	36	340	180-10	3050+50	3100	3070	0.079+0.012	0.050+0.011
604	A1235	1440	5211	970	4.000	4.070	4.077	4.077						43	28-5		253	175	952+12	2.440	70	57	330-10	180-10	3050+20	3100	3070	0.071-0.001	0.023+0.002
605	A1226	1440	5494	1033	4.060	4.060	4.055	4.053	1						17-6	4	130	181	953+3	2.590	70	72	360+10	180	3080-20	3070	3070	0.156-0.012	0.025
606	A1234	1440	5428	699	4.010	4.040	4.044	4.044							26-11	2	134	176	947+1	2.460		15	340+10	190	3120+20	3100	3070	0.070-0.007	0.023+0.002
607	A1225	1440	5825	775	4.000	4.010	4.012	4.012							18+0	8	120	182	955+3	2.470	70	67	330-10	190+10	3000-30	3070	3040	0.066-0.002	0.021
608	A1234	1440	4893	619	4.038	4.041	4.036	4.036							24+7		118	110	956+1	2.450	70	72	340	170-10	3000-10	3070	3040	0.069+0.001	0.023+0.002
609	A1225	1440	5712	716	4.010	4.047	4.043	4.043							13-2		181	180	947+7	2.410	60	46	340	180	3120+20	3100	3070	0.066	0.023+0.002
610	A1233	1439	6027	1092	4.048	4.056	4.051	4.051							23-3		148	169	950-1	2.390	60	62	340	180+20	3110+10	3100	3160	0.061-0.006	0.021-0.001
611	A1224	1440	5762	1074	4.030	4.036	4.032	4.032							15-9		147	190	949-3	2.340	60	57	340	180-10	3140+40	3070	3070	0.065+0.003	0.022
612	A1233	1440	5947	1109	4.000	4.032	4.034	4.034							17-13		157	172	952+10	2.300	65	62	340+10	190	3000	3160	3100	0.066+0.003	0.022+0.002
613	A1224	1440	5756	1073	4.070	4.080	4.082	4.082							11-2		128	164	954+4	2.460	60	52	340+10	190	3100+20	3100	3070	0.076	0.024+0.003
614	A1232	1439	5929	1115	4.010	4.062	4.061	4.061						62	26-1		168	174	947+3	2.450	60	57	340+10	190	3100-10	3070	3100	0.073+0.004	0.023
615	A1223	1439	5857	1092	4.000	4.028	4.029	4.029							19+0		183	199	946+6	2.480	50	46	330	180-10	3000	3100	3100	0.072-0.001	0.023
616	A1232	1439	5650	1053	4.000	4.071	4.070	4.070						2	34+14	8	-7	40	945+5	2.410	40	41	340	180-10	3100	3160	3100	0.075+0.003	0.022+0.001
617	A1223	1439	6205	1167	4.080	4.101	4.108	4.108							24-6	1	189	190	947+6	2.410	50	52	330-10	190	3140+70	3160	3160	0.071+0.004	0.022+0.001
618	A1231	1440	5738	1079	4.000	4.068	4.063	4.063							31+6	9	101	195	944-1	2.380	60	57	340	190+10	3120+20	3070	3070	0.066-0.003	0.020
619	A1222	1440	5797	1090	4.030	4.030	4.023	4.023							15+3	1	27	174	955+2	2.470	70	72	330-10	170-10	3110	3040	3040	0.064	0.021
620	A1231	1440	6009	1130	4.050	4.069	4.065	4.065							17-2		126	199	947+1	2.530	60	57	350	190	3020	3160	3160	0.072-0.003	0.021-0.001
621	A1222	1439	5791	1089	4.020	4.042	4.045	4.060	1		3		7.66		22-12		56	188	944+3	2.430	50	41	330-10	190+30	3100	3100	3100	0.070	0.022-0.001
622	A1230	1440	5818	1094	4.050	4.059	4.058	4.058							23+8		118	214	944	2.410	60	62	340	190	2000-1000	3100	3100	0.079+0.006	0.023+0.001
623	A1221	1440	5940	1117	4.080	4.080	4.075	4.075							18+2		84	195	951-1	2.490	70	67	350+20	150-40	3100+30	3040	3100	0.071-0.006	0.020
624	A1230	1440	5616	1056	4.030	4.053	4.052	4.052							26+6		135	183	944-3	2.420	60	57	350+10	180-10	3100	3100	3070	0.068	0.019-0.001
625	A1221	1440	5839	1098	3.990	3.990	3.986	3.986							15+0		96	133	947-5	2.480	60	62	330	190	3020+980	3040	3070	0.070+0.005	0.031+0.011
626	A1229	1439	5717	1075	4.070	4.127	4.135	4.135							35-11		121	213	945+1	2.430	60	62	320-10	160	3000-80	3070	3070	0.067	0.021-0.001
627	A1220	1440	5579	1049	3.990	4.053	4.050	4.050							28-3		102	184	940-5	2.430	30	41	340+10	190+10	3000-10	3070	3070	0.075+0.009	0.025+0.001
628	A1229	1440	5945	1118	4.050	4.108	4.107	4.107							21-11		138	180	940	2.410			340+10	180-10	3110+10	3100	3100	0.069+0.001	0.021+0.001
629	A1220	1440	5579	1049	4.050	4.080	4.079	4.079							22-8		154	186	945+1	2.340	60	62	330	190	3100	3100	3070	0.075+0.008	0.023+0.002
630	A1228	1440	5701	1072	4.000	4.060	4.058	4.058							40+0		14	184	944-3	2.400	50	36	330-10	170-10	3030+30	3070	3100	0.110-0.009	0.022+0.001
631	A1219	1440	5738	1079	4.000	4.059	4.058	4.060	1						26-17	2	216	197	952+14	2.330	60	36	360+10	160-20	3100	3160	3100	0.079+0.004	0.023+0.001

Figure 3. Actual Results from the Intelligent Breaking Control Device.

From the data of pots 606, 607, 608 and 609, it can be seen that breaking times reduced significantly—by 30 % in comparison to other pots. Meanwhile, processing speed for dealing with abnormal situations caused by uneven alumina concentration increased. This device in combination with MPPIC technology could also reduce the frequencies of AE, increase stability of pots and improve production and economic index.

5. Economic Benefits

The MPPIC technology can deliver several benefits to smelters:

- Technical and economic parameters can be improved: saving DC consumption by 50 kWh/t Al or more.
- Air consumption used for breaking can be reduced by 30 % or more, saving 20 kWh/t Al

energy.
- Lifetime of cylinders and breakers can be prolonged by more than 30 %, saving on costs of repairs of equipment.
- Intelligently identify and deal with breaker jams to save on manpower requirements.

Considering a 400-kA pot with average current efficiency of 93 % as an example, and given that the power price is CNY 0.3/kWh (~ 44 USD/MWh), the direct economic benefits can be calculated as:
- Direct economic benefit acquired by saving more power is CNY 16400 per pot (2380 USD/pot).
- Direct economic benefit acquired by saving 30 % compressed air is CNY 6560 per pot (950 USD/pot).
- As cylinder and breaker life is being prolonged by 30 %, annual equipment investment will be saved as CNY 3000 per pot (435 USD/pot).

All above direct economic benefits amount to CNY 25900 (3765 USD) annually for one pot. The calculation does not take some auxiliary and environmental benefits into consideration, such as reducing labor intensity, increasing current efficiency (CE), reducing AE, and stopping or halving air compressors after the device is fully implemented with all features.

At present, the new device and technology have applied for patent of invention/utility model [3]. With advantages of low production and installation cost, for a 400 to 500-kA large potline, if it has already installed MPPIC system, the total investment costs are only CNY 12000 per pot (1740 USD/pot) including spare parts for the device (domestic installation included as well), which means that only in one half a year the investment can be recovered .

6. Conclusion

By the end of 2018, CHALIECO GAMI's pot control system has been installed in more than 70 potlines with a combined capacity of more than 1.9 million tonnes all over the world.

The development and application of intelligent breaking control device not only creates advantages for alumina concentration control and intelligent control of larger aluminium pots, but also lays a solid foundation for stable production and operation and technical and economic index improvement of potlines.

7. References

1. Yi Xiaobing and Tian Qinghong, Development and Application of a Multivariate Process Parameters Intelligence Control Technology for Aluminum Reduction Cells, *Light Metals* 2010, 523-527.
2. Yi Xiaobing and Tian Qinghong, The Up-grading & Innovation of a Multivariate Process Parameters Intelligence Control (MPPIC) Technology for Aluminum Reduction Cells, *Proceedings of 36th International ICSOBA Conference*, Belem, Brazil, 28 October – 1 November 2018 Paper AL06, *TRAVAUX* 47*,* 655-662.
3. Chen Zhiyang et al., One kind of the Intelligent Breaking and Control Device as well as its Control Method, Application Patent No. for Invention /Utility Model： 201910110610.X/201920190630.8.