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Exergy Analysis of Raw Mill in a Cement Industry

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ABSTRACT

The cement Industry has very large energy requirement for cement production process. The major goal of the modern cement industry is to minimize energy loses in plant. The Exergy analysis is the thermodynamic tool that will provide the necessary information for the energy loses. The exergy analysis includes the investigation of the energy input in each stage of the cement production process. It helps to optimize the losses occurs in raw mill and leads to improve the plant's efficiency.

1. Introduction
The proper utilization of energy becomes very important nowadays, as power consumption rate has been increased rapidly. The cement industry has been one of the most energy intensive industries in the world.

The exergy analysis is the advanced tool used in thermodynamic to discover the imperfections in engineering process.

The purpose of exergy analysis in raw mill is to investigate energy loses and to optimize it to improve plant efficiency and cost effectiveness of plant.

2. System description
Cement production process starts from raw material preparation in raw mill which involves chemical reaction between calcium carbonates, silica, alumina and iron ore.[14]

2.1 Preparation of raw material in raw mill
The raw materials for cement production are quarried using powerful excavators or explosives.

2.2 Clinker preparation
During this stage, the mixture is passed through a kiln (and possibly a preheated system) and exposed to increasingly intense heat, up to 1400C̊ .This process drives off all moisture.

2.3 Finish grinding
Clinker is the basic ingredient of cement, and

It largely determines the quality of the end product. Cement, as a finished product is a very fine powder that requires for its manufacture a mix of clinker, gypsum and certain natural or artificial materials (such as pozzolana), which grant beneficial properties to the cement.

It is a fine powder, usually gray in colour, which consists of a mixture of the hydraulic cement minerals to which one or more forms of calcium sulfate have been added.

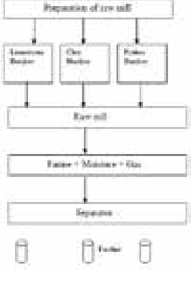

Figure 1 – Flow diagram of cement process

The Raw mill has two sections. The heat loses in "dry room" and "Grinding room" is required to be calculated. The lining plates are used in the surface of dry room. The grinding room is made of out mirror plates, lining, bump lining. The arithmetic average diameter of both rooms has been calculated by considering cross-section while calculating heat loses.

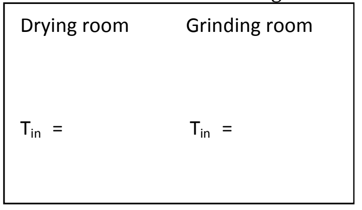

Fig 2 - Raw mill process flow

3. Exergy analysis
The Exergy is defined as "the maximum useful work that could be obtained from the system at a given state in a specified environment".[14]

The Exergy analysis of raw mill requires following assumptions:[15]

1. Steady state flow within the system.
2. Change in kinetic and potential energy at Inlet and outlet should be negligible.
3. No heat transferred to the system from the Outlet.
4. Electrical energy produces the shaft work in Mill.
5. The change in ambient temperature is Neglected.

The Exergy analysis of raw mill can be done using following equations:

The mass balance equation can be expressed as,

$\Sigma \dot{m}_{in} = \Sigma \dot{m}_{out}$ (1)

Where $\dot{m}_{in}$ is the mass flow rate in and $\dot{m}_{out}$

is the mass flow rate at outlet.

The energy balance can be expressed as,

$\Sigma \dot{E}_{in} = \Sigma \dot{E}_{out}$ (2)

Where $\dot{E}_{in}$ is the rate of energy transfer in, and

$\dot{E}_{out}$ is the rate of net energy transfer at outlet.

The general Exergy balance can be expressed as,

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$\Sigma \dot{E}x_{in} - \Sigma \dot{E}x_{out} = \Sigma \dot{E}x_{dest} - \dot{w} + \Sigma \dot{m}_{in}\Psi_{in}$

(3) Where,

$\Sigma \dot{m}\, o$

$\Psi = (h - h_0) - T_0\,(s - s_0)$ (4)

$\Sigma \dot{E}x_{dest} = \Sigma(1 - T_0/T_K)\,Q_K$ (5)

Where Q_K is the heat transfer rate through the boundary at temperature T_K at location k, $\dot{w}$ is the work rate, Ψ is the flow exergy, s is the specific entropy and the subscript zero indicates properties at the dead state of T_0 .

The exergy destroyed or the irreversibility may be expressed as follows:

$\dot{I} = \Sigma \dot{E}x_{dest} = T_0 s_{gen}$ (6)

Exergy efficiency may be written as,

$\varepsilon = \Sigma \dot{E}x_{out} / \Sigma \dot{E}x_{in}$ (7)

Now the methodology as mentioned above can be applied to raw mill for exergy analysis.

3. Literature Review

Kotas et al.[1] gave different industrial processes such as sulfuric acid, gas turbine and refrigeration plants. He has done extensive studies in exergy field.

Wall et al. [2] prepared the exergy flows for a pulp and paper mill and a steel plant by establishing the energy flows in processes and drawing up the exergy losses.

Schuer et al.[4] gave energy consumption values and represented the energy saving methods and potentials for cement industry in Germany. The energy saving methods involves two part, electrical energy and thermal energy. The results were structured in the form of energy flow diagram.

Saxena et al.[5] gave energy consumption data and means of conservation combine with estimated saving. The study considered all the stages of the cement production process, since many of the other studies preferred only energy intensive portions of the process.

Van Gool et al.[6] has also reported that improvement in the exergy efficiency for a process or system can be possible when the exergy loss or irreversibility is minimized. He advised that it is useful to utilized the concept of an exergetic "improvement potential" during the analysis of different process. They have reported that 35% of total input energy was being lost with the waste heat streams.They selected steam cycle and generated 44Ms of electricity.

Szargut et al [7], performed extensive studies in the exergy field. first time in exergy field. He has introduced the cumulative exergy consumption and cumulative degree of perfection for industrial processes and making the distinction between second law efficiency (exergetic efficiency or rational efficiency) and cumulative degree of perfection for industrial processes.

Dincer et al. [8, 10] gave the relation between energy and exergy, exergy and the environment, energy and sustainable development, and energy policy making and exergy in detail.

Worell et al. [9] performed an energy analysis for the US for the years 1970 and 1997.They reported an in-detail analysis of the US cement industry.

Khurana et al. [11] prepared an energy balance of a cogeneration system for a cement plant in India. They reported that about 35% of the input energy was being lost with the waste heat streams. A stream cycle was selected to recover the heat from the streams using a waste heat recovery steam generator and it was estimated that about 4.4 MW of electricity could be generated.

T.Engin and Ari et al. [12] performed an energy audit analysis of a dry type rotary kiln system working in a cement plant in Turkey. The klin has a capacity of 600 ton-clincker per day. They observed that about 40% of the input energy was being lost through hot flue gas (19.15%),cooler stack (5.61%) and klin shell (15.11% convection plus radiation).It was also mentioned that approximately 15.6% of the total input energy (4MW) could be recovered.

U.Camdali, A. Erisen et [13] has performed energy and exergy analyses of raw mill in cement industry Turkey. They found energy and exergy efficiencies of raw mill using actual operational data 84.3% and 25.2% respectively. The waste was estimated at about 16% of the energy input.

Zafer Utul, Ziya sogut, Arif hepbasli, Zuhal Oktay et al.[14],performed energy and exergy analyses of raw mill in cement industry in Turkey. They used operational data in finding energy and exergy efficiency of raw mill. It was 84.3% and25.2% respectively.

6. Conclusion

The exergy and energy analysis are the thermodynamical tool used in modern cement industries. The plant efficiencies can be calculated using actual operational data.

The improvements of plant efficiencies require investigation of major energy losses occurs in plant. Which can be possible by knowing energy input at each stage of process .The optimization of energy losses required actual data about energy conversion and parameters which affects it. It can be optimize using software like ANSYS.

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