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Recuperator for waste heat recovery from rotary kilns

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HIGHLIGHTS

► Mass, energy, and exergy balances of a rotary kiln are determined.
► Construction of a recuperator formed as an annulus over a rotary kiln is given.
► Mathematical model of the recuperator is made.
► Inclusion of recuperator in the kiln system decreases fuel consumption for 12.00%.
► The airflow and geometry of the recuperator influence exergy efficiency.

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ABSTRACT

The energy balance of a rotary kiln used for calcination of dolomite in a magnesium production company identified the kiln shell (26.35% of the input energy) and exhaust gases (18.95%) as the major sources of heat losses. To decrease the heat loss, a heat exchanger that forms an annular duct over the calcination zone of the kiln is used to preheat combustion air. The exchanger uses both the convective and radiant heat loss from the mantle, prevents overheating, does not require air tightness, and could be implemented over rotary kilns with the similar surface temperature distribution. A mathematical model that defines the geometry of the heat exchanger so as the heat transfer from the kiln to the combustion air to be equal to the heat dissipated from the bare kiln is presented. The exchanger decreases fuel consumption of the kiln for 12.00%, and increases its energy and exergy efficiency for 7.35% and 3.81%, respectively. To obtain a better performance the airflow and geometry of the exchanger should be arranged to achieve the smallest possible temperature difference between the kiln surface and the preheating air, whose amount should always be kept at the optimal value for the used fuel.

1. Introduction

Rotary kilns are pyroprocessing devices used to raise materials to a high temperature in a continuous process. They are frequently used devices in systems for production of wide variety of materials such as: cement, lime, alumina, refractories, magnesium etc. At present, two kinds of activities that improve this technology exist: one develops new types of rotary kilns that utilize solar energy e.g. Ref. [1], and other improves energy efficiency of the existing systems. In achieving the latter goal, reduction of heat loss from rotating kilns plays a significant role. In cement industry, this loss accounts for 8–15% of the total heat input [2], whereas in the dead burning of magnesite, Chakrabarti [3] obtained even larger losses: 24.8% and 34.7% of the total heat input for a rotary kiln housed in an enclosed hall and in open air, respectively. Among the factors that influence this heat loss are: characteristics of the technological process that takes place inside the kiln, temperature distribution, thermal stability and resistance of a refractory lining inside the kiln, ambient conditions at the location where the kiln is placed, its dimensions, thermal properties of the outer insulating layer, and rotational speed.

The heat loss of rotary kilns to surrounding is either recovered by the use of heat exchangers [2,4] or decreased by the use of stationary insulating shell around the kiln [5,6]. The heat exchangers are also part of a secondary external shell, and are, as in Refs. [2,4], usually used to preheat water for district heating. Caputo et al. [2] used the radiant heat loss from the kiln's mantle and technically and economically optimized the heat exchanger. They [2] also obtained the radius for which the operation of the energy recovery district heating system is profitable. In Ref. [4] the authors

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