Determination of Iron Source in Molten Aluminium by Using the Accumulation Ratio of Iron to Manganese

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Abstract

In this work the behaviour of iron (Fe) and manganese (Mn) was studied in the tapped out pots, pots which had collector bar cut and pots which had iron increasing from the stubs. The study included 7 tap-out pots, 30 pots of collector bar cut and 40 pots of increasing the iron from different sources, mainly from stubs. The analysis of the pots was collected. The difference between the value of Fe and the value before the start of increasing (set point taken ≤ 0.08 % Fe) was calculated and called "Accumulated Fe". The difference between the value of Mn in the same sample of the highest Fe and the Mn value in the same sample of Fe at set point (≤ 0.08 % Fe) was called "Accumulated Mn". Accumulation ratio is the Accumulation of Fe divided by the Accumulation of Mn. Accumulation ratio for all the pots under the study was used to determine if the source of iron were collector bars or anode stubs, which could be differentiated due to different composition of the cast iron of anode stubs and the cast iron of collector bars.

Keywords: Concentration of iron and manganese in liquid aluminium, composition of cast iron for anode rodding, composition of cast iron for collector bar casting, iron-to-manganese ratio in aluminium electrolysis cells.

1.   Introduction

Iron in molten aluminium metal comes from several sources, each of which has its own sources of impurities. The majority of iron contamination management is limited to a managing the separation between cell liquid metal and bath and the iron and steel components of the cell.

The iron in aluminium metal comes from the following sources:

a. **Raw materials**: Alumina, carbon, crushed bath, secondary alumina. Alumina and coke may contribute more iron than other factors. According Lindsay [1] iron content of raw materials varies and affects metal purity.
b. **Molten steel tools and potshell**: Bath grab, broken crust breakers, clamps, deck plate.
c. **Anode stubs**: Stub iron comes from the stubs and from the cast iron. Cast iron is used to provide good electrical, mechanical and thermal contact between anode carbon block and steel stub. Cast iron considered the material of choice for anode rodding due to its excellent founding characteristics. According Nofal, et al. [2] the composition of cast iron has been designed to ensure high fluidity in order to fill the cavity between the steel stub and anode carbon block.
d. **Iron from collector bars**: Collector bar iron comes from the steel collector bar and from the cast iron which is using for sealing the collector bar to the carbon blocks; 300 kg of cast iron is used for each collector bar. If there is any failure in cathode blocks, the metal will leak through the cathode blocks to the collector bars, it will be detected by increased iron in the metal and by measuring the collector bar temperature. There are some pots were shut down due to metal leakage from collector bars.

Early determination of the iron source, whether it comes from stubs or from collector bars, can help for saving pots and taking proper actions. In this study we use the accumulation of iron and manganese for the early detection of the iron source.

2.   Analysis and Calculations

The data of metal analysis was collected from the system for pots under study: 7 tapped-out pots, 30 pots in which the collector bar was cut after increasing the iron and 40 pots with iron increase from different sources mainly from stubs.

2.1.   Fe and Mn Accumulation

The accumulation of Fe and Mn was calculated in the following way:
- The accumulation of Fe is the highest value of Fe minus the value of Fe before increasing (set point ≤ 0.08 %),
- The accumulation of Mn is the value in the same sample of the highest value of Fe minus the value in the same sample of Fe set point.

For example, Table2.1 represents metal analysis of one pot in different times, the accumulation value for Fe is $(0.3213 - 0.0672) = 0.2541$ and the accumulation value for Mn is $(0.00188 - 0.00132) = 0.00056$.

Table 2.1. Analysis of Fe (%) and Mn (% x100) for one pot every four hours.

Sample No.	1	2	3	4	5	6	7	8	9	10	11	12
Fe analysis, %	0.067 (X_1)	0.13	0.142	0.15	0.18	0.21	0.23	0.263	0.28	0.295	0.312	0.321 (X_2)
Mn analysis x100, %	0.132 (Y_1)	0.11	0.129	0.12	0.12	0.14		0.162	0.16	0.174	0.175	0.188 (Y_2)

2.2.   Accumulation Ratio

By dividing the Fe accumulation by the Mn accumulation we get a new parameter called accumulation ratio, Equation (1). This ratio will be used as comparison between all test pots. Table 2.2 sows the accumulation ratio for tap-out pots, Table 2.3 shows the accumulation ratio for pots which have collector bar cut and Table 2.4 shows the accumulation ratio for the pots which have stub wash.

$$Accumulation\ ratio = AR = \frac{X_2 - X_1}{Y_2 - Y_1} \tag{1}$$

Where: X_2 The highest value of Fe,
 X_1 Fe value before increasing ≤ 0.08 %,
 Y_2 The value of Mn in the same sample of highest value of Fe,
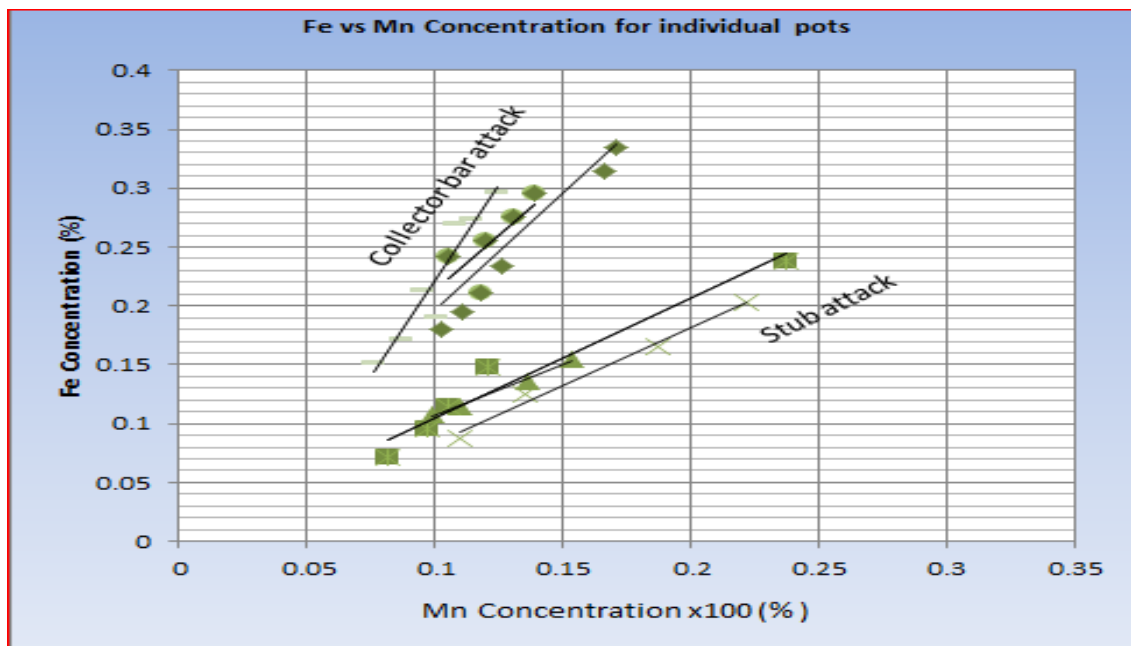 Y_1 Mn value in the same sample of Fe before increasing.

0.2374/0.00179 = 133, which is smaller than 200. We can conclude that the iron came from stub attack. This was proven later.

Table 3.2. Metal analysis of pot B152, which had sudden Fe increase.

Pot	Metal purity	Si (%)	Mn x 100 (%)	Fe (%)
B152	99.841	0.0382	0.116	0.0735
B152	99.608	0.0389	0.295	0.3109

3.5.   Fe-Mn Slope for Individual Pots

Figure 3.4 shows the slope of Fe vs Mn for pots attacked on collector bars and pots attacked on the stubs. The pots with collector bar attack have greater slope than the pots with stub attack. The reason for that is that the Mn % in collector bars is smaller than the Mn % in the stubs.

Figure 3.4. Fe vs Mn slope of individual pots.

4.   Conclusions

From the study we can conclude that by using of accumulation ratio of Fe/Mn, we can determine the source of iron attack whether it is from the collector bar or from the stubs. The early determination of iron source can help taking extra precautions. If the source is from collector bar, extra measurement or early measurement must be considered and appropriate further action taken. If the source is from the stubs, the focus must be on removing the anode which was stub-washed; also if the iron source is from the stubs, the collector bar measurement frequency can be reduced.

5.   References

1.   Stephen Lindsay, Measures to control metal purity in prebake reduction cells, *TMS Industrial Aluminum Electrolysis Course*, Dubai, 16 – 20 November 2014.

2.   A. Nofal, M. Ali, Amr Kandil and Mahmoud Agour, Characterization of new cast iron alloys for the stub-anode connection in the aluminum reduction, *Int. Journal of Engineering Research and Applications,* Vol. 3, Issue 5, Sept. - Oct. 2013, 414-419.