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Extended Exergy Accounting For Energy Consumption and CO_2 Emissions of Cement Industry—A Basic Framework

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Abstract

Owing to the intensive energy consumption and CO_2 emissions of cement production process, attention has been focused on exploring an integrated metric for mitigation potential. Exergy is thereby raised to analyze the system operation efficiency and environmental cost. In this paper, exergetic efficiency and CO_2 emission targeted at a typical cement production line are examined in detail with key factors of mitigation being identified. Moreover, the future emission trends are simulated based on dynamic prediction with different optimization scenarios in view of current mitigation targets. Finally, some preliminary results are presented.

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Keywords: Exergetic efficiency; Cement production; Life cycle assessment; CO_2 emissions

1. Introduction

With intensive development pattern, a series of problems has been emerged in industrialization such as resource consumption and environmental emission, which is a huge obstacle for sustainable development. As one of the most energy-intensive industries, cement industry accounts for about 30-40% of energy costs of production. It is shown that the cement industrial production in China has been 2.48 billion tons in 2014, 2.6% higher than 2013, accounting for almost 60% of global cement output [1]. This status is expected to continue in the next few years. Due to the extensive resources and energy consumption and inevitably environmental discharge in the production process, cement production has attracted growing concerns in exploring its emission reduction potential [2]. However, previous studies often ignored the own value of energy resource and its physics efficiency. Exergy, which is expounded from the second law

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of thermodynamics, has been widely used into resources accounting, the optimization of system energy consumption and environmental impact assessment [3-6].

This paper targeted at energy conservation and emissions mitigation in cement production process, determined the system boundaries and the main processes while establish the generalized physical model. The internal energy consumption is also calculated using extended exergy analysis in order to identify the key factor of emission reduction.

2. Methodology

Exergy has been widely used in analyzing the sustainability of industrial sectors [7-10]. Koroneos et al. took the chemical exergy of the craft process into consideration, showing that 50% of the exergy has been lost despite the waste recycling [11]. Sögüt analyzed the exergetic of Turkish cement production and CO_2 emissions caused by the sector and accounted the exergetic improvement potential, indicating that technology improvement is the most efficient pathway [12]. Madlool summarized the exergy analysis of cement industry and concluded that the exergy losses of kiln are higher than other units in cement production plant due to its irreversibility [13]. Tang established the exergy balance model of the system, and put forward some methods for energy efficiency improvement and energy losses reduction [14].

The goal of this study is to appraise the environmental performance of a typical New Suspension Preheaters (NSP) cement production chain. The considered functional unit is 1 ton Portland cement produced. For a NSP cement production chain, the system boundary includes direct production process and the embodiment from external environment for cement production. The whole process should include mining, transportation of raw materials, crushing, preblending, grinding, homogenization, preheating decomposition, clinker calcining, grinding, packaging, and waste treatment. To simplify the whole production chain, we merge the whole chain into 8 processes, i.e., mining, transportation, raw material preparation, calcination, waste gas treatment, grinding, packaging and others (see Fig. 1). The energy utilization efficiency is emphasized at these stages.

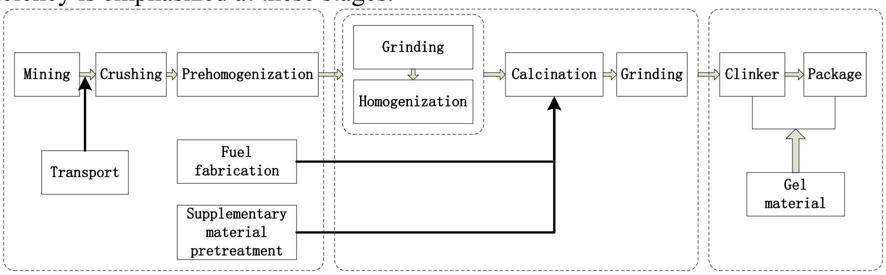

Fig. 1. System boundary of the typical cement production line

3. Exergy Analysis Framework of the Cement Production Inventory

Focusing on social economic development, energy efficiency, demand, policy, environment capacity, and technological progress, an exergetic model was established to evaluate the sustainability of the whole process. The materials and energy consumed in this system embrace: 1) limestone, sandstone, flyash, sulfuric-acid residue, gypsum and mixtures; 2) energy input from external systems such as coal and electricity. The system outputs include P.O 42.5 Portland cement (0.455 million tonnes) and P.F 42.5 Portland cement (0.578 million tonnes), and some direct and indirect environmental emissions. The data were all collected from an enterprise located in North China with a production capacity of 77.5E+04 tons per year.

Once the goal and scope of the analysis is defined, the exergy analysis consists of three main steps: (i) Determining the energy and material input and output of each unit; (ii) Calculating the internal exergy flows of cement production system; (iii) Analyzing the exergy conversion and utilization efficiency of the system from the perspective of the whole life process.

The environmental impact is calculated to be 1.87E+11kJ, of which the impact from calcination occupies 64.52%. The specific composition of the exergy is shown in Fig.2.

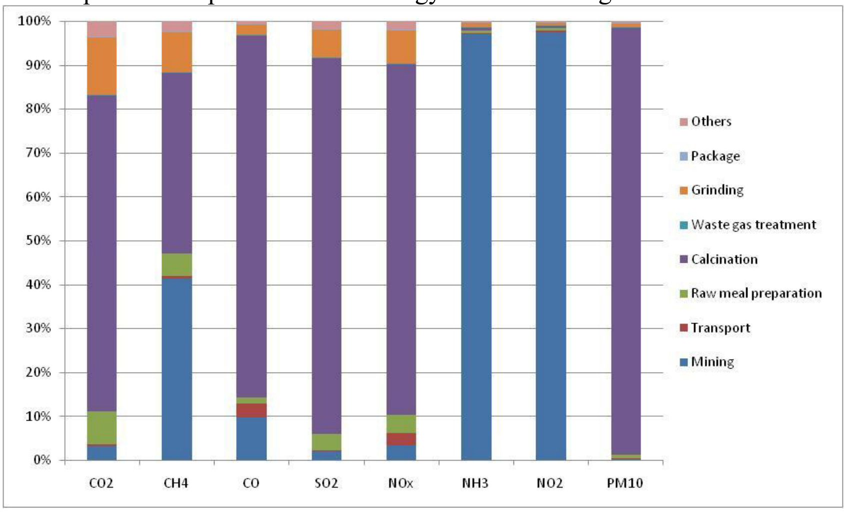

Fig.2. Exergy proportion of different stages

4. Conclusions

This paper provided a preliminary framework for exergy analysis of the cement production project. Compared with the proposed scenarios, an optimized way of sustainable development of cement industry was expected to be figured out in the future. The accounting framework may shed light on the coordination of minimizing environmental impact and optimizing energy efficiency for cement production.

5. Copyright

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Biography

Bin Chen is a professor of energy science at Beijing Normal University. Dr. Chen has published over 200 peer-reviewed papers in prestigious international journals. He is also serving as subject editor of Applied Energy and editorial board member of more than ten journals.