Modern Processing Techniques to minimize cost in Cement Industry

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1.0 INTRODUCTION

Cement industry in the present scenario is under pressure due to increased competition, rising input costs, lower realisation and reducing profit margins. The need of the hour is to offset the continual increase in input costs and minimising the producing cost through optimised operations. This can be achieved by incorporation of modern processing techniques in cement production.

The present paper highlights the available modern processing techniques in the different areas of cement production and their expected benefits.

2.0 OBJECTIVES

The main objectives of the adoption of the modern processing techniques in cement production are as follows:

- Improving capacity utilisation
- Energy savings.
- Improved environment.
- Use of waste heat.
- Use of by-products, wastes, alternative raw materials and fuels.
- Meeting market requirements in terms of quality and types of cement i.e. Quality assurance
- Lowering investment cost and thereby reducing cost of production.

3.0 SYSTEM DESIGN

The cost optimisation in production starts right at the system design stage. An efficient system design calls for certain typical decisions to be made during the conceptual stage of development of the plant technical concept. The type of decisions shall depend upon the availability of the sub-systems, investment cost, cost of operation covering maintenance, manpower and energy (fuel and power). The skilled manpower to operate the system also makes significant influence on the system design

Selecting equipment or a system has never been easy. Some of the key criterions are as follows:

- Systems availability and reliability
- Ease of operation & maintenance
- Availability of skilled manpower and support services
- Operating cost
- Investment cost

The purpose of system design is to select the most suitable solution, in order to satisfy all the above-mentioned criterias.

4.0 TECHNOLOGICAL DEVELOPMENTS

Over the years, the energy cost has been rising unabatedly. The main energy intensive unit operations involved in cement production are:

- Crushing
- Grinding systems
- Pyroprocessing
- Material handling & transport

4.1 Crushing

Most commonly used crushers are:

- Jaw crushers
- Gyratory or cone crushers
- Hammer crushers
- Roller crushers
- Impact crushers

Earlier, a typical crushing system used to be a two stage crushing with primary crusher in stage 1 (mostly jaw crusher) and hammer crusher in stage 2. This configuration was typically to suit ball mill applications for grinding. Moreover, the high capacity crushers for size reduction in single stage were not easily available at affordable costs. In view of factors like large capacity requirements, increased plant sizes, increasing application of vertical roller mills, etc. the following salient features are worth mentioning:

- The use of single stage crushing is beneficial from point of view of lower investment costs, savings in material handling as also in power. Most commonly used crushers for such application are impact crushers, hammer crushers, gyratory crushers and roll crushers.

- Depending upon the lead distance between mining area and crusher, the use of in-pit crushing, mobile or semi-mobile crushing system can be selected.

- The conventional crushing action in most of the crushers is impact/ compression/ attrition. This method of crushing results in greater wear, generation of appreciable amounts of fines and consumes more power. To take care of these problems, minerals sizers are also being used. These are particularly suitable for wet, sticky materials due to the self-cleaning action of twin roll crushers. An additional advantage with such crushers is the limited sizing of de-dusting equipment due to very low generation of fines.

- Use of careful mine planning and drilling & blasting techniques result into ease of crusher operation and improved energy efficiency.

4.2 Grinding Systems

The selection of the grinding system should be specific to particular situations, to achieve optimum system performance. The factors that influence the grinding system performance are:

- Material characteristics
- Moisture in feed materials
- Energy costs
- Maintenance
- Investment

Grinding is a highly energy intensive process in the cement industry. Approximately 60 – 70 % of the total electrical energy used in a cement plant is utilised for the grinding of raw materials, coal and clinker. Various technological improvements from the conventional ball mills in this area include:

- High efficiency separators (HES)
- Improved ball mill internals
- Vertical roller mills (VRM)
- High pressure grinding rolls (HPGR)
- Horizontal/ Ring Roller Mill

High Efficiency Separators (HES)

An obvious means of improving the performance of a ball mill is to equip it with a high efficiency separator. High efficiency separation improves the grain size distribution, increases production and reduces the grinding power requirements by 8 – 15 %. The improved design of separators prevents over-grinding by avoiding product going back to the ball mill. Introduced initially for cement grinding operations, these improved separators have also found application in raw material grinding ball mills and also the vertical roller mills. Recently developed HES have precise degrees of classification and generate a product with a narrow particle size distribution.

Ball Mill Internals

Ball mills have been conventionally an integral part of most cement plants for grinding raw materials, coal and clinker. The major technological advancements in conventional ball mills have been the improvement in diaphragm, liners and grinding media. The application of controlled flow diaphragm, classifying liners and high chrome grinding media have contributed to an increased rate of production and reduced specific power consumption in the grinding operation and wear rates.

Vertical Roller Mill (VRM)

The power used for the actual grinding process while grinding raw materials, depends mainly on the hardness of raw materials and the type of mill used, i.e. ball mill or vertical roller mill. Typically, the motor of the ball mill consumes about 14 - 15 kWh/ ton of raw mix whereas the VRM motor uses 7 - 8 kWh/ ton. On an overall basis, VRM consumes about 20 % lower specific energy than conventional closed circuit ball mills and is being widely used for raw material and coal grinding in the cement industry.

The adoption of an external raw material recirculation system has further improved the efficiency of VRM. These mills can also utilise large quantities of hot gases from the pre-heater and even the clinker cooler and thus are able to handle material with moisture contents of about 20 %.

VRM is now finding acceptance for clinker or slag grinding also, due to its energy saving potential. The apprehension regarding particle size distribution, cement strength, water cement ratio and consumer acceptance are being slowly addressed adequately.

High Pressure Grinding Rolls (HPGR or Roller Press)

These grinding circuits have recently been developed. These are pre-grinding, hybrid grinding, semi-finish grinding and finish grinding. The pre-grinding system is applied if a production increase of 20 – 30 % is required. Energy saving of 15 % to 20 % is achieved depending on material to be ground. With semi-finish grinding an increase in production capacity depends essentially on the size of the high pressure grinding rolls. The finish grinding system is the most advanced grinding system.

Horizontal/ Ring Roller Mill

The Horizontal/ Ring Roller Mill is a recent development in grinding. The mill has been developed by FCB, France (trade named Horomill) and FLS, Denmark (trade named Cemax Mill). Horomill is suitable for grinding raw meal, cement and minerals, whereas Cemax Mill is mainly for cement grinding. The mill can be used for pre-grinding and finish grinding. This mill-system claims to have advantages of ball mill, roller mill and roller press in terms of reliability and energy savings. The energy saving is claimed to be similar to roller press, around 20 % less compared to ball mill, but with a moderate circulating load and grinding pressure. This system claims to grind materials having moisture up to 20 %.

Thus, in future mainly the VRM, high pressure grinding rolls or Horizontal/ Ring Roller Mill shall be the acceptable propositions due to the simplicity of the systems and low specific energy consumption

4.3 Pyroprocessing

Pyroprocessing includes preheating, precalcining, burning and cooling as the major components and is the most important thermal energy consumption centre in the cement plant. Conversion from wet process to dry process technology for cement manufacturing has been one of the major technological developments bringing about drastic savings in thermal energy. Next came suspension preheater technology with varying stages of cyclones. Dry process cement plants with 4-stage suspension preheater systems have already become universal and further technological improvements have come from the introduction of precalcinator, 5/ 6-stage preheaters with Low pressure cyclones, improved burner and new generation of high efficiency clinker coolers.

With consistent developments in the technology of kiln systems, it has been possible to reduce the heat consumption to about 700 kcal/ kg clinker as shown in **Table 1**:

Kiln Process	Heat Consumption Kcal/ kg Clinker
Wet Process	1300 - 1450
Long dry process	1050 - 1250
1-stage cyclone preheater	900 - 1050
2-stage cyclone preheater	900 - 950
4-stage cyclone preheater + precalciner	740 - 760
5-stage preheater + precalciner	715 - 730
6-stage preheater + precalciner	685 - 705

Table 1: Specific heat consumption in various kiln systems

The various developments in the pyroprocessing section for conservation of energy are mainly in the following areas:

- Precalcinator
- 5/ 6- Stage Preheater with high efficiency low pressure cyclones
- Gas cooling water spray systems in the preheater down comer ducts.
- Low primary air burners
- Modern kiln seals with low leakage and maintenance
- High heat recuperation efficiency (upto 78 %) Clinker Cooler
- Improved Refractory Systems
- High Efficiency Fans (upto 82 %)
- Use of alternative fuels like pet coke, tyres, waste oil, rice husk, municipal waste, etc.

With incorporation of such techniques, several cement plants world over are operating their kilns with specific volumetric loading upto 6.5 tpd/ m^3 on sustained basis.

4.4 Material handling and transport

Till recently, pneumatic material conveying (Air Lift and Screw Pump) has been used in most plants for pulverized material conveying (e.g. raw meal, pulverized coal and cement). This system uses compressed air and is therefore very energy intensive compared to mechanical conveying systems. The main advantages of pneumatic conveying is its low maintenance requirement and operating flexibility.

However, modern bucket elevators require less maintenance and offer considerable energy savings for transporting pulverized materials like raw meal and cement. These are now increasingly being used in the cement industries. Another development has been the dense phase conveying system. Unlike the pneumatic screw pump, this system moves material with low velocity, which significantly reduces power consumption.

For handling dusty materials and also to avoid spillage and environmental pollution, pipe conveyor material transport systems are used. The advantages of this system are:

- Dust free transport of materials
- Zero spillage
- Ability to transport at steep angles
- Return belt can also be used for material transport

Typical power consumed for each type of material conveying system is given in **Table 2**.

Transport System	kWh/ t/ 100 m raw material
Airlift	1.10
Dense phase pump	0.59
Screw pump	1.20
Bucket elevator	0.41

Table 2: Comparison of typical values of power requirement for different types of transport systems

Air Lift and Screw Pump systems when used for kiln feed, introduce a considerable amount of air into the top stage preheater cyclones which results in a larger quantity of kiln exit gases to be handled by the fan and requires a dust collecting system with a larger capacity. The effective temperature of raw meal from the top cyclone is also reduced, adversely affecting fuel consumption. Thus, in modern plants invariably bucket elevators are used for kiln feed, which saves both heat and electrical energy.

5.0 PLANT OPERATIONAL APPROACH

Plant operational approach is another way of cost reduction. The objective is to optimise the operations to achieve the maximum productivity. A few examples of the optimisation measures are given below:

- The false air infiltration in the system to be kept as low as possible.
- The required operating parameters like temperature, pressure, etc. have to be maintained for a particular equipment. For example, at the outlet of the raw mill, the material temperature is to be maintained as 90-100^{o}C.
- In case of cement production in ball mills with high fineness i.e. more than 350 m^2/ kg, suitable grinding aid may be used.
- A kiln burner operation may be optimised to achieve the desired shape and intensity of flame with the minimum primary air.
- Kiln shell cooling fans may be operated if the kiln shell temperature exceeds a certain value say 250^{o}C.
- The clinker cooler operation should be optimised to achieve the maximum secondary air temperature and tertiary air temperature.
- Idle run of the equipment must be prevented particularly during start up and stoppage periods. Similarly, the feed interruptions/ reductions must be avoided.

Plant operational audit may also be carried out on regular basis. The objectives of a comprehensive operational audit of a plant should include:

- Optimisation of the output
- Reduction in specific energy consumption
- Trouble shooting in electrical, mechanical and process systems
- Dust abatement
- Quality assurance

6.0 PRODUCTION OF BLENDED CEMENTS

The main process steps that are involved during the production of blended cements are:

- Weighing and proportioning
- Grinding
- Intermediate storage
- Blending
- Packing and despatch

Manufacture of blended cements can be done either by intergrinding or separate grinding. The salient features of the above two systems are as under:

6.1 Intergrinding

During intergrinding, the relative difference in the particle size distribution of harder and softer components will result in a concentration of easily grindable material in the finer fraction. This can have a negative effect on the quality of the cement and also intergrinding causes overgrinding of a particular component.

- **Features**

  - Mill feed requires weighing and proportioning only once
  - All process operations in one unit.

- **Advantages/ Disadvantages**

  - High specific power consumption due to reduced grinding efficiency
  - Reduced flexibility
  - Difficult product optimisation
  - Low investment costs due to reduced number of equipment.

6.2 Separate Grinding

In separate grinding, each component can be ground to the desired fineness and the concentration of one component in the finer fraction can be avoided.

- **Features**

  - Separate weighing and proportioning of mill feed and intermediate products.
  - Two separate grinding units for clinker, gypsum and additives (slag or pozzolana or fly ash).
  - Mixing of the two ground components

- **Advantages/ Disadvantages**

  - High investment costs
  - No over grinding of one component
  - Maximum use of additives
  - More flexibility of operation
  - Low power consumption

7.0 PLANT LAYOUT

Preparing the plant layout is the most crucial stage for a cement plant. An effective plant layout aims at arranging various process buildings and material handling equipment in such a way that energy consumption in material handling is minimum, connectivity and approach is optimum in process buildings and structures. The installed equipment is required to follow the flow sheet and at the same time the route of travel should be minimum for the material.

Layout has a significant impact on the total energy consumption in a cement plant. So, emphasis should be laid on a good, energy efficient layout design.

An approach for a good layout would include:

- **Use of natural contours of the plant area**

The natural contours should be used as far as possible so as to have minimum length/ lift of the belt conveyors and height of the bucket elevators. Material flow should be kept in a direction of reducing elevation to keep the belt lift minimum.

- **Minimising the length of the ducting to reduce pressure losses**

In a cement plant layout, the most neglected area is the ducting. By judiciously locating the buildings, length of the ducting and orientation can be optimised. As fans consume lot of electrical energy, the efforts should be made to minimise no.

of bends and keep the duct length to have reduced pressure drop and thus reduced load on the fan. By minimising the length of the ducting heat losses can also be reduced.

- **Use of mechanical conveying instead of pneumatic conveying**

Conventionally F.K.Pumps and Airlifts were used for raw meal transport to blending silo, for kiln feed and for cement transport to cement silo. F.K.Pumps and airlifts use compressed air thus consuming major share of power. Replacing F.K.Pumps and air lifts with bucket elevator for blending silo / Cement Silo, Kiln feed can make substantial saving in power. This can be made possible by locating the blending silo and Cement Silos near the Raw Mill and Cement Mill building respectively.

- **Avoiding the transfer towers for the belt conveyors**

As far as possible, a streamlined layout should lead to minimum number of transfer towers in order to reduce the number of belt conveyors. Use of conveyor belt in diagonal direction can reduce the number of belts. Thus saving on an additional drive of belt conveyor, transfer tower, bag filter, lighting arrangement for transfer tower can save lot of energy.

- **Positioning the Load Centres in line to minimise power loss in cables**

Aligning the load centers near to the major buildings instead of having scattered load centers can lead to a substantial reduction in length of the cables. Shorter length of the cables shall certainly save the power by minimising the power losses in cables.

- **Proximity of coal mill building to preheater building**

Coal mill can be located near preheater building so that the preheater exhausted gases can be utilized inside the mill. Preheater exhaust gases contain about 4 – 5 % oxygen, thus utilizing these gases in coal mill leads to nearly inert gas at the mill exit and eliminates any chances of explosion.

Another advantage is the saving on conveying of fine coal. Since about 60 % of coal is fired in precalciner, the coal mill may be located near to preheater building.

- **Use of gravity for the flow of water**

As far as possible location of the overhead tank should be decided in such a way so as to use the gravity for the flow of water to the consumption points. Also the return water tank can be made underground to have the return water flow through gravity towards the tank.

- **Two compressor houses in place of one centralised compressor room**

Two compressor houses can be used instead of single, centralised compressor house. One can be located near raw mill area and another near cement mill area so as to reduce pressure losses and leakages in longer pipeline. Wherever the consumption point is very far away e.g. crusher, a dedicated compressor can be used to avoid long pipeline.

- **Use of cross country belt for conveying raw material from quarry**

Crusher and screen station can be located in the quarry itself so as to convey the screened material through cross-country belt. The movement of dumpers can be avoided by this and also can avoid the reject handling, thus substantial saving on the fuel can be achieved through this.

8.0 ELECTRICAL AND AUTOMATION

The important modern electrical and automation techniques used are as given below:

- Use of high efficiency motors
- Installation of capacitor banks to maintain a high power factor i.e. about 0.95
- Automatic control of plant illumination system
- Incorporation of speed regulation systems for high capacity process fans
- Installation of kiln optimisation package like, Fuzzy logic, Linkman, etc.
- Providing kiln shell temperature scanner with refractory management system
- Providing PID loops for plant operation

9.0 WASTE HEAT RECOVERY

In cement industry, there is a good potential for recovery of waste heat. The advantages of incorporating waste heat recovery system are as follows:

- It is possible to generate steam from this waste heat, which could be used in some other process like desalination of sea water for cement plant in coastal areas.

- Drying of materials such as slag, pozzolana, etc. is another possible application, which is already in practice in many cement plants. Normally, hot excess air from clinker cooler is used for this purpose.

- It is possible to generate electrical power from the waste heat. Normally, steam produced in waste heat boiler incorporated to recover heat from preheater gases/ cooler exhaust gases is used in a steam turbine to generate electrical energy.

10.0 CONCLUSION

Efforts to lower the cost of production are made on continuous basis in a cement plant. These measures include high capacity utilisation, reducing down time, saving in energy consumption, minimising maintenance cost, advanced automation level, waste heat utilisation, etc. Modern processing techniques help to achieve these objectives to a great extent. These techniques should be adopted preferably at plant installation stage. However, some of these techniques can also be incorporated during plant operation phase.