Pot Turnaround Time Reduction at Mahan Aluminium to Enhance Productivity

Senthil Nath[1], Kamal Kant Pandey[2], Pratap Sahu[3], Chandan Choudhury[4] and Jay Das[5]
1. Joint President,
2. Vice President,
3. General Manager,
4. Manager
5. Assistant General Manager
Hindalco Industries Ltd, Mahan Aluminium, Bargawan Singrauli, Madhya Pradesh, India
Corresponding author: pratap.s@adityabirla.com

Abstract

Mahan Aluminium pot line being a green field smelter, relining started three years after full commissioning. In order to maintain the normal life cycle of six years, pot line team has to reline approximate 9 - 10 pots/month as a proactive approach towards avoiding any sudden pot failure. To execute this plan, we have to achieve Pot Turnaround Time (TAT) below seven days. As pot replacement activity was carried out for the very first time in AP36 pots in Hindalco Mahan Aluminium pot line, many different challenges faced during the pot lining activity to maintain the pot turnaround time within target time. After a lot of brainstorming and analysis, various initiatives were applied during day-to-day operation and maintenance practices which helped to sustain as well as maximize the production volume by reducing pot idle time. Pot yearly TAT trend is as follows: 2018: 9.17 days, 2019: 8.82 days, 2020: 6.08 days, 2021: 5.16 days. Through continuous improvements in procedures and co-ordination among the teams, Mahan achieved the best ever average TAT of 5.16 days in full year 2021, against the target of 6.0 days.

Keywords: Pot idle time, Pot relining, Dead Pot, Pot change over, Potline productivity.

1. Introduction

An aluminium potroom can contain hundreds of electrolytic cells or pots that are connected electrically in series. We have 360 pots connected in series in two rooms of 180 pots each. Within each pot, molten aluminium is produced by the reduction of alumina (Hall-Héroult process). Optimizing energy use, preventing downtime and reducing costs of replacement are the key for improving potline performance. A well composed pot can be increased the pot running efficiency and sustained the critical process parameters. Henceforth, the critical or high aged pots need to be relined in regular intervals to avoid failure and meet the target production. The aged potshells need to be removed within the stipulated time frame and replaced to meet the yearly production target as well as maintain the symmetry for other parameters.

To compete in the global market in terms of production with quality, each smelter had to work strongly on the probable factors which might have appeared as major setbacks for the future. On the other hand, Mahan had to find a way to achieve the lowest ever turn around target below what Aluminium Pechiney (AP) Technology set worldwide i.e., six days. Reduction in TAT has significant impact on potline performance and consequentially on metal production cost.

2. Challenges in Reducing TAT

Mahan Aluminium has latest AP36 technology which is the first of its kind in India with 360 pots in operation. Aluminium smelting involves extraction of aluminium from its oxide (alumina) using an electrolysis process. Mahan ramped up and achieved full capacity of 360 kt/year in

August 2015. In an AP pot line of 360 kA, pot life is expected to be approximately 6 years. As all the 360 pots cannot be shut down at the same time, good planning and execution must be followed to avoid any sudden risk of failure and unsafe incidences. Since Mahan has had more than 40 black-outs and more than 100 times current reductions mainly due to Power Plant stabilization, grid disturbance and rectifier issues since the start-up, the pot life became critical, and we were forced to reline approximately 9-10 pots/month.

In the second-generation pots there are lots of challenges to conquer, such as, variation in pot performance due to commissioning normalizations in first generation, significant history of power outages, earthing trolley availability, difficulties in welding in high magnetic field, and development of solutions to these challenges.

Limitation of pot lining capacity is another major factor that needed to be considered. Since different pots have different pot life and to achieve a better pot life, the start-up had to be accelerated to approximately 9-10 pots per month. To achieve this with lining capacity of only 5-6 pots per month, the turn-around time for each pot will increase and this will not be a sustainable solution. Hence, we needed to enhance our lining capacity to almost equal or higher than our requirement, i.e., to ten pots per month, either by increasing the number of empty shell available, or by increasing the number of skilled crew to maintain the required re-lining rate.

Pot replacement needs specialised high-capacity cranes, such as tapping and miscellaneous assembly (TMA) (70 t capacity) and cathode transfer assembly (CTA) (185 t capacity) to handle the weight of pot superstructures and stopped potshells. These cranes are few (One TMA and One CTA) and hence their availability during requirement is very critical. Preventive maintenances quality and scheduling of this equipment are the keys to ensure more than 95 % availability to achieve performance of replacement within targeted time frame.

3. Execution Methodology:

Pot turnaround time is defined as the time between the pot cut-out and bath-up, the time when the aluminium production is resumed. Minimum turnaround time gives maximum production. Hence globally each smelter identifies best practices, keeping safety-first in mind to shorten turnaround from 9 to 8-7-6-5 days and so on to achieve better production.

A 360-kA pot line has a normal potline voltage of more than 1500 volts. The removal and replacement of a potshell need to be done very safely, hence an earthing trolley is connected to the pot replacement site to keep the potential difference between the pot and earth at zero volts to to achieve zero electrical hazards for the crew working in the near-by area. Since the pots in the entire pot line are connected in series, the earthing trolley must be connected only at one place; this restricts the work on multiple pots at a time, except if they are very near the earthed pot.

So, identifying the critical pot is most important to avoid multiple stoppages at a time which may lead to delays in pot replacement due to the constraint of earthing trolley. Hence a scientific model was developed on the basis of pot history like the number of power outages, pot age, cathode voltage drop (CVD) trend, Fe and Si in the metal, side shell temperature (SST) /Collector Bar Temperature (CBT) results, etc.

Pot performance literature of AP30 Technology around the world was analysed. A machine learning model was built, including pot life, machine availability, reliability of engineering equipment through good maintenance strategy, shut down planning based on critical pot index, validation through autopsy. All these parameters are required to stop pots in a potline, so that two pots are not stopped or fail at the same time, which would cause a replacement delay. After identifying such priority list a sequencing is made and plan need to execute accordingly to achieve sustain and continuous pot line start up.

In a potline with 360 pots, optimized for maximum output of each pot with best utilization of its age, the pots are required to be stopped with a faster rate than 9-10 pots per month on the average. Normally 360-pot smelters are equipped with four additional potshells and two pot superstructures. Achieving the same result with more limited fixed resources is difficult as normal relining turn-around time is 16 days as per OEM recommendations. Hence there was a need to increase the resources such as more additional pot shells and accelerating different relining processes. Basically, de-lining period can be reduced through mechanized digging instead of manual pneumatic digging. Cathode cooling can be enhanced by implementing different air ventilation in the de-lining shop. We also developed shorter curing time of mortar and adhesives in pot relining. These technical advancements can ensure 9-10 pots relining capacity with a reduced relining turnaround time from 16 days to 12 days to support increased production of the plant.

Cathode sealing plants can also operate during 16 h/day instead of normal day-shifts to meet sealed cathode requirements of mentioned pot relining capacity. Raw material availability subjected to their budget allocation, vendor finalization and releasing purchase orders on time, etc., are other necessary elements in the plan. Table 1 gives normal OEM recommended time frame required for activities to be performed between the stoppage and the start-up of a pot. Hence a detailed time motion study is done for each activity and each delay for more than 10 pots. The best practice all around the world also achieves lower than seven days TAT recommendation.

Table 1. Pot relining activities, in OEM recommended time frame.

DAYS	0			1			2			3			4			5			6		
DAYS	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N	M	A	N
GROUND							X	X	X												
	POT REMOVAL PREPARATIONS																				
STOPPED	X				X																
CLEANING					X																
CAFD REMOVAL					X																
	POT REMOVAL																				
CATHODE FLEX CUTTING							X														
SUPERSTRUCTURE RENOVAL							X														
POT SHELL REMOVAL								X													
DECKING IF REQUIRED								X													
	POT INSTALLATION																				
POT SHELL INSTALLATION									X												
SUPERSTRUCTURE INSTALLATION									X												
CATHODE FLEX WELDING									X												
	WIRING/ACCEPTANCE																				
WIRING CONNECTION									X												
POT ACCEPTANCE									X												
	START-UP																				
EQUIPMENT INSTALLATION													X								
ENERGIZING													X								
START-UP																			X		

Equipment removal time can be reduced by planning stoppage of a pot in such a way that equipment and skilled manpower is available for the task in minimum possible time. Joint disconnection work is planned in parallel by arranging different skilled crews which can work in parallel to do all cutting work within minimum possible time. Plasma and other advance cutting systems were also implemented for better results. During the second-generation operation works are also going on in parallel, hence a proper synchronization is required so that both work processes can be performed with 100 % efficiency and hence a skilled team is planning, executing and monitoring the job 24 hours a day, seven days per week.

Since pot shell removal is done normally at the end of entire pot life, i.e., approximately six years, hence after removal, some repairs of the basement and columns may be necessary. A better adhesive, having lower curing time has been developed to achieve minimum time between removal of the spent cathode and new lined potshell. Along with this advance maximum possible basement cleaning takes place before the removal of the potshell through mechanized mini dozer (Figure 1), which reduces basement cleaning time and TAT. Figure 2 shows a cleaned basement site of a pot.

Figure 1. Mini dozer cleaning the basement.

Figure 2. Clean pot site in the basement.

Advance basement cleaning is done after shell removal which helped in repairing column and epoxy at the earliest possible and also gave additional time for clad grinding.

The same parallel work philosophy again can be implemented while disconnecting the pot. Multiple crews can work together to re-join the risers and clads of a pot shell. A separate crew can parallelly work on pneumatic and air slide duct connections. Multiple risers and clads (Figure 3) can be disconnected and connected parallelly through multiple skilled crews.

Figure 3. Anode risers (left) and cathode clads (right) can be worked in parallel.

Proper sequencing can be planned from riser and non-riser sides and parallelly cathode slabs and feeders can be checked for working while all risers are getting welded. This reduces the repair time of other functions such as crust breaking and feeding devices. Hence multiple teams collaborate and to perform their task as much in parallel as possible, including checking and cleaning welded butts and checking good insulation values of different points which further helps achieving desired insulation values at joints.

Welding in high magnetic field is always a critical task since electrode material is diverted before deposition on joints. Hence a magnetic shield required and the quality shields helps improving the quality of welded connections as well as reducing welding time. Using of milling machine for machining out the anode beam to anode rod contact areas to maintain the roughness values between 6.5-12.5 micrometers and also eradicated the chances of rework saves time to ready the pot super structure.

Since entire second-generation jobs are quality jobs as their performance is required for the next six years, a well-designed system is required to hire highly skilled manpower to connect the pots. Otherwise, the quality of pot parameters may be affected in pot operation since uniformity is key of stability which directly impacts pot current efficiency and energy consumption. Arrangement of skilled manpower with competitive cost is also important to sustain as per geographical location, hence certified safety gear readiness of tested tools, tackles and other resources before second generation startup which helped us to reduce the contract cost. Knowledge and skill mapping of pre-qualification criteria through aptitude test with marking system was also established. Training through small awareness sessions and regular skill mapping with vendors and down the level through (Hazard Identification and Risk Assessment) HIRA and (Standard Work Instructions) SWI.

Turnaround time is reduced drastically by doing parallel work specially in pot preparation where graphite beds are laid on cathode blocks, upon which anodes are placed. This is followed by covering anode gaps with insulation strips and finally the sandwich bed of cryolite and soda is made with soda at the centre. Operation zone clearance for keeping materials near pot saves time along with crane availability, hence pot stoppage is planned in such a way that the job should be completed in such a manner so that pot preparation falls in miscellaneous working zone. These all directly impact the overall turnaround time from stoppage to pot energization when all aluminium wedges are removed and the current starts flowing through the pot, also known as power on. From this moment on pot preheating starts.

Duct air slide is connected done and (Crust Breaking and Alumina Feeding Devices) CAFDs placed parallelly and checked earlier to avoid delay after complete connection if found faulty operation later

Crane availability is also a major challenge in the entire second-generation works where engineering solutions were made to perform some jobs without crane to reduce crane loads and make them available for replacement jobs, such as metal pouring from tapping vehicle (Figure 5) instead of from a shifting tilter with crane and a normal ladle (Figure 6).

Preheating hours are decided by doing trials in different pots. Normal preheating duration varies between 38 hrs to 60 hrs with average of 54 hrs. Suitable resistivity of graphite can reduce preheating time. Along with that, advanced densified cathodes of some suppliers also reduce preheating time drastically and nowadays for AP36, the preheating time can be in the range of 45-52 for better results than before. At end of preheating the temperature of approximately 800-900 °C should be reached at centre channel of pot before bath pouring and the temperature should be uniform throughout the cathode for better pot life. The turnaround time of bath pouring activity, from wedge placing to bath pouring is calculated. Entire activities are planned to minimise this time as best possible to achieve maximum results.

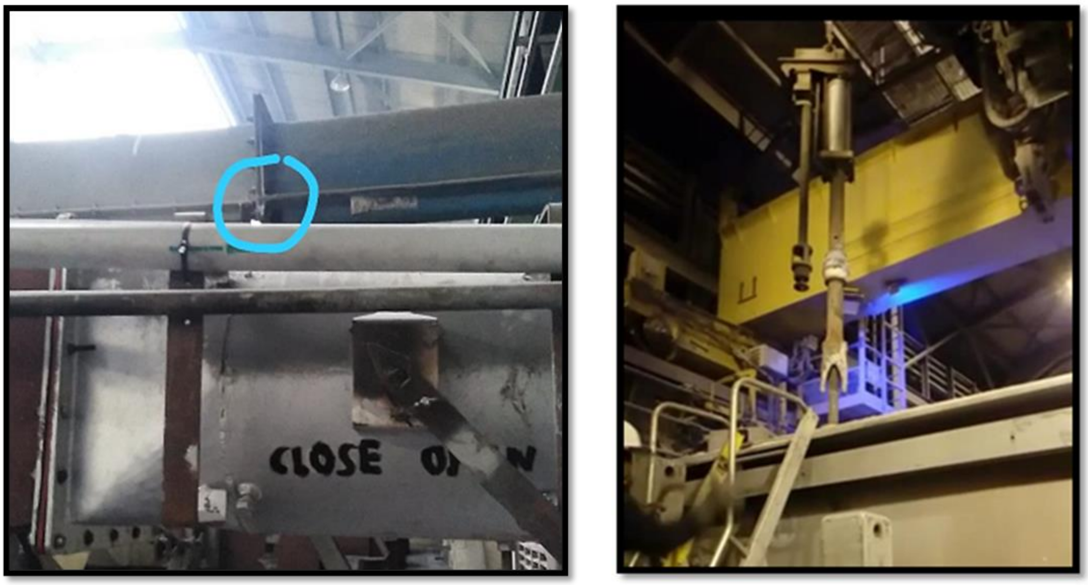


Figure 4. Air slide connection (left) and CAFD placement (right).

Figure 5. New practice of pouring metal from tapping vehicle instead of using crane.

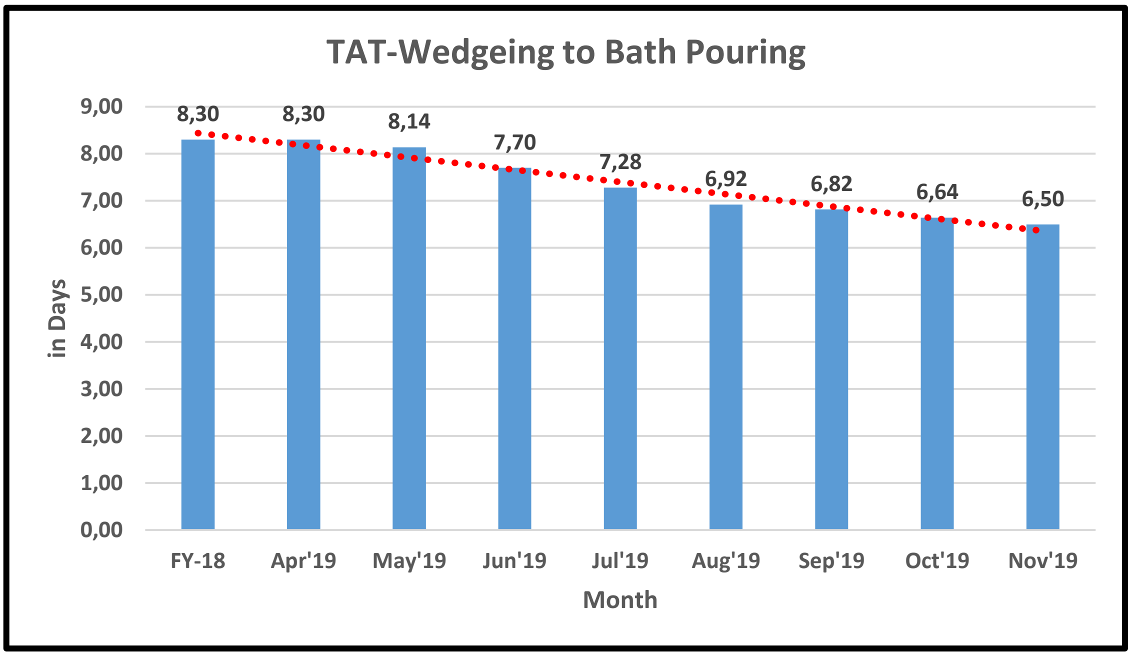
Figure 6. Metal tapping with PTA

As a summary of entire process from stoppage, also known as wedging the pot, to bath pouring at the end of preheating, when pot production starts, major methodology improvements were:

- Identification of non-value-added activity,
- Remarkably decreased cooling time between pot stoppage and starting of mechanical activity,
- Relining capacity constraint,
- Mechanized digging hence reduction in delining time,
- Skill enhancement of manpower,
- Development of vendor prequalification criteria and interaction with vendor for assessment of capability,
- TAT reduction in pot room,
- Earthing trolley engagement reduced by overlapping of different activity,
- Use of magnetic shields for welding,
- Crane availability increased > 91 % based on opportunity maintenance and predictive maintenance,
- Proper coordination between maintenance, operation and start-up team,
- In time execution and frequent communication to mitigate the gap through team meetings,
- Preheating time reduction by enhancing the cathode densification and graphite use of suitable resistivity.

4. Results

The above improvements resulted into consistent pot replacement TAT figure since August 2017 and also enabled us to produce even more opportunity of reduction of TAT for second-generation pot replacement as shown in Figure 6.



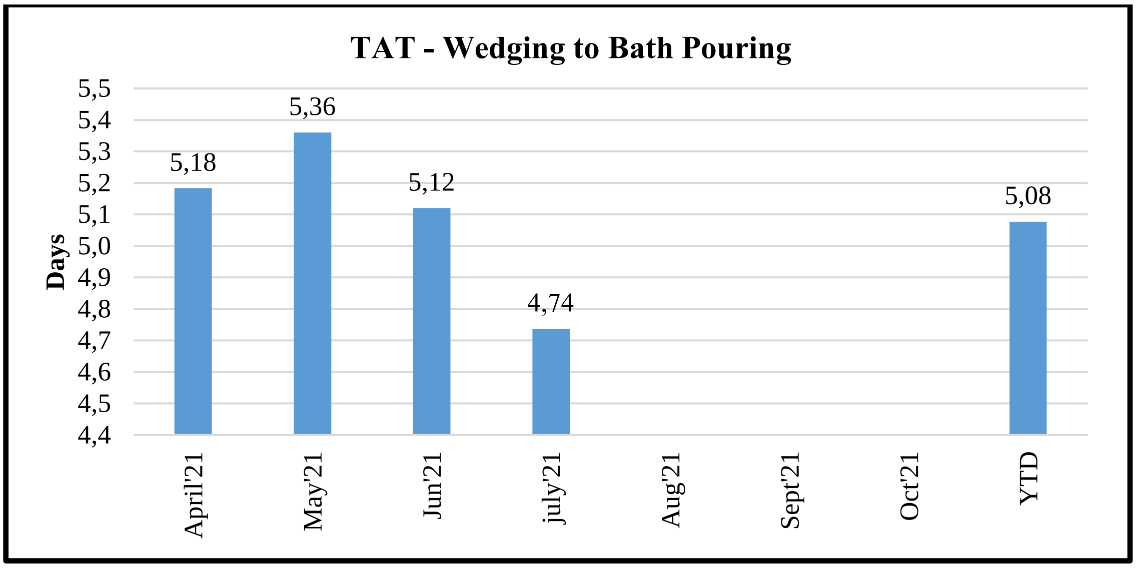


Figure 7. Average TAT for full year (FY) 2019-2020 (top) and FY 2020-2021 (bottom).

To improve the TAT, crews are used to track the delays of individual pots and try to mitigate the reasons through brainstorming sessions. The cause and effect and (Root Cause Analysis) RCAs are also prepared in every level by Gemba Walk and share the same within the groups.

Table 2. Example of pot replacement activities and TAT. PPS = Pot superstructure, Exp/Act TAT (Turn Around Time).

Pot No	Pot stoppage, and clearance	Shell & PSS (Pot Super structure) removal	Epoxy & clad grinding	Shell, PSS place-ment & handover	Pot prepa-ration & energi-sation	Pot start-up	Exp/ Act TAT	Re-marks
Target	6	16	12	22	8	56	5.0	(1)
Bench-mark	4	13	12	18	6	48.5	4.23	
B163	5	25	12	29	5	47	5.11	(2)
A131	4	15	12	26	21	46	5.16	(3)
A139	5	15	12	31	6	52	5.03	(4)
A151	5	13	11	20	5	52	4.35	
A110	4	14	12	23	6	53	4.63	
A137	5	13	12	23	6	56	4.77	
B105	6	12	12	20	6	53	4.55	
B170	4	16	12	31	5	48	4.81	(5)
B094	4	13	11	19	5	49	4.22	

Remarks:

(1) Status / Reason for delay (if any)
(2) 2 h delay due to semi-skilled operator, 2 h tie-rod failure during pot superstructure (PSS) removal, 2 h operation clearance delay
(3) 6 h welding machine blow-down, 3h Crust Breaking and Alumina Feeding Devices (CAFD) issues, TMA breakdown issues 16 hr caused Energization delay
(4) 3 h CAFD issue, 2 h anode beam issue delayed handover
(5) 1 h delay in shell readiness in lining shop. 2 h Raising Girder (RG) breakdown caused 5 more h clearance issue in Working Zone from Operation

5. Conclusions

Considering the importance of potshell replacement, it is clear that it has a direct impact on production and quality of the metal and more importantly the method of performing activities is used to save the pot and the potential hazards and associate risks related to leakage of the pots that are running in critical mode due to old age.

Mahan has taken up several new initiatives to develop the workflow ability as well as its team development to set a benchmarking target about the reduction of TAT in pot replacement work (Table 3), which must be of interest for other Indian primary aluminium producers.

Table 3. Activity wise tracking against Planning and Budgeting (P & B)

Activity	Full year 2020		Full year 2019 (h)	Full year 2018 (h)
	Target (hrs)	Actual (hrs)		
Pot stoppage to equipment removal	24	16	28	28
Riser, clad cutting to PSS, pot shell removal	28	26	32	32
Basement cleaning and other grinding works	16	16	26	28
Pot shell, PSS placement to handover	36	34	38	44
Total earthing trolley time	80	76	96	104
Pot preparation & energisation	20	15	24	24
Pot Energization to start up bath pouring	60	58	64	64
TAT in days	7.67	6.82	8.82	9.16
No. of Pots Started	90	92	77	47

This project was recognized in several platforms, such as **prestigious** PRIDE award, Appreciation by Business Unit and Cluster level Leaders, other Hindalco Industries Limited (HIL) smelters (Renukoot, Aditya and Hirakud). HIL corporate members visited Mahan Smelter to learn the best practices followed by Mahan, in order to replicate the best practices in other HIL smelters.

6. Acknowledgement

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