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Energy Optimized Modern Air Pollution Control System for Cement Plant

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Abstract : The cement plant is an energy and pollution intensive industry. In the face of rising environment costs and increasingly stringent standards, the conventional approaches for waste and pollution control have changed. Energy-environmentally optimized manufacturing, eco-efficient production, pollution prevention and green engineering have gained widespread acceptance. To reduce negative environmental problems, the environmental performance target should be identified and quantified at design or production stage. The plant production processes generate substantial quantities of air pollution and water waste, which is alarming and cause injuries to animals, forests and vegetation, and complete ecosystems. The cement industry cannot survive without Advanced or Modern manufacturing technology.

Index Terms - **Energy cost, Batch production, Advanced air pollution control system, Modern manufacturing technology.**

I. INTRODUCTION

The air pollution is a man-made major challenge to control industrialization and urbanization of any nation. Cement industries are one of the most top contributors for air pollution in different countries [8, 19]. The indoor and outdoor air quality is becoming worse day by day20. There is a high concentration of particulate matter in the ambient air, at plant nearby place, compared to WHO air quality guideline values in both day times and night times due to emission in cement plant [8]. The air pollution is described as presence of one or more air contamination in the atmosphere which is injurious to human health and other natural environmental processes. The pollution may be controlled at source or at exhaust or chimney. The pollution is classified as particulate air pollution or gaseous air pollution. Health hazards, reduced crop and killing of plants, damage buildings and other material, visibility reduction and danger to eco-system are concern of air pollution.
In the cement manufacturing the amount of nitric oxide is serious concern, which is formed at temperatures above 1,400 °C [3]. The Nitrogen oxides (NOx), sulphur dioxide (SO2), carbon monoxide (CO), and carbon dioxide (CO2) are the primary emissions in the manufacture of cement. Small quantities of Volatile organic compounds (NMVOC, methane (CH4)), nitrous oxide (N2O), and ammonia (NH3) also may be emitted [4].
The Compounds of sulphur are common constituents of most fuels and levels of sulphur may be as high as 5 % of wt. The sulphur content of both raw materials and fuels varies from plant to plant and with geographic location. Sulphur is normally present in the form of metal sulphide and sulphates. During calcining operation, sulphur dioxide is released [3].
The CO2 emissions from cement manufacturing are generated by two process steps: first with most high-temperature, energy-intensive industrial processes and combusting fuels to generate process energy releases substantial quantities of CO2. Secondly the substantial quantities of CO2 are also generated through calcining of limestone or other calcareous material. The amount of CO2 released in the calcining process is about 500 kilograms (kg) per Mg of Portland cement produced [10]. The industries have to improve the manufacturing and optimized the environmentand pollution system.
The Modern manufacturing technology (MMT) method helps to control energy losses, energy cost and environmental problem may automatically control. The impact of MMT for pollution control on production system performance is varies with different enterprises [9]. In this work, a methodology is proposed for the optimum design parameters setting for the pollution control system based on advanced technology, to obtain consistent performance on energy and environment front. The alternative process selection for air pollution control is essential and based on comparison on performance parameters like efficiency, electricity consumption and maintenance etc. [15].

II. INDIA'S SCENARIO

Climate change is one of the greatest challenges worldwide and environment-friendly processes are needed [9].The Cement industry is among the major emitters of greenhouse gases and air pollution. In India ACC plant has started reporting the CO2 emissions from clinker and cement production activities [16]. Gross CO2 emissions and Net CO2 emissions are calculated for the company as a whole using data provided by each individual cement plant. All ACC plants are certified with EMS (Environment Management System) – ISO 14001:2004.The ACC is carrying out baseline monitoring of emissions. This is to provide emissions values using conventional fuel and acts as a reference for evaluating the incremental change in emission from the usage of alternate fuels. It is also in the process of implementing Continuous Emission Monitoring Systems (CEMS) [16]. The Emissions may also include residual materials from the fuel and raw materials or products of incomplete combustion that are considered to be hazardous. Because some facilities burn waste fuels, particularly spent solvents, in the kiln, these systems also may emit small quantities of additional hazardous organic pollutants [13]. The dust emissions result from activities such as handling raw materials, on site transportation, firing of clinker, milling, and shipment. The largest emission sources are the three units of kiln operation: the feed system, the fuel firing system, and the clinker cooling and handling system.

Energy conservation is the most effective solutions to control pollution [19]. The energy economy is the main criteria to decide the type of plant[2].It is brings the profit by the cost reduction of the manufacturing and improves life of the employee also. In India the importance of energy cost consideration is very essential as the energy consumption to produce the same product is very high. The Japanese manufacturer developed the best energy practices for the industrial product and processes as they have limited or minimum energy and other resources [7]. The difference is mainly due to energy cost optimization by the best energy practices by the Japanese manufacturer. The energy efficiency act as pivotal to control the energy cost and to mitigate the climate change also [1].Cement industry is a potential and major contributor to dust and pollution in metropolitan areas and to be minimized.

III. CEMENT MANUFACTURING PROCESS

The three basic process steps in cement manufacturing are -

- Preparation, blending and milling of the raw material to raw meal that is used as kiln feed.
- Calcinations and burning (sintering). This conversion process takes place within the cement kiln and its associated equipment
- Finish milling, the grinding of clinker to produce cement.

Fig.1 represents the basic cement manufacturing processes and its flow diagram. The common materials used are limestone, shells and chalk or marl, combined with clay, silica sand, blast furnace slag, and iron ore [3]. Lime and silica make up about 85% of the mass.. Most desirable method of recycling of the collected dust is injection into the kiln burning zone and production of clinkers from the dust. If the alkali content of raw materials is too high, however, some of the dust is discarded and leached before returning to the kiln. In many instances, the maximum allowable cement alkali content of 0.6 % (calculated as sodium oxide) restricts the amount of dust that can be recycled [1].

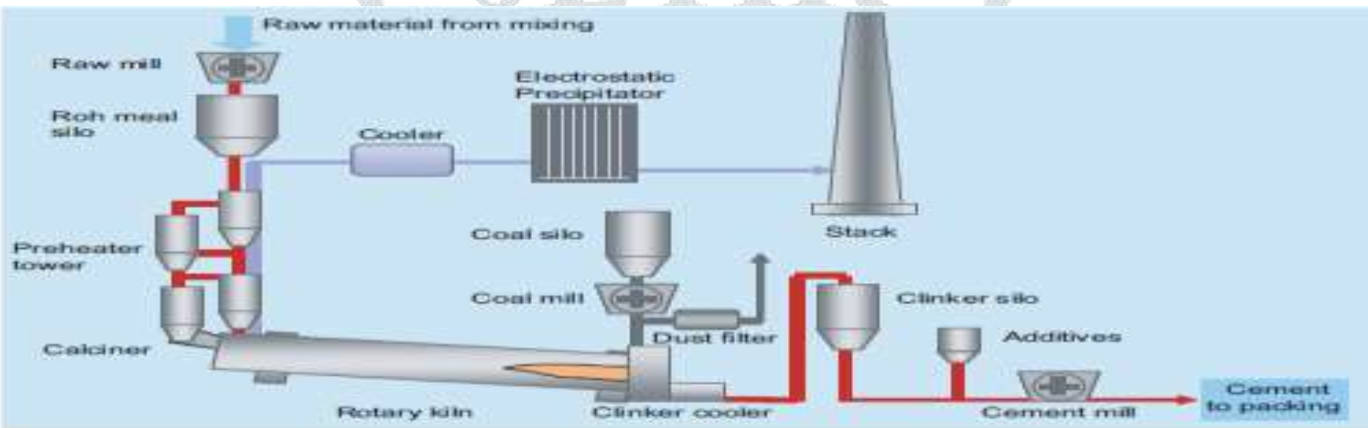

Fig: 1. Cement manufacturing flow diagram [1].

IV. ENERGY COST CONSIDERATIONS

The energy cost of any product is the minimum energy needed in mega joules MJ to produce one kg or MJ of the product [17]. The cement complete manufacturing process is energy based and any change in the energy consumption by help of manufacturing processes result in substantial saving for the plant. The energy cost of any product can be minimizes by energy optimization of processes used to manufacture the product [14]. The product and process final cost consists of R & D cost, manufacturing cost and the operating cost. The first two costs are incurred by the producer and last by the customer. The operating or usage cost is directly related to product quality and performance consistency [11]. A high failure rate of product and high maintenance and energy cost develop customer dissatisfaction [6]. The product monetary cost is also governed by the product energy cost. The energy cost of a component helps us to reduce energy consumption of manufacturing process and also to select resources with minimum energy cost [8]. The energy cost is also related with the environment emission and pollution control. The Table-1 shows the energy cost of various industrial products and energy content of various commonly used fuels. An efficient manufacturing process affects substantially, the industry and the society by controlling process and product energy cost [5].

Table-1Energy cost of various Substanceand Energy contentof various Fuels

Substance	Energy cost	Substance	Energy cost	Fuel	Energy Content
Milk bottle	8MJ	Glass	50 GJ/M^3	Coal	27500MJ/tonne
Color TV	25000MJ	Concrete	3-4 GJ/M^3	Heavy oil	43200 MJ/tonne
Car	22-58GJ	Steel	360GJ/M^3	Medium oil	43600 MJ/tonne
Electricity	3.6 MJ/kwh	Aluminum pure	360GJ/M^3	Gas	38.5 MJ/m^3

Cement manufacturing is an energy intensive process; the raw materials must be dried and heated to temperatures of about 1400 °C to initiate the chemical reaction that produces cement clinker. The development of any enterprises depends on the five key factors, Energy, Environments, Engineering, Economy and Efficiency ("5-E"). The energy cost constitutes a major portion of manufacturing cost [12]. To obtain the best energy cost results and productivity, proper product mix and energy efficiency are needed to reduce different wastages. The energy cost of energy and other resources is also an important consideration to control, product final cost [10].

V. TYPES OF AIR POLLUTION CONTROL SYSTEM

In pollution control system the exhaust gases are passes through the air pollution control device for separation of dust before being released to the atmosphere via stack [3].Dust collection is an online process for collecting any process-generated dust from the source point, on continuous basis. Dust collectors may be of single unit construction, or a collection of devices used to separate particulate matter from the process air. They are often used as an air pollution control device to maintain or improve air quality. Five principal types of industrial dust collectors are [4]:-Inertial separators, Electrostatic precipitators (ESP), Fabric Bag filters, Wet scrubbers, Unit collector.

An electrostatic precipitator is air pollution control device used to separate solid particulate matter from a contaminated air stream. Contaminated air flows into an ESP chamber and is ionized by electron emitting electrodes; also known as the corona chamber as shown in **Fig.2**. The suspended particles are charged by the electron field and migrate to a collection plate.

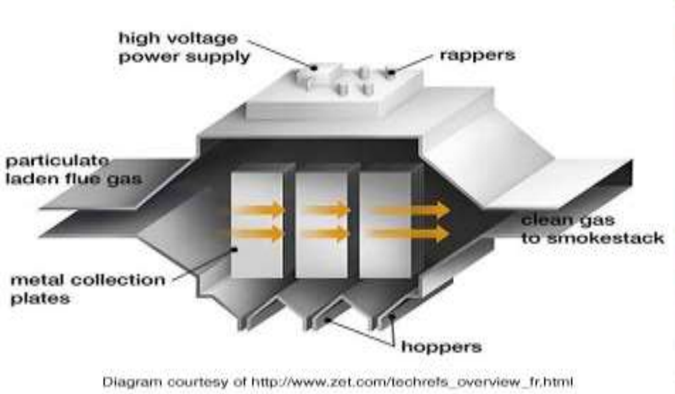

Fig.2. **ESP System and working principle of Bag-house filters**

Electrostatic precipitators (ESP) are used for gas cleaning in almost every section of cement manufacture. Application of ESP is studied, keeping in view Indian conditions. The characterization of dust emissions has been done for different units, such as rotary kiln and raw mill, alkali by-pass, clinker cooler, cement and coal mill, in terms of exit gas quantity, temperature, dew point, dust content and particle size. It is seen that all these characteristics have a wide range of variance. The ESP system must effectively deal with these variations.

The ESP system must effectively deal with these variations. Whereas the migration velocity (and the efficiency) varies directly with the particle size, it is proportional to the square and square root of applied voltage and absolute temperature of the gas, respectively.

The increase in efficiency due to temperature is not seen in dc based ESP, perhaps due to more pronounced negative effect on the applied voltage due to the increase in dust resistivity at higher temperatures. The effect of gas and dust characteristics on the collection efficiency of ESP, as seen in the industrial practice, is determined.An electrostatic precipitator is a means of putting an electric charge on the particles. The charge difference between the particles and the collecting plate causes attraction and collection. In these devices the efficiency of removal may even cross 99% with the added advantage of removal of particulate matter even less than one micrometers in sizes. The physical properties such as particle size, chemical composition and moisture content may have significant effect on particulate emissions.

Generally, gas conditioning entails higher operating and maintenance costs. Pulse energisation allows the use of hot gas, besides reducing the dust emissionand power consumption. The open top or vertical flow ESP has a limitation on collection efficiency as it provides for only one electric field.

Accumulate particulate matter is removed from the collection plates at periodic intervals by rapping or hitting the plates with rappers (mallets type hammers). Heavy particles fall to the base of the ESP where hoppers hold the removed particles for disposal. The following is a small list of typical industrial applications for ESPs.

- Refuse & sewerage sludge dryers and incinerators, Coal- and oil-fired boilers, coal driers and coal mills, Production plants for the cement, limestone, gypsum, pulp and paper industry (kilns, mills, driers and coolers), Electro-metallurgical, chemical, gas and detergent manufacturing plants, SO_2, SO_3, acid mist and ammonia control (wet ESPs).

VI. ESP PROBLEMS

The ESPs continue to be excellent devices for control of many industrial particulate emissions, including smoke from electricity-generating utilities (coal and oil fired), salt cake collection from black liquor boilers in pulp mills, and catalyst collection from fluidized bed catalytic cracker units in oil refineries to name a few. The ESPs are very efficient (up to 99% efficiency), even for small particle's, can be designed to handle wet and dry gas compositions for a wide range of gas temperatures and can handle large volumes. Table-2 shows the electricity consumption of ESP for month from March-June.

Table-2 Electricity Consumption of ESP (March-June)

S/N	Month	Line -1 Kiln ESP= KWH	Line -1 ESP Fan = KWH	Line -2 Kiln ESP= KWH	Line -2 ESP Fan = KWH
1	March	125228	321248	81015	204215
2	April	112668	311672	70318	194745
3	May	102689	297645	78267	196825
4	June	124318	335830	80491	204320

- The ESP pollution control system fail due to electrical problems, mechanical problems and overcapacity problems, in this case a stand by unit is required, which is not economical and practically feasible, so a ESP system with continuous working is impossible.
- It's not working at high temp above 150 °C.
- Consume more electricity, so high operation cost.
- Electrostatic Precipitator (ESP) plant was not suitable to reduce the emissions to below 60 mg/m3, so by upgrading the existing system, better performance may be obtained.
- High initial capital costs
- Dry ESPs can only control particulate emissions, not gas composition emissions
- Once installed, ESPs take up a lot of working space
- May not work on high electrical resistive particles.

VII. IMPROVED MODEL WITH HELP OF MMT

Table-3 shows the Technical Specification of Bag Filter or Bag-house for a batch production cement plant to replace the existing ESP system. The fabric filters used in Bughouses are a useful method of air filtration when particle size classification is not desired, operating temperatures are low to moderate, high efficiency is needed, the particulate needs to be recovered, or relatively low particulate volumes are encountered. Bag-house are already working satisfactorily in many plants and can be used in fossil fuel power plants, fertilizer plants, steel mills, food processing, hospital waste incinerators, cement manufacturing, paper mills, mining plants, industrial waste incinerators and pharmaceutical production.
In a Bag house, dirty air flows into and through a number of cloth filter bags that are placed in parallel. The **Table-5 & 6** shows the filter material properties and different material available. The filters remove the particulate from the gas stream while the cleaned gas passes through the cloth and is exhausted to the atmosphere. The fabric filters do some filtering of the dust particles; however, their more important role is to act as a support for the layer of dust (filter cake) that quickly accumulates on it. This layer then acts in a highly efficient manner to filter both the large and small particles from the gas stream and becomes the main filtration mechanism throughout the process. Classified by cleaning method, three common types of Bag-houses are-

- Mechanical Shaker, Reverse air and Reverse Jet

Table-3 Technical Specification of Bag FilterApplication-Kiln & Raw mill venting

	TECANICAL SPECIFICATION OF PULSE JET BAG HOUSE		
S.N.	**PARAMETER**	**UNIT**	**RESULT**
A	**INLET CONDITION**		
a1	Max gas flow rate per bag filter	m^3/hr	645,000
a2	Gas temp.at bag house inlet	deg.C	150 Max
a3	Max dust concentration	gm/Nm^3	60
a4	Static pressure at bag filter inlet	mm wg	100
a5	Type of dust		Kiln/Raw mill dust
	Dust concentration	mg/Nm^3	30
c1	Type		Pulse jet
c2	No of modules per bag filter		10
c3	Bag filter model		10*240-wmt-391
c4	Mode of operation		Offline
c5	No of filter bag per bag filter	Nos.	3910
c6	Air to Cloth ratio net	m^3/m^2.min	1.05
c7	Efficiency	%	99.99%
c8	Pressure drop across filter	mmwc	150-170
c9	Bag arrangement		23*17
c10	Air to Cloth ratio gross	m^3/m^2.min	0.94
d1	Hopper angel	Deg	60
d2	Type		Pyramidal
d3	No per bag filter		10
e1	**Bag details** Material		Fiber glass with PTFE lamination
e2	Diameter	Mm	152
e3	Length	Mm	6090
e4	Fabric weight	gm/m^2	745
e5	Max temp bag can withstand	Deg C	220
f1	**Cage details** wires	Mm	40mm,20no
g1	**Tube sheet** Material		Is2062
h1	**Pulse valve** Size	Inch	2.5"
h2	Type		Diaphragm
i1	**Cleaning arrangement** Type		Pulse jet
i2	Quantity of solenoid valve 2.5"	Nos.	230
i4	Pressure required	kg/cm^2	4.5-6
i5	Time rang of pulsation	Ms	50-100
i6	Time rang of off period	sce.	Feb-60
i7	Permissible moisture		Less then 5 ppm
i8	permissible oil content		Less then 5 ppm

k1	Type		Slide gate followed by rotary air lock valve
k3	Quantity	Nos.	1 no per hopper

Table-4 Comparison between ESP & BAG Filter

S.N.	Factor's	ESP	Bag Filter
1	Efficiency	94 %	99.50 %
2	Maintenance	Lower Maintenance	Higher & Easy Maintenance
3	Environment Emission	50-100 mg/Nm^3	30-60 mg/Nm^3
4	Capacity	Less compare to Bag Filter	Higher
5	Electricity consumption	100000-135000 KW per Month	10000-15000 KW per Month
6	Approximate cost	530 lacks	1250 lacks

Table-4 represents a comparison between ESP with the Bag-house filter system. The ESP system is now not applicable due to above problems, performance variations and high electricity, energy cost which increase the product energy cost also.

Fig. 3 Pollution monitoring system [18]

VIII. RESULTS AND DISCUSSION

Air pollution control is a great importance worldwide due to its major impacts on human health. The role of Pollution Control System in a Cement plant is very important and have key place to save environment and now essential to run and manufacture the cement. The options to achieve the new pollution requirements were to either upgrade the ESP with the latest in modern technology, or to convert the ESP to a Fabric Filter design as MMT. Due to the high temperature and gas flow, it was determined that even if the ESP internals were upgraded to modern technology, it would not be possible to guarantee the emissions below 60mg/Nm^3 without a significantly larger casing. Therefore, the only feasible option was to convert to a Fabric Filter which has added advantage of less energy consumption and a standby system. The pollution system work all time, even at break down time the standby unit will work & environment is saved and batch production has no delays.

Table-7 shows the pollution results of various pollutants' measured by the pollution monitoring system as shown in **Fig.3.** The aim of clean environment during the cement batch production is obtained. The importance of energy cost reduction by saving the energy cost resources, e.g. the electricity is obtained and this way the pollution system is improved and optimized. The reduction in cement final energy cost is achieved and final cost depends on success of new pollution system, its regular maintenance and its settings. The collected dust is in form of cake and it contains mainly the ingredient similar to cement ingredient and can be used in cement production by recycling process. The dust collected may be recycled by a plant designed especially for this application only and also no space requirement to store it.The losses due to poor efficiency on every operation constituted a major portion of cost of production, out of total manufacturing cost. From the customer's point of view; the purchase price plus the operating cost determine the economics of need satisfaction and are associated with energy efficiency.

In this work we try to determine the process parameter of pollution control system, so that process setting time will be reduce and at the same time performance and result are also improved. The recommendation to change the existing process of ESP by other Pollution control system of Bag house type which has added advantage of standby system, so pollution system work in a robust manner all time, even at break down time the standby unit will work & environment is saved. The role of Pollution Control System in a Cement plant is very important and have key place to save environment.

Table-5 Bag Filter Material

Fabric	Operating Temperature	Acid resistance	Alkali resistance	Abrasion resistance	Tensile Strength
Cotton	82	Poor	Good	Good	4920
Wool	93	Good	Poor	Good	1755
Nylon	93	Fare	Excellent	Excellent	5625
Dacron	135	Good	Excellent	Excellent	5625
Polypropylene	130	Excellent	Excellent	Excellent	7730
Fiber glass	290	Excellent	Excellent	Good	14060

Table-6 Filter Material Resistance Properties

Fabric	PP	PES	PAC	PPS	APA	PI	PTFE	GLS
Acid	5	4	4	4	2	4	5	4
Alkali	5	2	3	4	4	2	5	3
Hydrolysis	5	1	4	5	2	2	5	5
Oxidation	3	5	3	1	3	3	5	5
Abrasion	5	5	4	3	5	4	3	1

1-Bad, 2-Moderate, 3-Generally good, 4-Good, 5-Excellent

Table-7Results of Measurement

Particle	Range	Unit	Result
No	500	ppm	245.5
So2	200	ppm	1.7
Co2	20	% vol.	15.48
O2	25	% vol.	11.65
Dust	150	Mg/Nm^3	75

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