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.

Table2.2. Accumulation ratio for tap-out pots.

	POT	Fe Acc. ,%	Mn Acc. x 100 ,%	Acc. Ratio (AR)
1	C120	0.2422	0.063	384
2	C037	0.2446	0.102	239
3	D081	0.2803	0.125	224
4	D161	0.3592	0.144	249
5	D050	0.2571	0.073	352
6	A068	0.4024	0.154	261
7	D092	0.3044	0.118	257

Table2.3. Accumulation ratio for pots which have collector bar cut.

	POT	Fe Acc. ,%	Mn Acc. x100 ,%	Acc. Ratio (AR)
1	A027	0.2806	0.107	262
2	A093	0.1004	0.023	436
3	B008	0.2901	0.068	426
4	B027	0.1517	0.036	421
5	C062	0.1724	0.07	246
6	C089	0.263	0.082	320
7	D099	0.3058	0.128	238
8	C091	0.4571	0.183	249
9	D093	0.2681	0.071	377
10	D116	0.2049	0.077	266
11	B024	0.2262	0.084	269
12	D088	0.2744	0.102	269
13	D017	0.1851	0.057	324
14	D042	0.2861	0.102	280
15	D057	0.2214	0.076	291
16	D069	0.2385	0.099	240
17	D088	0.2823	0.106	266
18	D089	0.2264	0.081	279
19	D101	0.1964	0.041	479
20	D103	0.2088	0.079	264
21	D116	0.1922	0.088	218
22	D117	0.2541	0.056	453
23	C147	0.2348	0.095	247
24	C117	0.1438	0.038	378
25	C112	0.1468	0.064	229
26	A002	0.2037	0.079	257
27	C046	0.1596	0.075	219
28	B028	0.1627	0.06	271
29	C108	0.1948	0.067	290
30	C163	0.3271	0.125	261
31	D052	0.2827	0.115	245

Table 2.4. Accumulation ratios for the pots which have stub wash.

	POT	Acc. Fe ,%	Acc.Mnx100 ,%	Acc. Ratio (AR)
1	A010	0.1016	0.114	89
2	A026	0.1268	0.148	85
3	A033	0.5614	0.297	189
4	A060	0.1248	0.078	160
5	A063	0.1123	0.094	119
6	A105	0.2761	0.224	123
7	A112	0.1123	0.08	140
8	A115	0.2908	0.208	139
9	A123	0.1217	0.072	169
10	A126	0.0814	0.114	71
11	A127	0.1062	0.08	132
12	A131	0.1299	0.13	99
13	A137	0.155	0.096	161
14	A171	0.1211	0.102	118
15	A176	0.1816	0.127	142
16	B006	0.1671	0.094	177
17	B021	0.2385	0.206	115
18	B035	0.153	0.101	151
19	B036	0.0798	0.049	162
20	D073	0.2629	0.151	174
21	C153	0.2677	0.218	122
22	D161	0.2064	0.12	172
23	C107	0.5633	0.356	158
24	D016	0.1772	0.183	96
25	B124	0.3863	0.243	158
26	B138	0.0732	0.074	98
27	D024	0.2096	0.203	103
28	D038	0.125	0.114	109
29	D077	0.2082	0.161	129
30	B152	0.2474	0.194	127
31	B168	0.1052	0.074	142
32	C063	0.4409	0.31	142
33	D131	0.1157	0.068	170
34	D141	0.1475	0.089	165
35	D161	0.2079	0.12	173
36	C171	0.1641	0.092	178
37	C153	0.2933	0.236	124
38	C145	0.1454	0.092	158
39	C107	0.5633	0.356	158
40	C090	0.6086	0.522	116
41	B132	0.3041	0.181	168
42	A019	0.3597	0.346	103

2.3. Cast iron Composition

Table 2.5 shows the composition of cast iron used for casting the stubs and the standard analysis of cast iron used for sealing the collector bars.

Table 2.5. Cast iron composition.

Cast iron	C %	Mn %	Si %
Stubs	3.47	0.88	2.32
Collector bar	3.2 - 3.6	0.4 - 0.6	2.0 - 2.5

3. Results and Discussion

3.1. Accumulation Ratio for Tapped-out Pots

Figure 3.1 shows the accumulation ratio for some pots tapped out from collector bars, from the graph we can see that the ratio for all pots is greater than 200; this means that Fe concentration is more than 200 times Mn concentration.

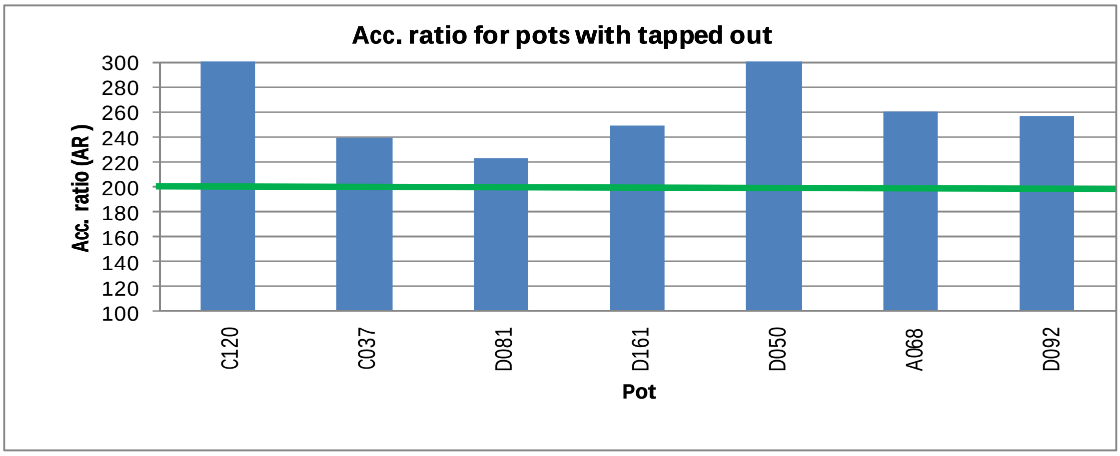

Figure 3.1. Accumulation ratio for tapped-out pots.

3.2. Accumulation Ratio for Pots Attacked on The Collector bar

Figure 3.2 shows the graph of the accumulation ratio for the pots attacked on the collector bars. The graph shows that the accumulation ratio for all the pots under the study is higher than 200.

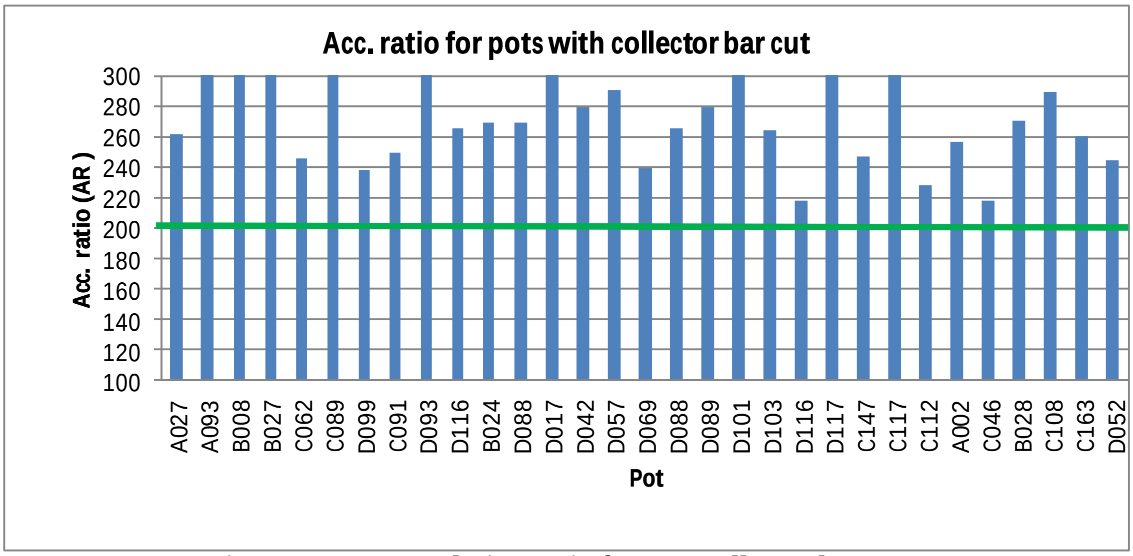

Figure 3.2. Accumulation ratio for pots collector bar cut.

3.3. Accumulation Ratio for Pots Attacked on Stubs

Figure 3.3 shows the graph of accumulation ratio for the pots attacked on the stubs. The graph shows that the accumulation ratio of all the pots attacked from the stubs is smaller than 200.

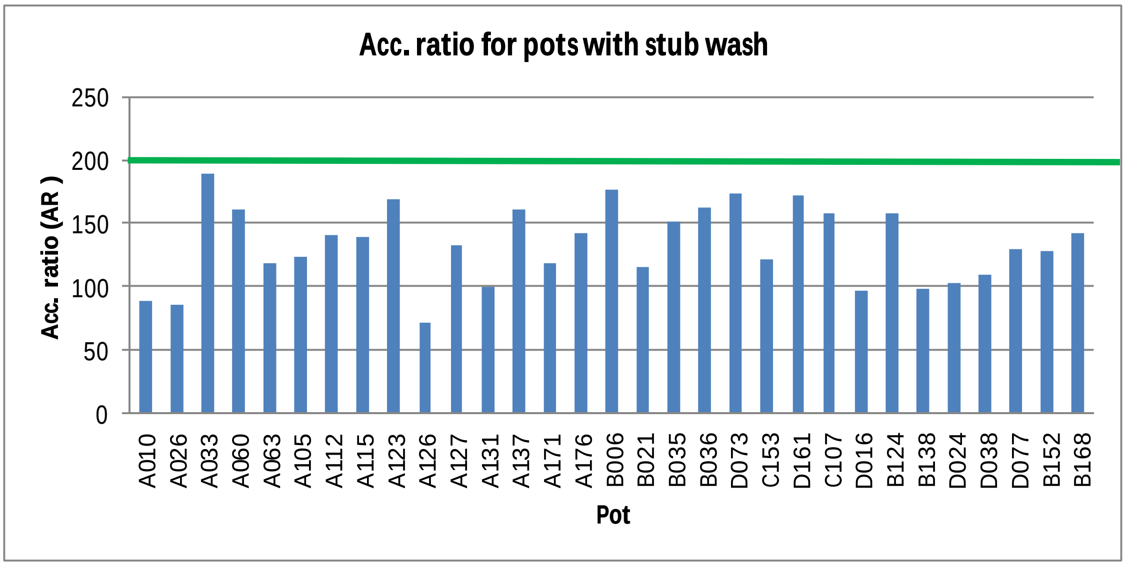

Figure 3.3. Accumulation ratio for pots with stub attack.

In the pots which are attacked from collector bar (7 tap-out pots and 30 pots with collector bar cut), the accumulation ratio is higher than 200. In the pots which have stub-wash, the accumulation ratio is less than 200. If the accumulation ratio is high, this means less accumulation of Mn as in the case of pots attacked from collector bar. If the accumulation ratio is low, this means high accumulation of Mn as in the case of pots attacked from the stubs. The reason of high accumulation ratio in case of stub attack is shown in Table 2.5: The concentration of Mn in cast iron of the stubs is greater than in the cathode collector bar cast iron. In the case of insufficient anode cover height or high bath, the bath will be on direct contact with cast iron of the stubs which contains high Mn.

3.4. Sudden Increase of Fe

Below is the analysis of two pots as examples of sudden increase of Fe. From Equation (1) we can determine the type of attack, which is either collector bar attack or stub attack. Pot B044 suddenly increased Fe as shown in Table 3.1.

Table 3.1. Metal analysis of pot B044, which had sudden Fe increase.

Pot	Metal purity (%)	Si (%)	Mn x 100 (%)	Fe (%)
B044	99.828	0.0375	0.091	0.0895
B044	99.553	0.0377	0.217	0.3607

According the Equation (1), the accumulation ratio = (0.3607- 0.0895) ÷ (0.00217-0.00091) = 0.2712/0.00126 = 215 which is greater than 200, we can suspect that the iron increase is from the collector bar attack.

Pot B152 is another example of sudden increase of iron. The data are in Table 3.2. According Equation (1), the accumulation ratio = (0.3109 – 0.0735) ÷ (0.00295 - 0.00116) =

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.

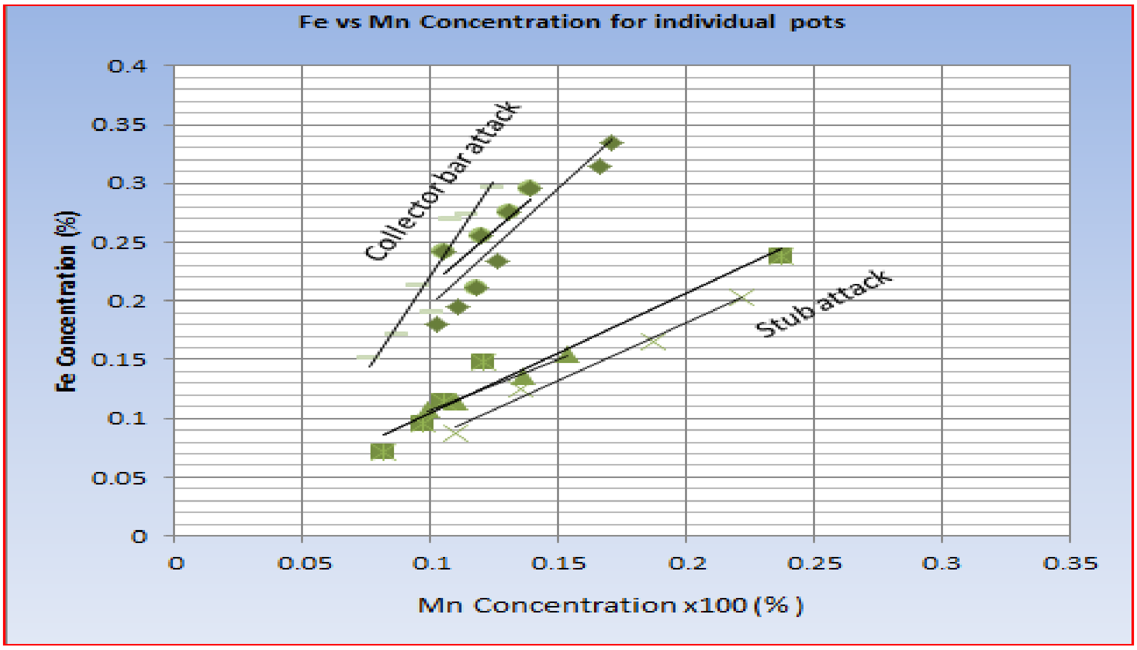

Figure 3.4. Fe vs Mn slope of individual pots.

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.