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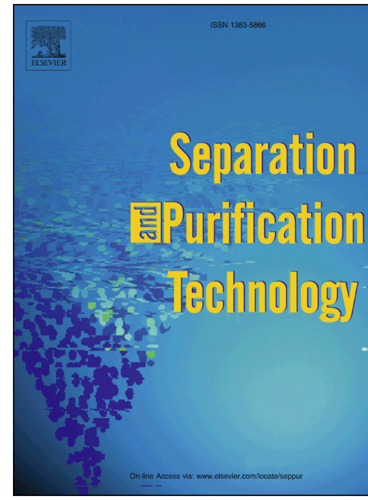

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Separation efficiency and heat exchange optimization in a cyclone

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Abstract

This work presents a study on a gas-solid cyclone separator used in a complex cement production plant. The objective of the study consists on the performance evaluation and optimization of the cyclone separator in terms of particle separation and heat transfer efficiencies, while keeping pressure losses under control. The thermal interaction is between two gas-solid mixtures, one feeded at 850 °C and the other at 600 °C, respectively. The solid phase consists, mostly, of calcium carbonate subsequently intended to the so-called baking process for the production of clinker and then cement. The main goal of the study is maximizing the separation efficiency, minimizing the temperature at the exit of the plant and maintain the pressure drop not far from its value in the running plant. In a previous study, the authors defined the suitable setup of the mesh, physical models and turbulence; the same setup has been adopted in the present work during all the optimization phase. Vortex finder length (initially of cylindrical shape), its conicity angle and the pressure losses are the parameters (independent variables), taken into account to optimize the separation efficiency and the temperature of the gas at the exit of the plant. The optimization process was started with the *base case* that replies the geometric shape of the plant in operation.

A detailed overview of the classical and recent optimization methods, is included in the Appendix, together with a brief illustration of a general pattern concerning an optimal design procedure. The numerical approach, for all the cases, is based on implicit unsteady simulations using the Eulerian Multiphase model.

Keywords: cyclone; Eulerian multiphase; gas-solid heat exchange; computational fluid dynamics; geometrical optimization

1 Introduction

1.1 The industrial process

The present study is a step of a longer activity aimed at the study of possible technological solutions that allow to optimize the heat exchange between a flow of gas at high temperature (about 900°C) and the raw material powder (consisting largely of calcium carbonate), to be submitted to the cooking process for the production of "clinker", and then of cement. Much of this heat exchange takes place in a preheating tower constituted by cyclones and connection pipes: the flow of hot air from the oven meets, in countercurrent, the raw material to be preheated. Current technologies provide that the heat exchange between gas and raw materials takes place in a very limited area of the circuit (the preheating tower), that is in the connecting lines between the various cyclones. In these areas a mixing takes place (in equi-current) between the gas and the powder of raw material which allows a certain heat transfer. In the cyclones, which constitute the main part of the structure, does not take place any important heat exchange because the gas-powdery material separation is almost immediate; on the other hand, the separation process is also very important for a good thermal efficiency of the system. The introduction of the suspension preheater, in the early thirties, was an important evolution of the clinkerization process. The dried raw meal is preheated and even partially calcined (dry/semi-wet processes) while it is held in suspension with the hot gases coming from the rotary kiln. At least in theory, a wider contact surface allows a nearly complete heat exchange; for this reason there are several suspension pre-heating systems as that shown in figure 1(a). These systems usually have four to six stages of cyclones, which are arranged one over the other to form a tower with a height varying from 50 to 120 m. The stadium on top can be constituted by two parallel cyclones for a better separation of the powder. The gas exhausted from the furnace flows through the various stages of cyclones from the bottom upwards. The finely ground raw and dry meal, mixes with the gas before the highest stage of cyclones; it is separated from the gas in the cyclone and rejoins it before the next stage of cyclones. This procedure is repeated for each stage until the material is discharged from the last cyclone (the lowest), into the rotary kiln. This cyclical process of mixing, separation and re-mixing occurs at high temperature to optimize the heat transfer. The cement is produced by a particularly energy-intensive process: in fact, each tonne of finished product requires about 120 kWh of electric energy and $6x10^5$ kcal of thermal energy. A standard plant which produces about 10^6 t/year, employs about $12x10^4$ MWh/y of electric energy and $6x10^5$