AA08 - Increase in Bauxite Grinding Mill Throughput

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Abstract

Ground bauxite slurry supply is a key factor in stable alumina refinery operation. Maaden refinery has three semi-autogenous grinding (SAG) mills and the requirement to sustain refinery's demand was more than two mill operations. This left very little time window for maintenance activity of SAG mill. Refinery suffered high production losses because of this bottleneck.

Various initiatives were undertaken to improve mill throughput so that two mills can supply the demand of the refinery. The one that worked most effectively was changing the cyclone design. Cyclone receives the mill output and classifies the slurry based on bauxite size fraction. While the cyclone overflow captures the finer fraction and becomes the input for the refinery, the underflow, having the coarser fraction is recycled back to mill as part of closed-circuit grinding design.

The cyclone capacity was the bottleneck to increase the mill throughput. The design was reviewed and changed. A trial newly designed cyclone was installed. The throughput could be increased by about 10 %. This is enough to run the refinery using two mills, sparing the third one for maintenance without affecting production.

Keywords: Bauxite grinding mill, Bauxite size fraction, Cyclone design.

1. Introduction

Maaden Alumina Refinery was established and start producing smelter grade alumina (SGA) in 2014. As a mining leader in Saudi Maaden has its own captive mine at Al Ba'itha. The Al Ba'itha mine is the only bauxite mine in the Middle East. It is an open pit mine with an annual capacity of over 4 million tonnes of bauxite ore. The bauxite ore is refined in the Gulf Cooperation Council (GCC)'s first alumina refinery at Ras Al Khair (Maaden Refinery) to produce 1.8 Mt of alumina per year, which is processed in the Maaden smelter to produce aluminium metal.

Ground bauxite slurry supply is a key factor for the stable alumina refinery operation. Maaden Refinery has three semi-autogenous grinding (SAG) mills. The Refinery's demand requires more than two mill operations. This left very little time for maintenance activity of SAG mills. The Refinery suffered production losses because of this bottleneck.

Various initiatives were undertaken to improve mill throughput so that two mills can supply the demand of the refinery. The one that worked most effectively was changing the cyclone design. Cyclone receives the mill output and classifies the slurry based on bauxite size fraction. While the cyclone overflow captures the finer fraction and becomes the input for the refinery, the underflow, having the coarser fraction, is recycled back to the mill as part of closed-circuit grinding design.

The cyclone capacity was the bottleneck to increase the mill throughput, other components of the closed-circuit grinding system still had leftover capacity. The design was reviewed and changed. The spigot size was increased from 6-inch to 7-inch. A newly designed cyclone was installed as a trial. The throughput could be increased by about 10 %. This proved to be enough to run the refinery using two mills if all the six cyclones were to change, sparing the third mill for maintenance without affecting production.

2. Materials and Methods

2.1 Material

Simulation was done with Standard software and a 7-inch spigot was chosen for the trial. In order to accommodate the increased spigot, the lower cone was also to be truncated. Keeping in consideration the room available on site, a set of new lower cone, 7-ich spigot and splash guard, both housing and liner material, were procured. (Figure 1).

2.2 Installation of Modified Cyclone

The picture below shows the actual installation of the modified cyclone. The lower cone, spigot and splash guard were the newly installed components, fixed to the existing upper cone.

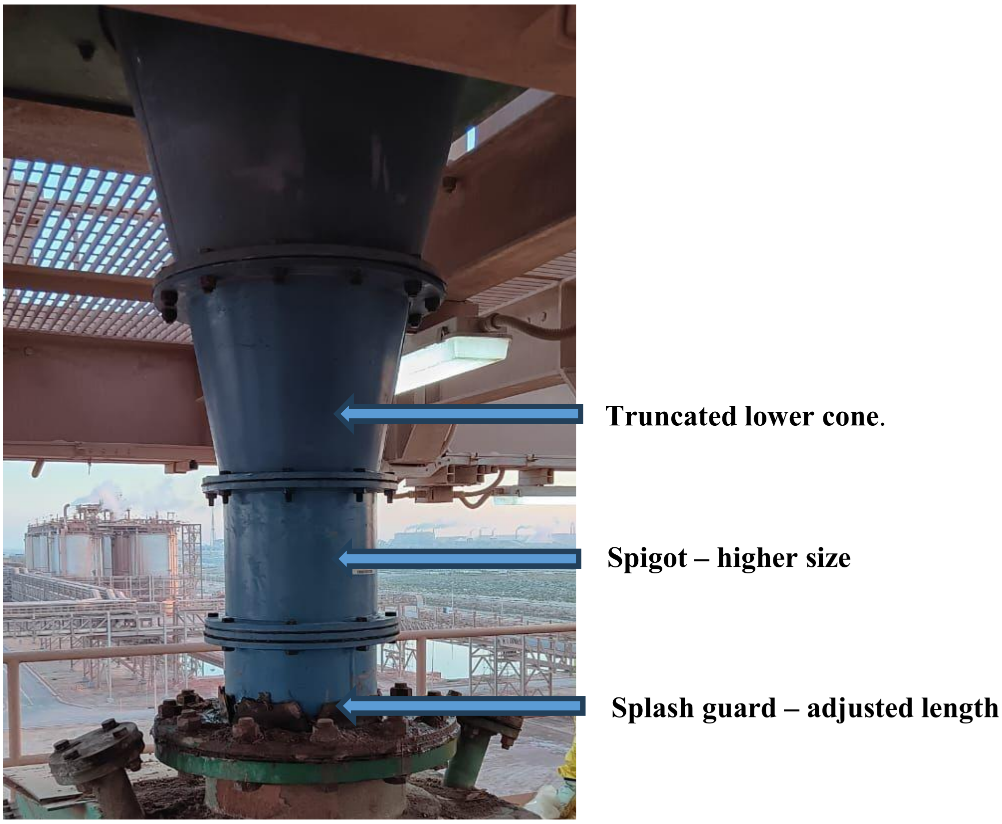

Figure 1. Picture of installed cyclone

2.3 Methods

The basis of any throughput increase was to feed more bauxite to the Mill and Cyclone. This would increase the inlet pressure limit in the trial cyclone. Some adjustments were made in the milling circuit control for conducting the trial.

- The trial Mill weigh feeder range increased by about 30% of previous peak, in field and DCS.
- The trial cyclone feed pressure operating range increased 85 %, still within engineering design limit. A suitable High and High-High alarm pressure set point was also chosen.
- Mill discharge pump motor frequency was increased to design limit of 60 Hz to accommodate higher pumping rate. The Product pump already had the required headroom and hence no changes were made.
- Mill Discharge pump suction and discharge lines and all the sample points and drains were cleaned.

3. Process Flow Diagram

Figure 2 shows the Process Flow Diagram in schematics. It shows where the cyclones are in the flowsheet.

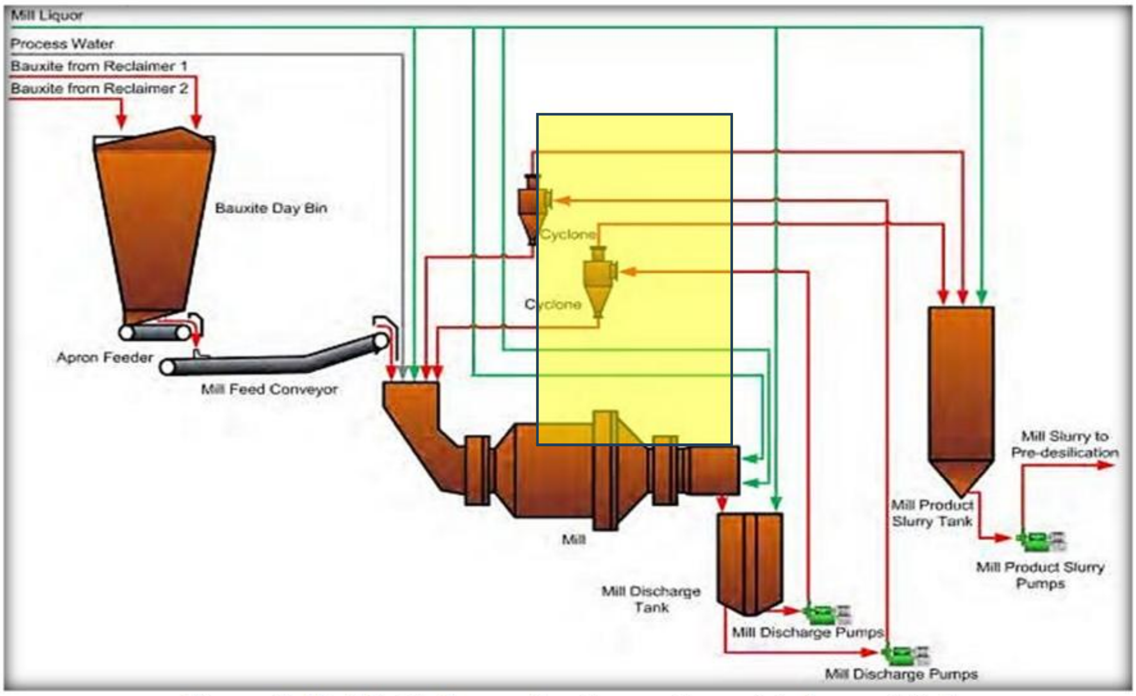

Figure 2. Highlighted area showing equipment to be modified.

4. Trial Process

The Trial mill was run at previous capacity for two days to ensure integrity of the circuit. The throughput was increased in steps to see the physical limit of the circuit – expected to be discharge pump capacity, cyclone underflow roping or mill weight limit. It was established that at about 12–14 % increase in throughput the discharge pump would reach its limit and cyclone underflow would be bordering roping. Based on these observations, it was decided to run the trial up to 11 % throughput increase.

On the trial day, the mill throughput was run at 93 % and 100 % of previous peak throughput. This formed the baseline for the trial run. The mill throughput was increased in steps to 105 %, 108.5 % and 111 % of previous peak throughput. At each step mill feed and circuit were stabilized for an hour before sampling was done. Two cyclone feed samples were collected at the beginning and end of the trial. An average is taken for the cyclone feed sizing for the trial duration. The cyclone feed density was stable as it was in cascade control with liquor input to system.

5. Results

The results of the trial are tabulated below.

Table 1. Particle size analysis of cyclone feed, overflow (O/F) and underflow (U/F) at different throughput and conditions

	Mill Through-put	Cyclone Feed Pressure	Solid Concent-ration	+1.7	+1.18	+850	+600	-600
	% Previous Peak	kPa	gpl	mm	mm	µm	µm	µm
Refinery O/F Target				0.50		4.40		
Feed			895	7.44	13.39	20.25	28.52	71.48
Cyclone O/F	93.0	120.2	863	0.11	0.55	2.01	6.02	93.98
Cyclone U/F			1230	16.03	24.93	34.07	44.61	55.39
Cyclone O/F	100.0	134.9	862	0.12	0.56	1.93	5.73	94.27
Cyclone U/F			1378	18.36	26.8	36.01	47.48	52.52
Cyclone O/F	105.0	165.2	864	0.11	0.82	2.76	7.76	92.24
Cyclone U/F			1408	20.66	29.97	39.51	50.18	49.82
Cyclone O/F	108.5	183.2	855	0.17	0.92	3.13	8.08	91.92
Cyclone U/F			1420	23.03	32.27	41.96	52.66	47.34
Cyclone O/F	111.0	200.7	835	0.32	1.57	4.70	10.68	89.32
Cyclone U/F			1410	27.12	38.65	49.12	59.85	40.15

6. Observations

6.1 Pressure and Solid Concentration

The key observations were as follows.

- As the mill feed increased, the cyclone feed pressure increased in the expected line (Figure 3). This is because of the increase in cyclone feed flow. The cyclone feed flow increase was due to higher throughput as well as higher recirculation load through increased cyclone underflow.

- Mill discharge pump flow (feed to cyclone has increased from 350 m^3/h. to 500 m^3/h. with modified cyclone, hence the recirculation load has been increased to 30 %.

- As the throughput increased and cyclone pressure increased as a result, the cyclone overflows solid concentration reduced (Figure 4) and underflow solid concentration increased (Figure 5). This is because at higher pressure more liquor went to the overflow.

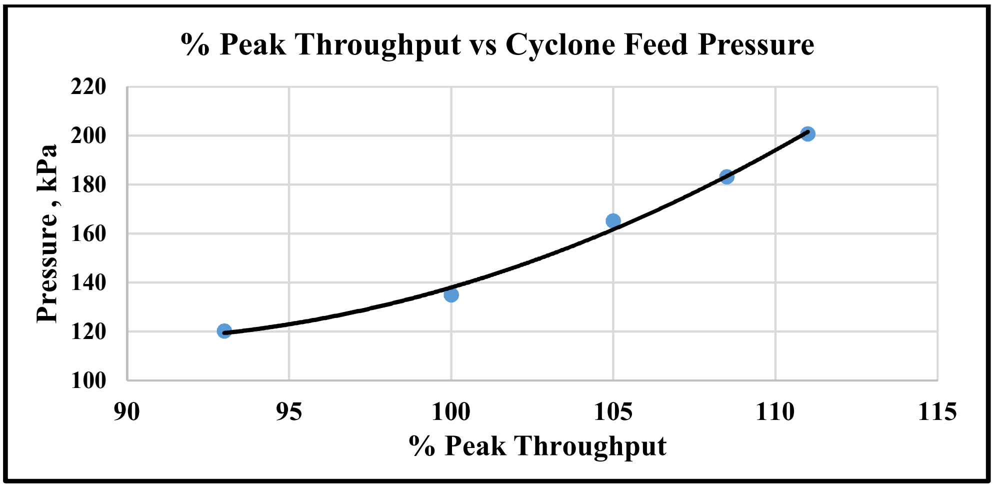

Figure 3. % Peak Throughput vs Cyclone Feed Pressure

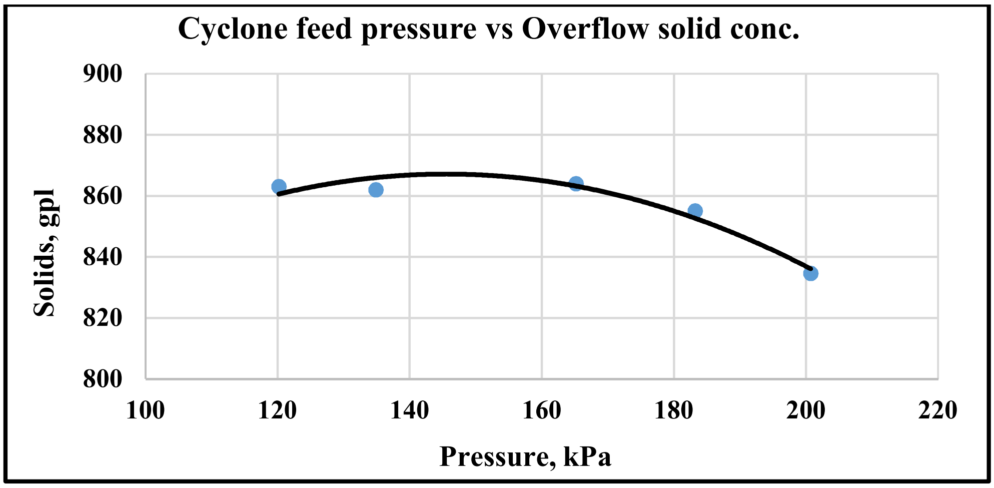

Figure 4. Pressure vs Overflow Solid Concentration

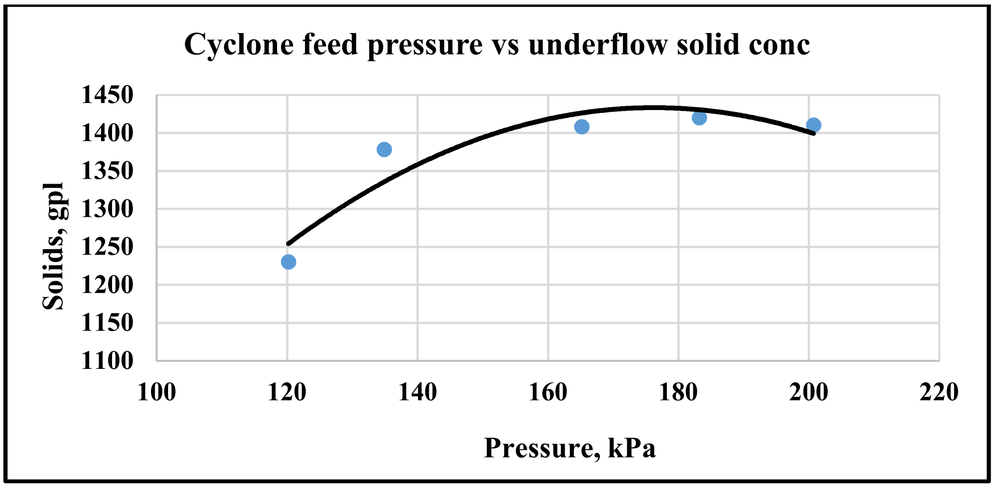

Figure 5. Cyclone Feed Pressure vs Underflow Solids concentration

6.2 Throughput and sizing behaviour

Based on the cyclone and mill system behaviour during the trial, the following conclusions can be drawn.

- At 111 % throughput, the discharge pump was at its current limit and discharge tank level got high. It indicates that discharge pump is now the new limit of the mill system at 111 % throughput.

- At various throughput rate, the cyclone overflow size remained within the Refinery's target specification. Only exception was at 111 % throughput when the +850 µm was 4.7 % against target of 4.4 % (Figure 6).

- At 111 % throughput rate both overflow and underflow sizing were away from the size distribution band obtained at lower throughput. This indicates that at 111 % throughput, the cyclone was getting crowded. Any further throughput increase would lead to underflow roping and loss of classification.

- Based on the above observations, it is recommended to run the mill at 108–110 % of previous peak throughput.

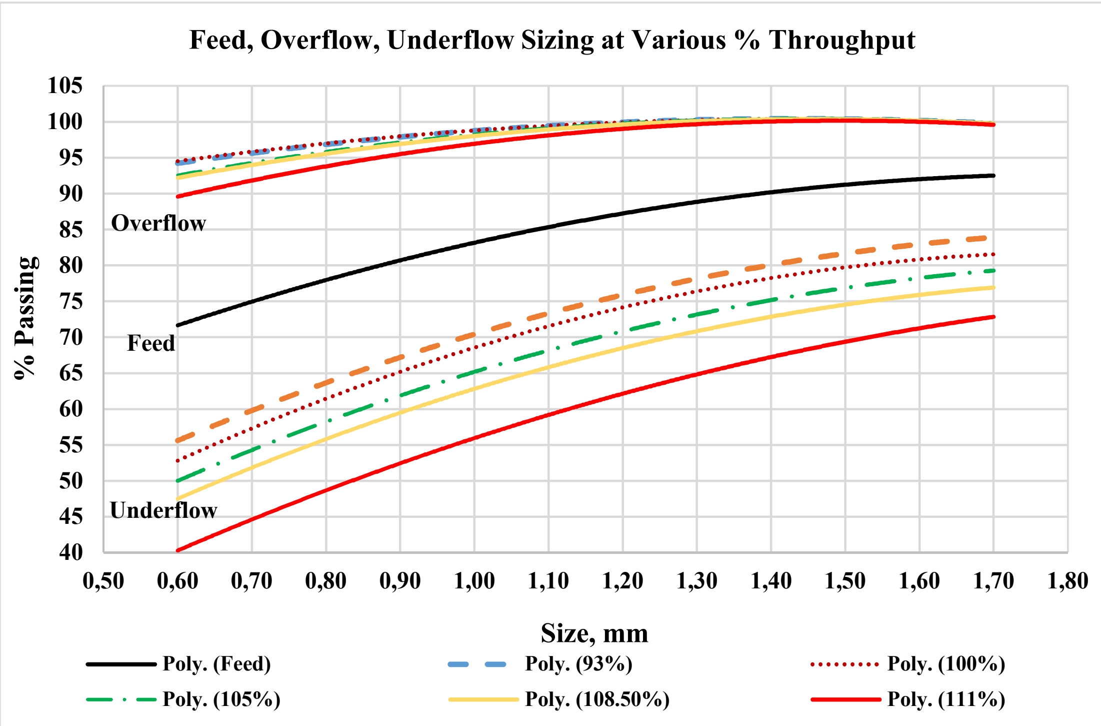

Figure 6. Cyclone Feed and Overflow sizing distribution at different throughput

7. Discussion

The purpose of the trial was to increase Mill throughput so that two mills could fulfil the Refinery's demand. The trial results show the objective could be achieved without compromising product sizing. An increase in spigot size allowed more flow into the cyclone at higher pressure without the previous limit of underflow roping. Even with a higher size spigot, a cyclone would reach the underflow roping, if pressure and feed flow is increased sufficiently. However, the mill discharge (cyclone feed) pump reached the capacity limit before the roping point. It was concluded that operating the mill at 108–110% of the previous peak is most optimum with a 7-

inch spigot, without stressing another component of the Mill system or compromising on grind size.
Earlier SAG mill cyclones were operated with a 6-inch spigot size at 350 tonnes per hour mill throughput. Increased Cyclone Spigot to 7-inch with modified lower cone, providing opportunities to increase mill throughput by about +10 %, with desired cyclone overflow product quality.

8. Conclusion

The SAG mill improvement process started in 2020, to maximize its throughput below steps were carried out:

1. From 2020 SAG mill grinding media loading has been increased from 95 to 105 tonnes.
2. SAG mill Grate design has been upgraded from circular studded to slotted grate, The design upgrade process started with Mill # 3 in August 2021, after its performance review, the Ma'aden technical team has decided to continue with the grate modification of other SAG mills in 2023. SAG mill # 2 grate upgrade completed, SAG mill # 1 planned on Dec-2023.
3. With the help of grate change and maximizing grinding media charge it improves grinding efficiency and sustains at 350 tph mill throughput, above 350 tph cyclone was showing roping action.
4. In the year 2022, the Ma'aden & Alcoa technical team studied the cyclone design and carried out modelling to understand the suitable apex design to avoid roping at higher mill throughput.
5. Hence in early 2023, Maaden SAG mills were operated with cyclone with modified apex and the performance was satisfactory.