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Optimizing Electrical Energy Consumption In Cement Process Plants: Strategies For Energy Conservation And Sustainability

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Abstract: With rapid industrialization and urbanization there is a tremendous demand for energy. There are today greater differences than ever before among the communities of man in their access to energy in their material standard of living and in their potential for survival. The lifestyles that have evolved in recent times are energy intensive in character. The resources for coal, oil, natural gas, petroleum, hydro power and nuclear power are very finite and get depleted at a very faster rate as these are exploited and explored to meet the demand of energy. The burning of fossil fuel has created air pollution and it leads to ecological imbalances. Industrial pollution leads to global warming and sea level rise. Keeping in view the above facts there is great need for energy conservation. Energy conservation means the most efficient use of energy or to minimize the utilization of energy. In order to tackle energy crisis renewable energy sources are the alternate sources of energy. Industrial sector is the foremost sector of an economy. The progress and economic development of any nation depends on industrial growth. Besides raw material and man power, energy plays a dominant role in industries. Cement industry is one of the major energy consuming industries and the optimum use of energy is at present important for our national economy. The energy cost is the highest component of cost structure of cement manufacture. Energy cost in Indian cement industry account for over 40 to 50 percent of the manufacturing cost of the cement. Out of this the share of thermal energy alone in the form of fuel is about 30 to 35 percent while the remaining 15 to 20 percent accounts for mainly electrical energy. The major sources of energy to Indian Cement Industry are coal and electrical power. In cement industry Electrical energy is used for many operations like Crushing,Grinding,Rolling etc., The present paper deals with the methods and technologies that can be adopted in cement process plants to optimize Electrical energy consumption to conserve energy.

Index Terms **- Cement industry, Energy conservation, Electrical Energy, Optimization.**

I. INTRODUCTION

The most efficient use of energy which is termed as Energy Conservation is an important step to tackle the Energy crisis. Energy conservation has become necessary in almost all chemical industries mainly for two reasons. Firstly there is a sharp rise in the cost of energy which sometimes makes the product uneconomical. Secondly there is an increasing awareness that the sources of Energy depleting at a very fast rate must be conserved until alternate sources of Energy are developed. With population explosion, ever increasing demand for industrial products, Energy conservation is inevitable and Need of the Hour.

Cement Industry is an energy intensive industry and the energy consumption accounts for 40-50% of the total manufacturing cost. Hence there is a great need to evolve ways and Methods for conserving energy in this industry.

In cement Industry, conservation of energy can be done by two principal methods, (i.e) by Optimization and Modernizations, Optimizing the operating parameters at existing conditions and also by adopting the energy saving process and installing machines as a part of modernization.

2. OPTIMISATION OF ELECTRICAL ENERGY GENERAL APPLICABILITY TO ANY CEMENT INDUSTRY

Comminution &Optimisation of operating parameters for ball mill

In cement plant about 75% electric power is consumed by comminution equipment such as crushers and ball mills and theoretically only 2% of the whole power is used by comminution, the rest being wasted as heat and noise.

Selection of comminution equipment has to be based on the raw material characteristics such as hardness, abrasion index, roughness, breaking pattern, free silica content and grindability index. Indian limestone deposits vary widely in chemical properties, free silica content, abrasion index, Bond's work index and breaking pattern. Silica content varies from 2 to 22% and hardness being proportional to the silica content, while Bond's index may vary from as low as 4.7-16 KWh / short ton depending on the deposit. Different type of equipment such as Jaw crushers, Gyratory crushers, Impactors, Rotor hammer mill etc, are used for crushing limestone of different characteristics.

The mill performance is known to be dependent on the following parameters.

- Material characteristics such as hardness. granulometry, temperature moisture content and grindability.
- Mill construction like L/D ratio, number and length of chambers and types of liners and diaphragms.
- Process variables such as speed of mills, optimum revolutions of the mill, ball charge and gradation recirculating load and effective separation.
- Amount, type and size of grinding media.
- Correct size of grinding compartments.
- Mill system.

The performance of the mill can be assessed through the following

- Mill throughput.
- Fineness and granulometry of product.
- Specific power consumption.
- Metal ware rate.
- Quality of the product.

If all the above mentioned parameters are optimized by experimentation on mills then mill output can be increased by 5.2 - 20% of its rated output and thereby reduce the specific energy consumption. Addition of grinding aids may also increase the efficiency in clinker grinding. The installation of weigh table feeders and sound measuring equipments is still more necessary. Efficient air classifiers and the use of roller mills, instead of ball mill provide scope for saving energy.

System Design

The system design is largely determined by the nature of the material handled and the degree of performance required. For instance, selection of drying - grinding system should take into account the grindability, abrasiveness, moisture and granulometry of raw mix, available gases for drying, operating cost, investment cost, environmental aspects such as dust, noise and vibration levels, maintainability and reliability and a

number of these factors have direct bearing on energy conservation. Similarly, the choice of conveying system should consider power consumption as one of the important parameters in addition to other considerations like reliability, ease of maintenance etc. for example a typical conveying system of 220 tph over 250 m horizontal and 75 vertical distance of travel would have specific energy consumption with different types of conveyors as follows.

Sl. No.	Description of the conveying System	Energy Consumption (kwh / t)
1	Pneumatic screen pump	3.5
2	Combined air slide & air lift	0.9
3	Air slide & bucket elevator	0.45

Layout Planning

Some of the techniques for realising energy economy through optimum plant layout are given below.

- Designing of the shortest routing of materials conveying.
- Use of natural gradients for conveying systems whenever feasible for reducing energy consumption as well as generation of power for plant operations.
- Proper flooring and sheds for avoiding water and mud to go along with raw materials and coal which may otherwise result in substantial electrical and thermal energy consumption.
- Centralising stockpiles and silos to enable integration and simplification of feed and withdrawal of systems service and auxiliary equipment.
- Centralising plant service facilities.

Selection of Energy Efficient Equipment

Selection of appropriate energy efficient equipment for various unit operations in a cement plant like stacker - reclaimer systems for pre-blending, selection of crusher and its location, high efficiency air separators, grinding rolls, vertical roller mills, 5 stage suspension preheater with precalcinators etc. can help in achieving substantial energy savings as outlined in the following sections. Typical power consumption per tonne of cement in different unit operations is given below.

Cement Mill - 33%
Raw Mill - 24%
Kiln - 23%
Losses and crane etc - 10%
Coal Mill - 7%
Quarry Crusher & Stock Pile - 3%

Crushing Operations

Gyratory crusher Vs Jaw crusher

Gyratory crushers which can normally be used only above 600 - 800 tph capacity from the view point of cost effectiveness, results in considerable energy saving. For instance the capacity of gyratory crusher per kwh is 1.3 - 3.6 times higher than that of jaw crusher while idling, gyratory crushers use only about 30% of the full load energy, the jaw crushers correspondingly consume 45-50% of the full load energy.

Single stage & Multi-stage crushers

Large capacity single stage impact type hammer crushers, which eliminate the need for additional secondary crushing, can help in considerable reduction of energy consumption. However while going for such single - line crushing system in place of conventional dual crusher systems, its effect on the plant down time and performance specially in case of abrasive materials, might be given due consideration.

Mobile crushers

Use of walking and crawler mounted crushers or pneumatic typed mobile crushers can considerably reduce the energy consumption levels by reducing the transportation distance.

A comparison of the energy consideration for different types of crushers is given below:

Comparision of Different Crushers

Sl. No.	Type	Specific Power Consumption (kwh/ton)	Reduction Ration
1	Jaw crusher	0.46 – 1.1	5-8
2	Gyratory Crusher	0.38-0.55	5-8
3	Impact Crusher	0.4-0.6	80
4	Hammer mill with grate		
	a. Single Rotor	1.0 – 2.0	22-30
	b. Double Rotor	1.3 – 2.0	30-40
5	Swing Hammer without grate	0.75 – 0.80	10-20

Raw Materials Grinding

For reducing the power consumption for grinding operation, the developments that have taken place are given below:

Roller Mills

Roller mills can be used very effectively for grinding of raw materials in place of conventional close circuit ball mills. From the recent data of roller mills, it is shown that they require between 40-60% of kWh / ton of average ball mills. Advantages of roller mills are.

- Lower specific energy consumption.
- No secondary crusher, it should be fed with 100 mm material.
- Easy adjustment of grinding pressure with the help of hydraulic compression system.
- High moisture feed material with 16% moisture could be fed.
- Less noise – 10DB.
- Lower investment cost for building and construction.

Comparison of typical energy consumption figures for various mills systems are given below.

Mill System	Mill only Kwh / ton	Fan & Auxiliaries Kwh / ton	Total Kwh / ton
Air swept ball mill	14.5	4.0	18.5
Double Rotor ball mill	11.6	4.8	16.4
Short single chamber bucket elevator mill	4.6	4.5	16.1
Vertical Spindle / roller mill	6.9	6.4	13.3

(This is for a product of 12% residue on 90 micron)

Comparison of energy consumption in a roller mill and a ball mill of same capacity.

Material	Capacity	Rated Power kwh	
	TPH	Roller Mill	Ball Mills
Limestone grinding	175	1750	3400
Limestone grinding	125	1300	2600
Coal grinding	25	310	730

High pressure grinding rolls

High pressure grinding rolls can be used as pre-mill in open circuit or as a finish mill in a close circuit mode. The comminution of the material to be ground in the high pressure grinding roll takes place under very high pressure in a bed of materials. The fact that the material is drawn in by the grinding roll and thus cannot escape the impending pressure stresses increases the energy utilisation efficiency as compared to the conventional tube mill.

Vertical shaft kiln

Development of modern vertical shaft kiln made the manufacture of cement in small scale techno-economically feasible thus resulting in a number of advantages like lower investment cost, utilisation of scattered raw material deposits, reduction of strain on national transportation infrastructure and other socio-economic benefits.

Modern CRI-VSK technology was pioneered in India by Cement Research Institute of National Council for Cement and Building materials as early as 1972. The consumption of electrical energy in most of the CRI – MVSK plants is between 9.5 and 110 Kwh /ton cement. On an average the energy consumption of rotary kiln plant in between 120 - 150 Kwh / ton cement.

Thus CRI - MVSK technology is economical as well as more efficient due to combining of various unit operations like preheating, precalcining, burning and cooling in a single stationary vertical shaft.

Use of grinding aids in cement grinding

The cement particles agglomeration occurs during grinding is due to opposite charge on the surfaces created by the compressing action of the grinding media. The agglomeration will consequently increase with the increased fineness hence resulting in more energy required to continue the grinding process.

Grinding aids improve the grinding performance as they either inhibit or control the particles agglomeration. The grinding aids are chemicals additive, mostly organic surface - active agents, liquid organic chemicals such as amines, acetones etc. and helps in reducing incrustation on grinding balls and lining plates, minimize adhesion of finer grains on coarser ones, thereby facilitating pulverization action and separation of fine grains from the material. Investigations revealed that the grinding aids improved the clinker grinding efficiency particularly above 3000 cm^2/g fineness.

The following table shows saving in power consumption through use of sulphate dyes as grinding aids.

Fineness	Power consumption in the absence of grinding aid Kwh / ton	Power consumption in the presence of grinding aid Kwh / ton	Saving Kwh / ton
2900	34.36	33	1.36
3400	42.28	33	9.28
4000	52.20	33	19.20
4500	60.84	33	27.84

Conservation of Energy in the Operation of Electrical Machineries

Substantial saving of electrical energy can be achieved by methods such as improving the power factor ensuring uniform and uninterrupted power supply, improving the efficiency of motors etc. Power factor improvement, particularly has significant effect on the electrical energy consumption for instance.

- With the improvement in the power factor, the heat losses (I^2R) in the motors decrease.
- With the increase in power factor, there is a reduction in the total KVA demand e.g with an improvement of power factor from 0.8 lag to 0.9 lag in a 15 MW plants, the maximum MVA demand comes down by almost 2 MVA (11%).
- Increase in power factor results into less loading of the power distribution system which would also result in less voltage drop.

Use of capacitors to improve power factor is well known. These require wide adoption, particularly since the capacitors do not affect motor efficiency and have no effect on motor applied voltage.

Slip Energy Recovery

Modern slip energy recovery techniques incorporating semi-conductor convertors in slip ring induction motor drives like large fans etc facilitate speed control and thus conserving energy. The energy at the slip frequencies captured by semi-conductor convertors and converted to the mains frequency and then fed back to the mains thus fully utilizing the slip energy.

Variable speed drives

Proper selection of electrical machinery will also contribute to considerable saving in electrical energy. For instance in the case of constant torque drive like kiln drive variable speed DC motor fed from thyristor convertor requires less power on comparison to DC motors fed from MG sets (Motor generator sets). In the case of fans use of variable speed drive results in saving in energy compared to a throttle damper control.

As a part of modernisation, Roller mills, Waste, Heat utilisation, Sophisticated equipment, Conversion of Process, Suspension cyclone preheaters, Precalciners can boost up cement plant and leads to energy conservation.

3. CONCLUSION

Today energy conservation has greater relevance than that was in the before. The energy conservation covers the improvements in efficiency and use of energy in existing technologies and processes. Energy technologies available worldwide provide substantial opportunities for improving energy efficiencies.

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