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Iron Ore-Dressing Plant Performance Improvement - A Case Study

C. Rudrappa, M.R. Patil, S.J.G. Krishna, P.S. Kumar, P.C. Naganoor and B.P. Ravi

Mineral Processing Department, VSKU PG Centre, Nandihalli-Sandur, Karnataka, India

Correspondence should be addressed to B.P. Ravi, ravibelavadi@gmail.com

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Abstract The sustainable viability of mineral enterprise during recession time depends on improving concentrate product quality, generating readily salable by-products, improving recovery, throughput, and reduction of expenses at minimum unit cost rate and maximum unit profit rate. The present paper discuses the importance of process plant audit for improving the mineral processing plant performance as indicated by different case studies of iron ore dressing plants in Hospet region, Bellary, Karnataka.
Keywords *Iron Ore Processing, Plant Audit*

1. Introduction

The viability of a mineral enterprise necessitates the development of specific techno-economic model. The techno-economic model predicts the operating strategy during the economic recession. The co-dependence of process variables, interdependence of different operations in a mineral enterprise, non-quantifiable factors needs continuous monitoring. This continuous monitoring and generation of techno-economic model is difficult. Hence, age old philosophy of improving viability by maximizing recovery and productivity seems unsustainable till significant overall unit cost rate reduction and enhancement of overall unit profit rate is achieved. With stress on cost reduction, project engineers engaged in multiple projects, usually opt profitable projects than looking into performance improvement studies. However, the performance improvement of the plant needs the routine auditing studies, for reducing the overall unit cost and to improve the cash flow.

Audit is defined as a formal, thorough and periodic examination – evaluation of a system. The global audit is divided into geological audit, mining audit, marketing audit, energy audit, process audit and environmental-safety audit. The present paper deals with metallurgical process audit and its role in plant overall performance improvement. A few case studies are discussed, to reinforce the importance of auditing for performance improvement.

2. Experimental

The aim of process auditing is to understand the effect of the process variables on the profitability. Table 1 denotes the steps and outline of process auditing. The performance improvement studies by process auditing are demanding from time – economic viewpoint. Sometimes it is frustrating due to ill defined objective, improper problem identification and lack of will for implementation. It is a tough job as conceptual ideas have to be sold enumerating the costs, time and risk factors with relation to the benefits obtained. The problem compounds if the historical data is improperly logged and improper location of sampling points in the circuit. However, the total involvement of plant team with proper communications is the key to solve the problems associated with auditing. The data is analysed logically, scientifically, stastically keeping techno-economics in view. Once the problem is identified, test works under simulated conditions, based on evolutionary and revolutionary concepts, are conducted. Conclusions are drawn evaluating the alternatives for solving the problems. The recommendations are made based on sustainable benefits. After on-site implementations, circuit is sampled, the results with techno-economic benefits are evaluated with reference to base line and projected values. Recommendations for improvements are suggested.

The flexibility of process auditing for diverse cases to improve the overall performance of plant from techno-economic view point are discussed below. The program objectives vary due to the time, money and operating philosophy constraints of the company. The process auditing has to be flexible to cater the present needs in stages with an integrated approach in future.

The mid-sized secondary steel manufacturer established a concentrator and pelletization plant producing 1 MTPY BF grade pellets for export and for its sponge iron plant by utilizing sub-grade iron ore fine dumps from the region. The process comprises of closed circuit screen - ball mill grinding of iron ore fines to – 0.5 mm, cycloning, spiraling of cyclone underflow, HGMS of spiral tails, open circuit grinding of concentrate (thick pulp) followed by pressure filtration yielding BF grade pellet concentrate. Figure 1 shows the process flow-sheet. As the plant productivity was below the design level, auditing was conducted to improve productivity with minimum alterations and cost.

Table 1: *Outline of Steps in a Metallurgical Process Auditing*

Outline of Steps
Define project objective
Check the objective
Identify the problem
Review the historical data
Designing the sampling campaign
Sample the unit operations/circuit
Logical data analysis and base line data preparation
Test work in simulated conditions-evolutionary and revolutionary concepts
Techno –economic evaluation of alternatives, comparing with similar industrial data base
Recommendations, on site implementation and evaluation
Conclusions

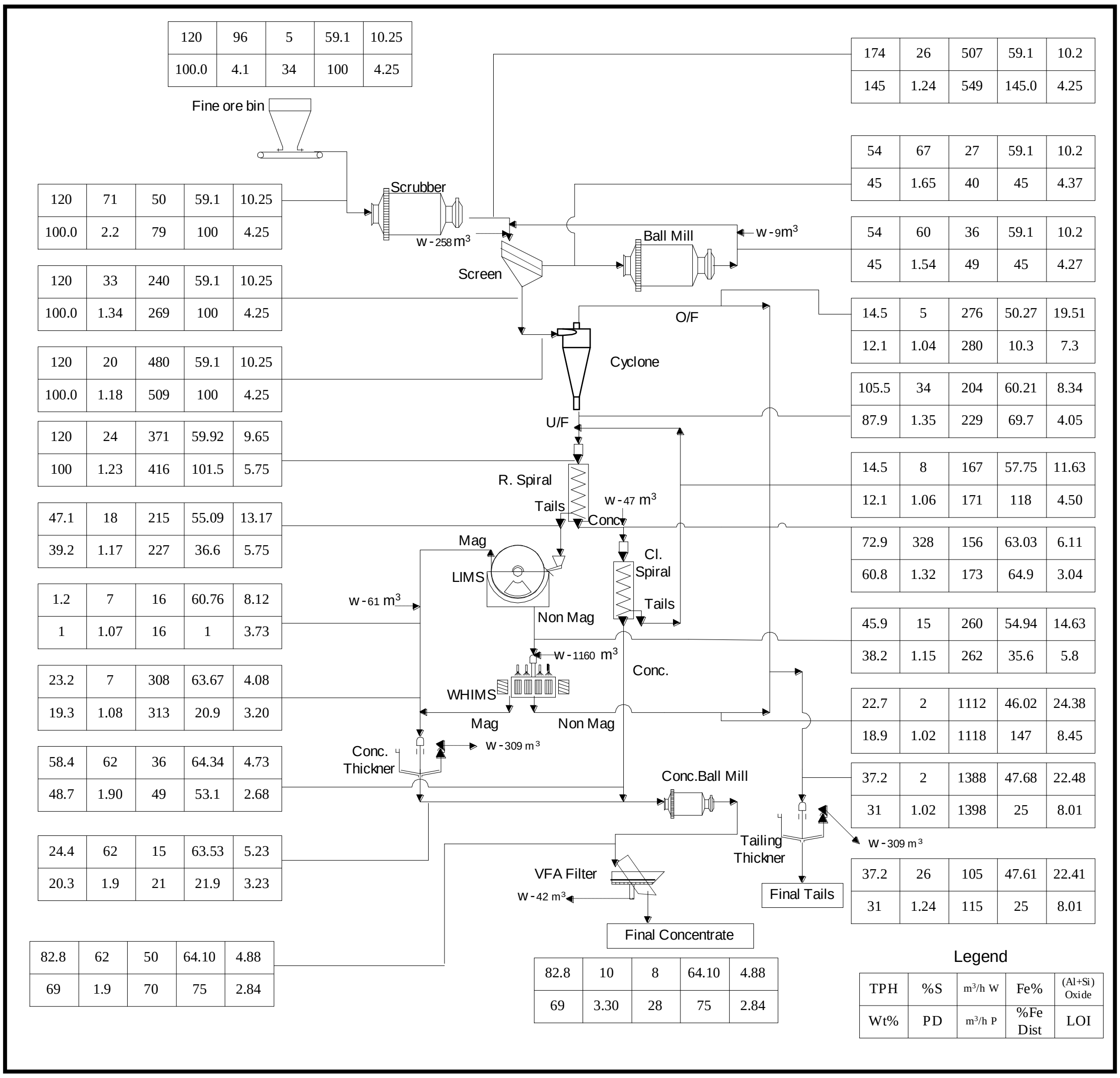

Figure 1: *Process Flow Sheet with Base Line Data Material and Metallurgical Balance*

3. Results and Discussion of Plant Auditing of a Mid Size Iron Ore Dressing Plant

The activity comprised of (a) Review of historical and design data, sample the unit circuits, observation, characterization – test work, data analysis and base line data preparation; (b) Short term modification (STM –1) and evaluation of its benefits with reference to base line data. The plant was run on designated process at stable condition. The periodical incremental samples from all the streams were collected and sampled as per standard methods. The products were chemically, granulometrically and mineralogically characterized. The material and metallurgical balances were prepared and rechecked with production data. Comminution tests were conducted on feed and concentrates samples. The productivity problems in plants lie in grinding - classification circuits with mismatched concentration and auxiliary circuits [1, 2]. The historical ore variability data indicated that the goethite (3-35%), hematite (45-75%), aluminous gangue mineral (1-20%), slimes (6-26% minus 45 microns), and Bond's work index (7-15 Kwh/short ton) varied widely [3].

3.1. Base Line Data (BLD)

Tables 3 and 2 give the overall results and the metallurgical results of BLD. It indicated that; a) The plant is run in a custom mode with variable ore types in a discontinuous fashion affecting the operation.

Improper maintenance of process parameters like % solids and granulometry resulted in marginally high tail value *w.r.t* design tail values (refer Table 2). b) The plant was run at 120 tph much below the designed rate with little load on primary closed circuit screen – ball mill grinding, de-sliming and gravity concentration circuits; This led to slimes generation, finer MOG, and operation at lower % solids. c) Insufficient mill capacity (50%) for open circuit concentrate grinding was noticed even at design Bond's work index value of 7.2. Kwh/short ton. The plant and the lab data indicated that the Bond's ball mill work index of the concentrate was found be >13 Kwh/short ton. d) The size analysis of different concentrates indicated that the HGMS concentrate was of very fine size (-200mesh) and nearly 50% of the un-ground composite concentrate passed the pellet feed size requirement (-200mesh). The grinding of composite concentrate with 50% finished size material generates slimes, which may affect the filtration. The filtration rate was low due to insufficient filter area (60%) and increased slime content (30% - 10 microns).

3.2. Short Term Modifications (STM-1)

The plant was run at a high throughput in an ascending sequence, after the following STM-1 was made. The cyclone parameters were adjusted to get a finer cut (-20 microns) in overflow. 60% cut was implemented in I cleaner spiral circuit to increase the grade and re-circulating load. The plant was run at slightly thicker pulp. The HGMS circuit parameters were adjusted to increase the recovery by pulp density, ring speed and intensity. The thickened slimy HGMS concentrate (-200 mesh) was by-passed from the concentrate ball mill grinding. The ball charge volume in the concentrate mill was raised to maximum level of 45%. The thickened slimy HGMS concentrates and ground sandy concentrate (-200 mesh) thick pulps were subjected to VPA filtration at high percent solids of 70% (PD > 2.2) with minimum pumping and air blow time. The overall results and metallurgical results of STM 1 are given in Tables 3 and 2 respectively. The STM-1 data indicated that

a) Ore throughput was raised steadily from 120 to 162 tph (35% w.r.t. BLD);

b) The concentrate production increased from 82.8 to 120.7tph (46% *w.r.t*. BLD). The tail losses reduced from 47.68% to 40.62%Fe increasing Fe recovery from 75 to 82%;

c) The concentrate regrinding mill capacity was increased by bypassing the -200 mesh from the circuit preventing slimes generation by over grinding. The VPA cycle time was reduced from 11 to 8 minutes;

d) The cost benefit analysis indicated a reduction of 65 Rs./t of ore (10% savings *w.r.t*. BLD).

Table 2: *Metallurgical Results at Various Conditions*

Products	Design (200 tph)			Base line (120 tph)			STM-1 (162 tph)		
	Wt.%	Assay %	%Dist.	Wt.%	Assay %	%Dist.	Wt.%	Assay %	%Dist.
Cyclone O/F	9.4	55.00	8.8	12.1	50.27	10.3	11.2	45.70	8.8
I Cl. Sp. Conc.	48.9	66.60	55.2	48.7	64.34	53.1	56.5	64.21	62.6
Mag. Conc.	19.0	61.17	19.7	20.3	63.53	21.9	18.0	62.67	19.5
Non-Mag tails	22.7	42.36	16.3	18.9	46.02	14.7	14.3	36.64	9.1
Head(Calc.)	100.0	59.00	100.0	100.0	59.01	100.0	100.0	57.92	100.0

Final Tails	32.1	46.20	25.1	31.0	47.68	25.0	25.5	40.62	17.9
Final Conc.	67.9	65.08	74.9	69.0	64.10	75.0	74.5	63.84	82.1

Table 3: *Results of Base Line (BLD) and STM-1 Data*

Data	Base Line			STM-1		
	Feed	Conc.	Tails	Feed	Conc.	Tails
TPH	120.0	82.8	37.2	162	120.7	41.3
Size % - 45 microns	65.0	72.0	94.6	59.0	70.9	93.9
Hematite + Martite %	60 – 65	85 – 90	5 – 10	80 – 85	85 – 90	20 – 25
Goethite %	15 – 20	8 – 12	50 – 60	5 – 10	3 - 5	35 – 40
Clay %	10 – 15	3 – 5	30 – 35	3 – 5	1 – 2	4 – 5
Gibbsite %	5 – 10	1 2	10 – 15	1 – 2	1 – 2	1 – 2
Quartz %	Traces	Traces	3 – 4	5 – 10	~1	35 – 40
Work index Kwh/short ton	11.72	13.00	--	13.0	13.00	--
Wet Screen CL%	45	--	--	98	--	--
Wet Screen Efficiency %	99.8	--	--	90	--	--
Feed ball mill Efficiency% @ 10 WI	60.9	--	--	78.2	--	--
Cyclone Efficiency%	60.3	--		59.7	--	--
Thickener UTA m^2/t/d	--	0.0256	0.0392	--	0.0215	0.0353
Conc. ball mill Efficiency% @ 10 WI	--	64.2	--	--	73.1	--
VPA rate t/m^2/hr	--	0.196	--	--	0.286	--
% cake moisture	--	9.0	--	--	9.2	--
Power & water Rs/t	122.0	--	--	93.0	--	--
Consumables Rs/t	89.7	--	--	79.5	--	--
Salary wages Rs/t	44.9	--	--	39.8	--	--
Ore Rs/t	400.0	--	--	378.6	--	--
(Total) operating cost Rs/t	656.6	--	--	590.9	--	--

4. Conclusion

Base line auditing and short term modification of the iron ore concentrator increased the concentrate productivity and reduced operating cost significantly. Based on the recommendation the company removed bottlenecks like adding additional filters, regrind ball mill, running feed ball mill open circuit, using de-sliming cyclones ahead of WHIMS to maintain pulp density and by-passing drum scrubber and averting pumping of coarse pulps. This enabled in reducing the operating cost by Rs. 100/t and reducing. Tails losses to <40% and increasing productivity to 250tph and concentrate yield to 75%. The audit study indicated that there is scope for further improvement in productivity and cost reduction by detailed auditing studies, which needs to be immediately taken up.

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