

# Energetic and Exergetic Efficiencies of a Grate Cooler in an Iraqi Cement Industry

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**Abstract.** Extensively, the grate coolers are used in cement industry in order to recover heat from hot clinkers coming out of rotary kilns. This work focuses on the thermal performance of the clinker cooling system in a cement production plant employing the dry process. The aim is to study how the ambient temperature affects the energetic and exergetic performance of the clinker cooler. The energetic and exergetic analysis is based on the operating data of Al-Muthanna cement plant in the south of Iraq. It is found that the energy efficiencies vary from 46.18% to 45.19% while exergy efficiencies vary from 54.55% to 55.62% respectively at different ambient temperatures. On the other side, it is found that (energy, exergy) recovery efficiencies have inversely been affected by variation of ambient temperature.

**Keywords:** Energy; exergy; grate cooler; recovery efficiency; cement industry

## 1. Introduction

According to high energy consumption, the cement production industry can be considered very essential from the socio-economic view point in addition to criteria air pollutants and greenhouse gas high emissions [1]. Continually, the industry adopts more efficient technologies in energy use to improve its profitability and competitiveness. It was reported that this segment of industry consumed about 12% of total energy in Malaysia and 15% of total consumption in Iran [2]. Engin and Ari, and Kabir et al [3, 4] carried out an energy audit analysis of a dry process cement plant. Khurana et al [5] presented the thermodynamic analysis and cogeneration for cement production plant. In Indonesia, thermal performance and energy conservation opportunities of a cement industry were assessed by [1]. Mundhara and Sharma [6] presented a model to simulate the operational parameters for grate coolers. There is a lot of studies concerned with energetic and exergetic analysis, which were conducted in advance individually for instance in the raw mill [7], trass mill [8], rotary burner with pre-calcination [9], for serial flow, four-stage cyclone pre-calciner [10], and on the other hand, Kolip and Savas [11] presented the energy and exergy analysis for a parallel flow, four-stage cyclone pre-calciner type. In addition to these studies for these units, Koroneos et al [12] displayed the exergy analysis for whole system in the cement production. Sogut et al [13] studied the varying dead-temperature effect on the efficiencies of energy and exergy for a raw mill process in the cement plant. Ambient conditions variations may influence positively or negatively on the thermal performance of energy conversion systems [14, 15]. Consequently, the exergy balance is necessary from the viewpoint of identifying sources of losses in the production processes. This work is divided in twofold: firstly, examining the energy use and thermodynamic performance of the grate cooler in addition to study the effect of ambient temperature on the energy and exergy efficiencies. Secondly, the effects of variable ambient conditions on

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system efficiency are discussed to get the clear insights about the source of losses and working to improve the system efficiency.

## 2. Clinker cooler

Grate cooler, the modern type cooler is utilized in almost all modern kilns. The large capacity of grate cooler will allow large kiln capacities in addition to its ability to recover the heat efficiently when compared with other types of cooler. For instance the pre-calciner required tertiary heat recovery, and that it is impossible with planetary coolers, limiting heat recovery efficiency. Large capacity plants preferred the grate coolers which have been proven its ability to recover heat more than the other types of coolers [16].

## 3. Energetic & Exergetic Analysis

For a general steady state, steady-flow process

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

The energy balance in general form:

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

Heat input into the cooler:

$$\dot{Q}_{in} = \dot{Q}_{ch} + \dot{Q}_{ca} \quad (3)$$

Heat output from the cooler:

$$\dot{Q}_{out} = \dot{Q}_{sa} + \dot{Q}_{ta} + \dot{Q}_{cc} + \dot{Q}_{ha} \quad (4)$$

While the exergy balance in the general can be expressed as following:

$$\sum \dot{E}x_{in} - \sum \dot{E}x_{out} = \sum \dot{E}x_{dest} \quad (5)$$

Energy efficiency is the ratio between the outputs to inputs energy.

$$\eta_E = \frac{\sum \dot{E}_{out}}{\sum \dot{E}_{in}} \quad (6)$$

The energy recovery efficiency can be expressed as [1]:

$$\eta_{E_{rec}} = \frac{\dot{Q}_{sa} + \dot{Q}_{ta}}{\dot{Q}_{in}} \quad (7)$$

Exergy efficiency

$$\eta_{Ex} = \frac{\sum \dot{E}x_{out}}{\sum \dot{E}x_{in}} \quad (8)$$

Whereas the exergy recovery efficiency

$$\eta_{Ex_{rec}} = \frac{\dot{E}x_{sa} + \dot{E}x_{ta}}{\sum \dot{E}x_{in}} \quad (9)$$

## 4. Clinker cooler efficiencies

The cooler efficiency plays a key role in which its function is recovery heat from the hot clinkers and pre-heating the air that is used for combustion as secondary air for the rotary kiln and tertiary air for calciner. Heat from the clinkers that leaves the cooler is representing actual loss of the system. Reduction of energy consumption in a cement plant required optimization the values of cooler operating parameters [6]. Worrell et al [16] explained that the improvement the efficiency of heat recovery will cause fuel saving as well as it may effect on the quality of production and emission levels. The influence of variation of clinker temperature

in the cooler is important on the cement quality in the plant. Accordingly of higher combustion temperatures of air, further heat recovery as a result reduces energy use in the kiln and pre-calciner. Fig.1 shows the energy efficiency of the clinker cooler decreases with increasing of the ambient temperature. Meanwhile, Fig.2 presents the inverse behavior of its energy recovery efficiency with ambient temperature. On the other hand, Fig. 3 shows the exergy efficiency increases with increasing of the ambient temperature but the exergy recovery efficiency has inversely proportional with ambient temperature as shown in Fig.4.

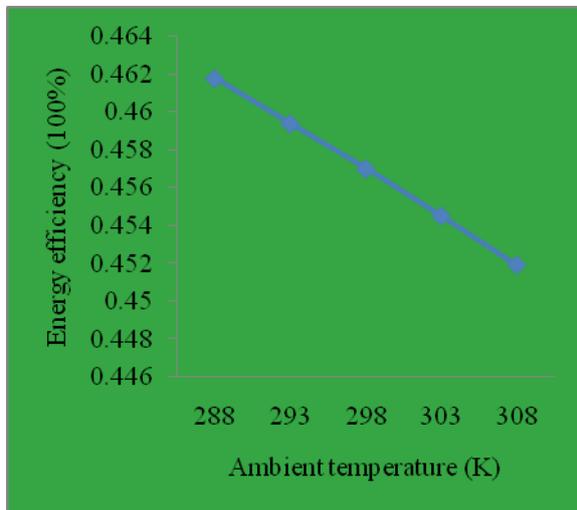


Fig. 1: Clinker cooler energy efficiency

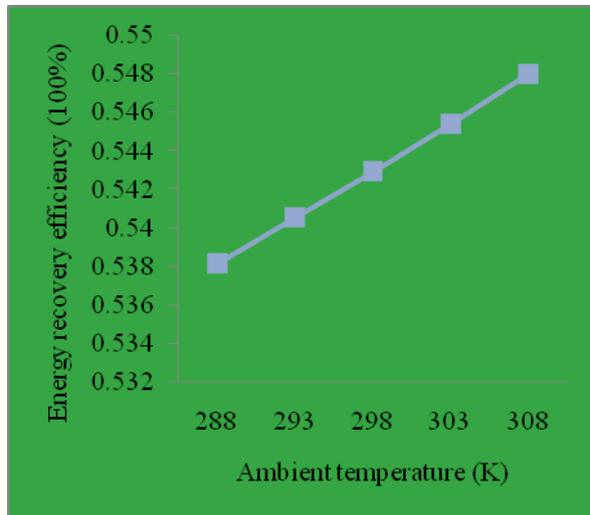


Fig. 2: Clinker cooler energy recovery efficiency

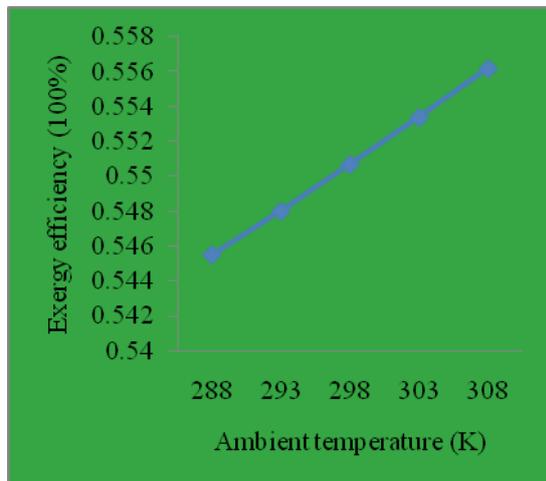


Fig. 3: Clinker cooler exergy efficiency

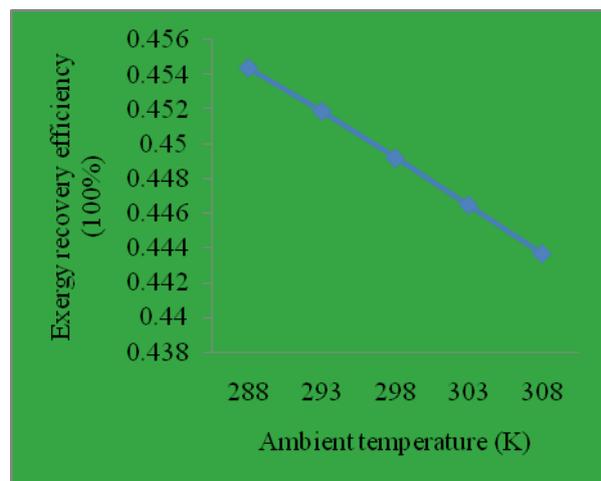


Fig. 4: Clinker cooler exergy recovery efficiency

## 5. Conclusions

1. The energy efficiency is inversely influenced to the increase of ambient temperature, for instance the energy efficiency varies from 46.18% to 45.19% while the recovery efficiency increases from 53.81% to 54.8% at the same variation of ambient temperature.

2. Exergy and exergy recovery efficiencies were found to change from (54.55%, 45.44%) to (55.62%, 44.37%) respectively with increase in the ambient temperature.

## 6. Acknowledgement

The authors would like to acknowledge the financial support from the Vice Chancellor, University of Malaya. This research was carried under the High Impact Research Grant (HIRG) scheme.

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