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# Thermal efficiency modelling of the cement clinker manufacturing process

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ABSTRACT

The cement clinker manufacturing process is a complex process which involves energy conversion and consumption. The objective of this study is to establish the thermal efficiency analytic model of this process. Energy flow models of the whole process and its three process units of raw material preheating & decomposition, clinker calcination, clinker cooling are established in this paper. The thermal efficiency of the whole process is quantitatively described based on the energy consumption fraction of each process unit. Energy consumption fractions of the three process units in a cement plant are 1.15, 0.43 and 0.47 respectively. It shows that the thermal efficiency of the raw material preheating & decomposition process unit has the greatest impact on the thermal efficiency of the whole process, successively followed by the clinker cooling and clinker calcination process units. Methods to improve the thermal efficiency of the whole process are discussed.



## 1. Introduction

The cement industry is a typical energy intensive industry with energy accounting for 50%–60% of production costs [1]. Scholars have studied on energy models and energy conservation measures of various high energy consumption industries such as the cement industry. In the aspect of energy consumption modelling, Jebaraj and Iniyan summarized the existing energy models, including the energy demand supply model, the energy consumption forecasting model, the energy optimization model and the energy dissipation model [2]. In addition, some scholars advanced the energy consumption model [3,4] and the energy flow model [5,6] which were independent of specific energy forms and energy equipment. On the other hand, some researches advanced the energy flow models in the manufacturing processes of cement, steel and aluminium [7–10]. They further analysed the impacts of relevant changes on energy consumptions. In the aspect of energy efficiency models, Giacone and Mancò defined the energy efficiencies in industrial processes [11]. Some scholars analysed the useful energy for manufacturing processes [12,13] and established the energy efficiency indexes of industrial processes [14]. Some researches discussed the energy conservation measures of process units from the perspective of manufacturing technology and equipment [15–18]. The above-mentioned literatures analysed the high energy consumption industries such as the cement industry in the aspects of energy models, energy efficiencies and energy conservation measures. All of these results played an important role in the implementation of energy conservations and emission reductions. However, the previous literatures did not consider the energy efficiency relationships between industrial processes and their process units, and lacked corresponding theoretical guidance on the implementation of energy conservation measures. In addition, the energy conservation measures in above literatures were based on the manufacturing techniques and the production equipment of industrial processes. For stable manufacturing processes, the optimal control of process parameters is an effective method for improving the energy efficiency of the cement clinker manufacturing process. Therefore, the establishment of energy efficiency analytic relations between the cement clinker manufacturing process and its process units has a great significance for analysing and formulating reasonable energy efficiency improvement measures.

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The cement clinker manufacturing process consists of three process units, including the raw materials preheating & decomposition, clinker calcination and clinker cooling. In order to analyse the energy efficiency relationship between the cement clinker manufacturing process and its three process units, the energy flow models of the whole process and each process unit are established. The thermal efficiency analytic model of the whole process is quantitatively described based on the energy flow models and the energy consumption fractions of its three process units. It is found that improving the decomposition rate of raw materials fed into kiln, stabilizing the temperature of the rotary kiln burning zone and improving the temperature of the secondary and tertiary air are effective approaches to improve the thermal efficiency of the whole process.

## 2. Brief introduction of the cement clinker manufacturing process

There are four main devices used in the cement clinker manufacturing process, namely preheater, calciner, rotary kiln and grate cooler, achieving raw materials preheating and decomposing, clinker burning and cooling respectively. The manufacturing system, considered for modelling, is schematically shown in Fig. 1. The raw materials decompose in the calciner after preheated by the cyclone preheater, and then, with the updraft, enter into the last level cyclone for gas–solid biphasic separation. Later the raw materials enter into the rotary kiln for calcination. Due to the inclined placement and the continuous rotation of rotary kiln, the raw materials continuously move to the grate cooler, and form clinker after the high temperature calcination through the rotary kiln burning zone. Finally, the hot clinker falls towards to grate cooler for rapid cooling. During the cement clinker manufacturing process, the airflow direction is just opposite to the materials flow direction [7].

## 3. Energy flow modelling of the cement clinker manufacturing process

### 3.1. The energy flow model of process units

The cement clinker manufacturing process is a mass transfer and energy conversion process. There are six categories of energy flow in each process unit according to the energy sources and destinations. The definitions and descriptions of the energy flow model in process units are shown in Table 1.

The input–output relationship of the energy flow in each process unit is shown in Fig. 2. The energy balance in a process unit is:

$$E_u + E_i + E_r = E_d + E_e + E_l + E_r \tag{1}$$

The energy consumption of a process unit is:

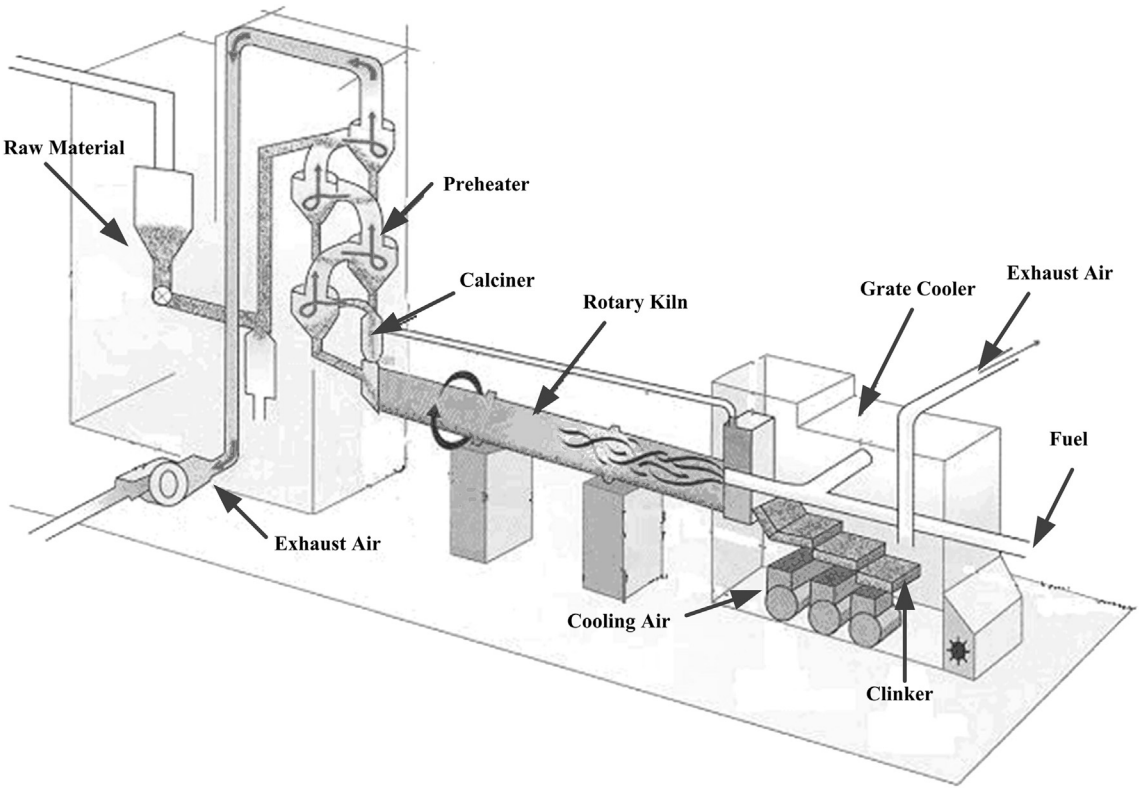


**Fig. 1.** Schematic diagram of the cement clinker manufacturing process.