Guest Column

Improving Energy Efficiency

Kamal Kumar and **Dinesh Satija**, leading experts in process optimsation, share insights into the concept of energy efficiency and elaborate the concepts with a relevant case study.

Cement production being an energy intensive process, the industry needs to focus on improving energy efficiency to reduce the cost of production and for conservation of conventional energy resources. Realising this, several companies have initiated focused programmes for optimisation that cover various aspects of cement production. While the conventional approach may yield moderate to good results, extraordinary benefits can be reaped by harnessing the multi-functional dimensions of all internally controllable variables in an integrated manner.

For obtaining real benefits, some general rules that must be followed:

- Improve operational efficiency and optimise unit operations.
- Troubleshoot problems in raw materials, electrical systems, instrumentation, mechanical and process engineering sections through diagnostic studies.
- Integrate maximum capacities of sections to enhance the overall plant productivity and consequently reduce specific energy consumption.
- Effectively utilise the available waste heat.
- Utilise resources optimally to assure the quality of product.
- Explore every possibility for cost reduction.

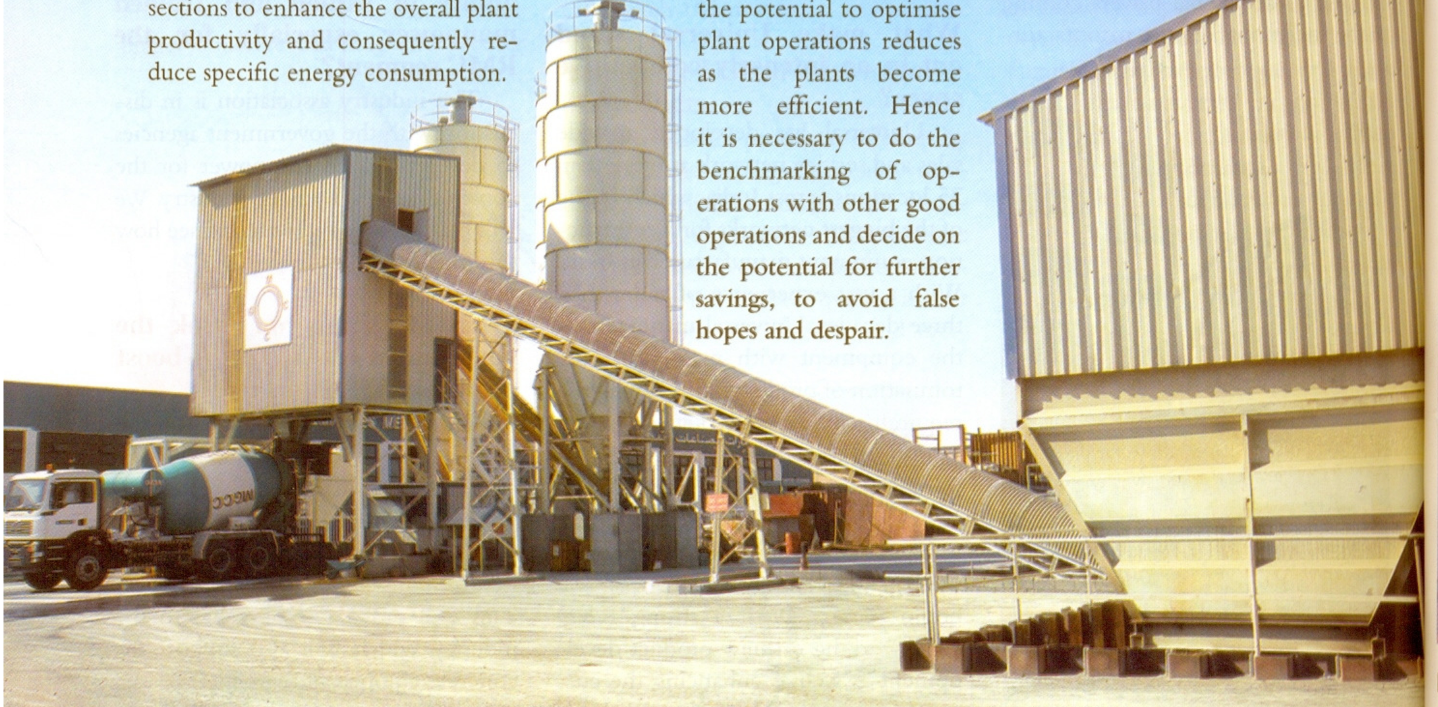
Being an energy intensive process, cement manufacturing needs focused effort on minimising energy consumption. It cannot be emphasised enough how important it is to utilise the available capacity to reduce the specific energy consumption and the production cost.

Identification of focus areas

To start with, various costs involved from purchase of raw material, up to delivering the product to the final consumer, are identified and tabulated. An analysis of this data will help in identifying areas that are controllable and where reduction in costs can be attempted. There is no point in wasting efforts where no significant difference can be made. It may also be noted that the potential to optimise plant operations reduces as the plants become more efficient. Hence it is necessary to do the benchmarking of operations with other good operations and decide on the potential for further savings, to avoid false hopes and despair.

Discussions with various producers, regarding the measures invoked by them has led to several ideas and conclusions. Few of the significant ones are discussed here.

- Sub-optimisation seems to be a recurring problem. For example while deciding the product mix, the cost of raw material is given precedence over the impact of the mix on fuel consumption (due to varying heats of formation of different mixes) or power consumption in finish grinding (due to varying clinker properties). Energy consumption profile of the new mix is often not adequately assessed before it is finalised.
- Internal innovations for cost reduction have generally been restricted to the area of maintenance where focus has been on restricting consumption rates. Most other initiatives have followed a beaten track.



Significant attention is usually paid to the most cost intensive processes, which for cement industry is the freight of goods to market. Neither the optimisation tools are used effectively and adequately, nor the measures for reducing the fleet queue length are researched suitably, to provide incentives to transport contractors for reducing freight rates.

- Performance benchmarking has still to come of age. Most companies and plants appear to be a little obsessed with conditions peculiar to their environment. The attitude is often 'why something cannot be done.' The role of the marketplace, as an equaliser is often ignored.
- Finally, cost reduction alone may not suffice. A combination of steps for increasing revenue and decreasing costs is crucial.

Managing costs

Realising the need for continuous improvement as a means of retaining a competitive edge, most companies have initiated ongoing programmes, covering various aspects of operations. This focus on continuous improvement has led to fairly good results with a number of key performance indicators showing improvement. However, a structured approach, that tries to address all the issues previously mentioned, can significantly complement these continuous improvement initiatives. The key features of this approach are:

- Ensuring an integrated coverage, thus eliminating the phenomenon of sub-optimisation.
- Focus on both, revenue generation as well as possible reductions in input costs.
- Exploration of non-conventional areas that are normally not looked-at.
- Value addition to on-going initiatives in terms of cost saving and improved target setting.
- Use of optimisation tools to arrive at better solutions.
- Structuring the improvement initiative through a three-step approach consisting of assessment, action and monitoring.

Use of optimal market access strategy as well as a well-formulated product/ customer mix strategy, can be extremely effective in order to realise a higher return for every unit shipped. Even in the case of Indian cement industry, several firms have gained significantly from optimised re-distribution/ product mix strategy.

Cyclone	1	2	3	4	5
Size, mm	2 x 4,000	5,800	5,800	2 x 4,300	6,300

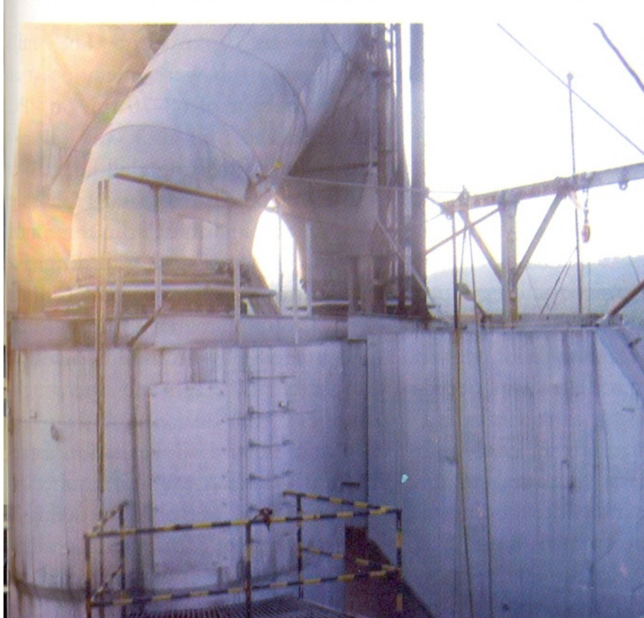
Process optimisation

The initial design capacity of the plant was 1,400 tpd, which was upgraded to 2,000 tpd through modifications and utilising inherent capacities available. The clinkerisation capacity was planned to be increased from 2,000 tpd to 2,400 tpd. At the time of the study, average specific fuel and power consumption were about 800 - 850 kcal/kg of clinker and about 95 - 100 kWh/t of cement respectively.

After preliminary data collection, measurements and evaluation study, the capacity and the potential for improvement was established. Importance was given first to establish the potential of clinkerisation capacity. Subsequently, potentialof other unit operations was established for balancing the capacities.

Kiln

The kiln size was assessed at existing production. The kiln filling at operating speed of 4.5 rpm was 15.0 per cent. The specific volumetric and thermal loading was 5.2 $t/d/m^3$ and 3.3 $Gcal/hr/m^2$ and the retention time was 21.7 min. At enhanced production of 2,400 tpd, the kiln specific volumetric and thermal loading worked out as 6.3 $t/d/m^3$ and 3.7 $Gcal/hr/m^2$ respectively, which



Before modification.

After Modification.

are within acceptable limits. At a kiln speed of 5 rpm, the kiln filling worked out as 16.3 per cent and retention time as 19.5 min, which are manageable.

Pre-heater system

Pre-heater consisted of five stage pre-heater with swirl type calciner. Cyclone diameters were:

Pre-heater was operated at high pressure of 850 mmWG at pre-heater outlet and high gas temperature of 354 °C. The pre-heater fan was operating with extra leakages at a specific gas volume of 1.6 Nm3/ kg clinker.

Calciner

Calciner was examined for the requirement of residence time for fuel combustion and heat transfer for calcination of the material. Based on the active volume of calciner, mixing chamber and calciner loop, the residence time for coal combustion worked out to be 4.17 sec at 2,000 tpd and 3.5 sec at 2.400 tpd.

Cooler, cooler ESP and cooling air fans

The installed cooler was a conventional grate cooler with fixed inlet and effective grate of 36 m^2. At 2,400 tpd the cooler loading worked out to be 66.7 tpd/m^2, which was very high. It was recommended to increase the effective grate area by installing additional grate. This was suggested to reduce the cooler loading below 45 tpd/ m^2. Addition of more cooling air fans was also recommended. The existing duct from cooler to cooler ESP was severely damaged leading to excessive leakage. The cooling air had to be restricted at 1.50 - 1.55 Nm^3/ kg of clinker at hundred precent ESP fan speed.

With the addition of third grate a new duct was suggested to be installed from cooler to cooler ESP. The vent duct and take off area was suitably recommended to handle the extra vent air volume at increased production.

Tertiary air duct (TAD)

Hot air velocity in the existing tertiary air duct worked out to be 20 m/s and 24 m/s at 2,000 tpd and 2,400 tpd clinker production respectively.

There is no point in wasting efforts where no significant difference can be made.

The velocity at the TAD take off point worked out to be 4.00 m/s and 4.8 m/s at the two production capacities. Hence, existing tertiary air duct diameter and take off area was found suitable for 2,400 tpd production. However, to reduce the pressure drop across the system it was suggested to realign the TAD by making the duct inclined and eliminating the two 90° bends. It was discussed and planned to be executed in the second phase for further improvement.

Observations on pyro-processing system

Following observations were made on the pyro-processing system:

- Pressure drop across each cyclone was high at existing production except for cyclone 2 and 3.
- Draught at top cyclone outlet was expected to exceed 1,200 mmWG at 2400 tpd against normally accepted value of 850 mmWG.
- Temperature drop across bottom two cyclones was not significant. It could be due to internal recirculation of material since dip tube was missing in the fifth cyclone.
- Even without dip tube in cyclone 5, pressure drop was measured as 165 mmWG. As this pressure drop also accounts for most of the calciner duct, it was acceptable.
- At the entry point of cyclone 4 and cyclone 5, substantial horizontal portion in the duct caused frequent material buildups resulting into higher pressure drop.
- Cooler modification to increase the effective grate area was necessary for increasing clinker capacity.
- New vent duct from cooler to cooler ESP was required to be installed to handle the additional hot air volume from the modified cooler.
- TAD modification was recommended to be executed in the second phase.

Implementation

Following modifications were done to hit production capacity of 2,400 tpd and optimise plant operation:

- Installation of higher capacity preheater fan.
- Modification of down comer duct.
- Installation of third cyclone (cyclone 1C) at top stage.
- Modification of cyclone 4 A and 4 B.
- Modification of cyclone 5.

Other unit operations

Raw material grinding: A central discharge close circuit ball mill of size 3.8 m x 13.81m was being used for raw material grinding. This mill was operated at 175 tph at higher residue. The requirement of raw meal for the enhanced capacity worked out to be 171 tph. Hence no modification was recommended in raw mill system. However, it was observed during the mill audit that at times, the raw mill feed had substantially large particles of shale limiting the raw mill capacity. It is recommended to install a screen at outlet of tertiary crusher installed in plant to remove the bigger shale particles.

Cement grinding: The mills rated for 60 tph were operating at an average output of 68-70 tph on PPC. Based on the mill audit and capacity assessment of existing mill and motor size it was concluded that 70 tph is the best achievable output from these mills.

Coal drying and grinding: For coal grinding, one air swept ball mill of size 2.8 m diameter x 7.32 m length was installed. This mill was designed for a capacity of 12 tph and operating at 14 tph.

At 2,400 tpd clinkerisation capacity, coal grinding milling requirement worked out as 16 tph considering 21 hours of daily operation. First chamber (drying chamber) was converted into grinding chamber for increasing the grinding path length. An overhanging drying chamber was installed at

The cyclone pressure drops were reduced (as shown in table 1).

Pre-heater stages	Before Modifications Pressure drop at 2,000 tpd	After Modifications Pressure drop at 2325 tpd
Cyclone 1 A Cyclone 1 B Cyclone 1C	180	65
Cyclone 2	110	85
Cyclone 3	118	95
Cyclone 4 A	130	115
Cyclone 4 B	125	115
Cyclone 5	165	45

Table 1: Comparison of pressure drop before and after modification.

the inlet of the mill to meet the drying requirement in coal. It was recommended to replace the existing grit separator by a dynamic separator in second phase. This will further increase the classifying capacity of the system and enhance the mill output.

Limestone crushing: A primary crusher of capacity 350 tph was installed for limestone crushing. At present the crushing plant is operating at an average capacity of about 215 tph. The main reason for low output rate is inadequate feeding to limestone crusher hopper. The required crushing capacity at the sustainable kiln capacity of 2,400 tpd worked out to 328 tph, which can be achieved by improving the feeding system and time cycle to the crushing plant. Hence no modification was proposed for plant expansion.

Plant optimisation process should begin with a thorough technical audit and should be followed with a goal setting exercise that lists out achievable targets.

Raw meal storage: The raw meal storage capacity for 2,400 tpd kiln capacity considering 2.5 day storage (1.5 days active storage) worked out to be as 9,000 t. At present, storage is available for 7,500 t, which falls short by around 1,500 t. This shortfall is manageable.

Kiln feed system: For the kiln feed, the plant had bucket elevators, kiln feed bin on top of the silo and solid flow meter for measuring the feed. The present capacity of kiln feed is about 180 tph which is sufficient to take care of kiln feed requirements at enhanced kiln capacity of 2,400 tpd. Hence no modification was recommended in the kiln feed arrangement.

Clinker transport and storage: The deep pan conveyor capacity had been selected as 170 tph, which had 70 per cent margin even on 2,400 tpd clinkerisation capacity. Hence no modifications were required on the deep pan conveyor arrangement. The present clinker storage capacity of 50,000 tons is sufficient for storage of more than 20 days of clinker production, which is adequate.

Packing and dispatch: Two 8 spout packers along with two truck loaders were installed. Each of the system was capable of packing and loading approximately 100 tph or about 3,000 tpd of cement considering 15 hrs of effective operations. Hence, no new capacity addition was proposed.

Achievements after implementation

- The kiln was operating at 2,300 tpd clinker at kiln feed of 155 tph, speed of 4.5 rpm and specific volumetric and thermal loading of 6.1 tpd/m3 and 3.58 Gcal/h/m^2 respectively. Further enhancement in production was due to speed restriction imposed on kiln to be at 4.5 rpm against recommended speed of 5.0 rpm. The restriction will be in effect till recommended modifications in the drive system are implemented.
- The pre-heater exit pressure was reduced from 850 mmWG at 2,000 tpd clinker to 550 mmWG at 2325 tpd clinker.
- Pre-heater fan inlet pressure (after damper) reduced from 850mmWG at 2,000 tpd to 610 mmWG at 2,325 tpd.
- The return dust in pre-heater down comer duct reduced from being more than 12 per cent at 2,000 tpd to 8 per cent at 2,325 tpd.
- The raw meal to clinker factor improved from 1.7 to 1.6 after the improvement in cyclone efficiency and reduction in return dust.
- Specific heat consumption was reduced from 825 kcal/kg clinker to 750 kcal/kg clinker.
- The overall specific power consumption was reduced by 10 kWh/t clinker.
- The coal mill production increased from 14 tph to an average 17 tph.

Conclusion

Plant optimisation process should begin with a thorough technical audit and should be followed with a goal setting exercise that lists out achievable targets. Efficiency improvement and reduction in energy consumption should be kept in mind at every stage right from choosing the cement mix to dispatch of goods. Knowing the optimum capacity of unit equipment and running them at that capacity is one way to achieve energy efficiency. Constant vigilance for opportunities to optimise the process goes a long way in improving product quality and bringing consistency in plant operation. ICR

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