Process optimisation and Retrofiting

In the current scenario of limited demand growth and competitive industrial environment, enhancing productivity and reducing the energy consumption has become the need of the hour for survival.

Over the years, Operations Audit has been found to be an effective tool for identifying the measures required to optimise the plant process operations and drawing action plans for exploring the hidden potential for enhancing the capacity through retrofitting route.

This paper discusses case studies to highlight the benefits accrued through conducting operations audit of plants.

Moreover, in view of the fact that cement production is an energy-intensive process, it is important for the cement production units to unleash the plant potential capacity so as to improve the capacity utilization and lower the energy consumption, ensuring reduced unit cost of production.

Process Audit helps in identifying the possibilities to upgrade the available equipment with optimum capital expenditure. A set of action plans are formulated based on identified improvement measures for implementation in the plant covering operational debottlenecking, establishing potential plant capacity, improving key performance indicators etc.

Objectives

The main objectives of the process optimisation study are to identify the inherent potential in the entire production process starting from mining operations to packing. Each unit operation is studied and analysed including plant stoppages in detail with an objective to identify the potential improvement areas for optimisation of operational practices for sustained operation covering all the aspects.

Case Study - 1

Holtec Consulting Private Limited **(HOLTEC)** had carried out a Plant Operations Audit for a cement plant in the Kingdom of Saudi Arabia with following objectives:

- Exploring the available potential in clinkering capacity for further capacity enhancement of both production lines
- Improving the overall efficiency in terms of fuel & power consumption and performance to realise its objective of reducing its demand for HFO.
- Optimisation of Bypass Operation for minimising heat and dust losses.

The said plant has two production lines having 4 stage SP kilns & Flash calciner, ball mills for raw and finish grinding operating at an average production level of 3,600 tpd each. The plant is manufacturing Type I & Type V cement. The fuel used for manufacture of clinker is HFO being supplied by refinery within Kingdom of Saudi Arabia.

Plant is operating at specific fuel consumption of about 880 kcal/kg and specific power consumption of about 121 kWh/t cement with about 50% bypass to avoid operational problems caused by presence of excess sulphur present in fuel and raw materials.

HOLTEC suggested the following improvement measures for reducing the bypass extent and reduced specific heat and power consumption:

Raw Mill

- Installation of VFD for mill vent

The broad specifications of the grate cooler are furnished below:

Type	Inclined grate cooler
Size	(6x2.8) + (13.5x2.8) m
Grate load	32.3 tpd /m^2
Grate area	51 m^2
Clinker Outlet Temperature	60-80° C
No. of grates	2
No. of chambers	5
No. of cooling fans	5
No. of rows:	
– Chamber 1	6
– Chamber 2	18
– Chamber 3,4,5	45

Table: Parameters considered during period of measurement

Parameter	Unit	Value	Basis
Ambient temperature	°C	31	Measurement
Total kiln feed	tph	103	CCR indication
PH exhaust gases	Nm^3/ kg clk.	2.196	Measurement and calculation
PH exhaust gas temperature	°C	365.7	Measurement
Oxygen at PH exhaust gas	%	6.9	Measurement
CO at PH exhaust gas	ppm	325	Measurement

Parameter	Unit	Value	Basis
Cooling air input to clinker cooler	Nm^3/kg clk.	3.129	Measurement & Calculation
Secondary air quantity	Nm^3/kg clk.	0.091	Estimated based on air balance
Tertiary Air quantity	Nm^3/kg clk.	0.306	Measurement and calculation
Cooler vent air quantity	Nm^3/kg clk.	1.780	Measurement and calculation
Cooling air escaping for cooler air chamber 1 & 2	Nm^3/kg clk.	0.954	Estimated based on air balance in cooler
Hot Clinker temperature	°C	1400	Assumed
Tertiary air temperature,	°C	970	Calculated based on cooler heat balance
Secondary air temperature			
Cold clinker temperature	°C	73	Measurement

fan and opening the damper fully
- To improve the separator efficiency through optimisation
- Installation of VFD for separator fan and opening the damper fully
- Reducing pressure drop across separator bag filter

Pyro Process

- Replacement of existing dust settling chamber with a suitably designed new dust settling chamber TA damper opening to be re-adjusted after installation of new dust settling chamber
- The cooling fans for which efficiencies are lower even after upgradation of cooler vent Heat exchanger, replace the fans with new suitably designed high efficiency fans with VFD in phased manner
- Increase the cooler grate area by extending the cooler length
- Reduce preheater return dust by replacing top stage cyclone with high efficiency cyclone
- To increase kiln inlet area
- Use of silicon carbide refractory for kiln inlet area
- Installation of new LP cyclone
- Addition of 3rd parallel module of heat exchanger for reducing the bypass extent
- Use of alkali rich material like feldspar, soda ash in raw mix to neutralise presence of excess sulphur
- Installation of air blasters.

Plant Capacity Assessment has been carried out based on the process measurements conducted by the **HOLTEC** team, data collected and discussions held with plant personnel during the site visit. The production capacity can be upgraded to 4,200 tpd clinker at a specific investment of USD 75

Plant implemented some of the above measures in a phased manner. Plant is currently operating at an average production level of about 4,200 tpd clinker at an average specific heat and power consumption of 800 kcal/kg clinker and 100 kWh/t cement.

Case Study - 2

Holtec Consulting Private Limited **(HOLTEC)** carried out a comprehensive technical audit for cooler optimisation in a cement plant in India having a dry process coal fired kiln with 5-stage suspension pre-heater, Separate Line Calciner (SLC), Grate cooler and Roller Press for Raw, Clinker and Slag grinding.

The target cement plant had operational issues with the cooler, affecting the kiln performance leading to reduced clinker production.

Status

The rated capacity of the plant is 1,650 tpd and has operated at a peak production of about 1,900 tpd in the past. Due to operational issues with the cooler, the clinker production is reduced to 1,300 – 1,400 tpd.

Key Operational Issues

- Kiln feed is restricted up to clinker production level of 1,300 – 1,400 tpd due to the frequent cooler grate plate failure
- In-house trials to operate the cooler at lower speed to maintain higher clinker bed (typically in the range of 300 – 400 mm), led to clinker heap formation in the grate 1. The operators were forced to increase the cooler speed to

avoid snowman formation and disturbance in kiln operation
- The grate structure and frame got damaged due to over filling of under grate hopper of chamber 1, up to grate level

Operating the cooler at higher grate speed of 16–17 spm leads to:
- Low clinker bed height of 150–200 mm
- High wear & tear of grate plates because of hot clinker movement and plate to plate abrasion
- Low under grate pressure of 25–30 mbar, (against 45-50 mbar recommended) with full opening of cooling air fan damper
- Exposure of grate plates to higher temperature causing premature oxidation/burning and more impact from the falling clinker.

Observations Based on Internal Inspection of Cooler
- Deformations and misalignment in the support structure/frame and cooler grate plates in grate 1 (chamber 1 & 2)
- Cracks observed in 3 plates, starting from the edge to centre
- High wear on surface due to near zero gap between the fixed and moving plates observed in 10 nos plates.
- 6 plates in Row 1, 2 and 3 were observed burnt due to excessive temperature condition
- Failure of T-bolt reported due to mechanical stress development because of misalignment
- The following gaps were observed in grate plates which is caused due to misalignment:
  - ➢ 8 – 10 mm between plates of two consecutive rows as against 2 mm recommended
  - ➢ 5 – 6 mm between adjacent plates of same row as against zero gap
  - ➢ ~ 20 mm gap between the side seal and grate plate.

The phenomenon of burning, faster wear, premature failure of the grate plates is attributable to deformations and misalignment in the support structure/frame which has now led to unwarranted gaps between the plates and cause of clinker fall through as well.

Table2: Mass and Heat Balance of Clinker cooler

Sn	Description	Flow kg/kg clk	Temp °C	Cp kcal/kg °C	Heat kcal/kg clk
	HEAT INPUT				
1	Hot Clinker	1.00	1400	0.261	366
2	Cooling Air	4.05	31	0.238	30
	Total	**5.05**			**396**
	HEAT OUTPUT				
3	Cooler Exhaust	2.30	425	0.247	241
4	Tertiary Air	0.40	970	0.259	99
5	Secondary	0.12	970	0.259	30
6	Clinker Leaving cooler	1.00	73	0.190	14
7	Cooling air leakage	1.23	31	0.238	9
8	Radiation losses				3
	Total	**5.05**			**396**

Observations Based on Process Measurement

Mass and Gas balance was done across the clinker cooler system in order to ascertain the present thermal efficiency of the clinker cooler system and cooler losses.

Details of heat balance worked out for clinker cooler is given in Table 2.

Following are the observation based on process measurements:
- Cooling input air measured is 3.13 Nm3/kg clk (4.05 kg/kg clk) against typical value of 2.2 – 2.5 Nm3/kg clk for such type of coolers
- Cooler heat recuperation efficiency: 33% against a typical value of 55 – 60%
- Clinker cooler losses: 264 kcal/kg clk against a typical value of 140 – 160 kcal/kg clk
- Cooling air losses: 30% of total input air escapes from drive shaft, flanges etc of grate 1, which is avoidable
- Cooler vent air temperature measured as 425oC (near vent take off) reduces to 150 oC (near cooler ESP fan inlet) due to false air ingress from cooler ESP inlet duct, cooler ESP and Cooler vent fan inlet duct. False air ingress increases the volume of air being handled by the fan leading to higher ESP fan power consumption

Recommendations

Following actions were suggested for the improvement in cooler performance:
- Intermediate plugging of air escaping from drive shaft & flanges of chamber 1 & 2, to increase undergrate pressure, guide cooling air to pass through aeration holes, and improve the cooler recuperation/thermal efficiency
- After arresting the air leakages, trials may be taken to gradually

reduce the cooler grate speed for increasing the undergrate pressure. Regular monitoring should be made to check any build-up/ snowman formation in 1st chamber.
- Reducing cooler vent ESP fan load by arresting false air ingress in the cooler vent ESP inlet and outlet duct
- Minimising the gaps in cooler grate plates and side seals till the implementation of long term solutions
- Modification of existing grate 1 by installing static grate plates for the first 7/8 rows along with the new dedicated air distribution system and blasters
- Balance portion of grate 1 to be modified/replaced to suit the installation of above proposed modification
- Installations of VFD for all the cooler fans.

Case Study - 3

Holtec Consulting Private Limited **(HOLTEC)** had carried out a process optimisation study in a cement plant in Pakistan. The plant was operating at a production level of about 1,800 tpd clinker. The average values of specific fuel consumption and specific power consumption at the time of study were about 977 kcal/kg clinker and about 131.55 kWh/t cement respectively. The major equipments in the plant were a two chambers central discharge ball mill for raw material grinding, a dry process kiln with twin string preheater (PH) and a precalciner (PC) in calciner string, grate cooler and a two chamber, closed circuit ball mill for cement grinding.

Following actions were suggested:
- Plugging the false air infiltration in the system
- Provision and functioning of the mechanical flaps at the bottom of dust settling chamber in the tertiary air duct (TAD)
- Adjusting the feed distribution in kiln and calciner string PH
- Reducing the primary air quantity in PC and kiln
- Adjusting the flame momentum of kiln firing burner
- Optimisation of grate cooler operation.

With implementation of above improvement measures and under **HOLTEC's** operational supervision, the following were achieved:
- Increase in kiln capacity to about 2,400 tpd clinker
- Lowering of the specific fuel consumption to about 885 kcal/ kg clinker
- Reduction in specific power consumption to about 103 kWh/t cement.

HOLTEC assessed the potential capacity of plant as 3,000 tpd clinker. For achieving this capacity, some important recommendations made are as given below:
- Installation of dust suppression system on crusher hopper and its conveyors.
- Installation of line -2 raw mill for raw materials grinding.
- Installation of one additional belt conveyor for feeding the raw mill hoppers.
- Replacing the fuel oil by coal as fuel and installation of a coal mill of capacity 30 tph.
- Removal of venturies in down comer ducts of kiln and PC string PH.
- Installation of compressed air assisted water spray in PC string down comer duct.
- Installation of 3rd cyclone in parallel to the existing top stage twin cyclones in PC string for saving in pressure drop.
- Extension of PC height by 5 meters.
- Installation of grid resistance regulators for HV fans.
- Relocating the PC string ID fan after GCT for saving in electrical energy consumption of ID fan.
- Replacement of PC string ID fan by a new suitably designed, high efficiency fan.
- Installation of kiln shell temperature scanner.
- Installation of variable speed drive for cooler fans and one of the cooler exhaust fans. \• Extension of clinker cooler area by provision of 3rd grate and increasing the capacity of cooling air fans.

With **HOLTEC's** assistance, the plant implemented some of the above measures. Implementation of these improvement measures were done in a planned manner in consultation and supervision of **HOLTEC**, in a planned shutdown of about 5 weeks. The plant was able to achieve an average production level of about 2,850 tpd clinker.

With complete implementation of the above recommendations, the expected kiln production is 3,000 - 3,100 tpd clinker. At this production level, the expected specific fuel consumption and specific power consumption shall be about 750 kcal/kg clinker and 90 kWh/t cement. Estimated payback period for the capacity upgradation worked out to about 5 months. Moreover, the plant operational consistency has improved a lot as a result the annual production has increased significantly.

Conclusion

The above case studies demonstrate that Operations Audit is an effective tool for identifying the measures required to optimise the plant process operations and drawing action plans for exploring and exploiting the hidden plant potential through retrofit route.

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