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Technical benefit and risk analysis on cement clinkering process with compact internal burning of carbon

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HIGHLIGHTS

- Compact internal burning of carbon enables cement shaft kiln to run stably.
- Compact internal burning of carbon enables cement shaft kiln to scale up.
- New process triples energy efficiency with excellent environmental performance.
- It will be able to compete with and replace the existing precalciner kiln process.
- It will become the mainstream clinkering process in low carbon economy.

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ABSTRACT

This article demonstrates the potential technical benefit and risk for cement clinkering process with compact internal burning of carbon, a laboratory-phase developing technique, from 9 aspects, including the heat consumption of clinkering and exhaust heat utilization, clinker quality, adaptability to alternative fuels, the disposal ability of industrial offal and civil garbage, adaptability to the raw materials and fuels with high content of chlorine, sulphur and alkali, the feasibility of process scale up, the briquetting process of the coal-containing cement raw meal pellet, NO_x emission and the capital cost and benefit of conversion project. It is concluded that it will be able to replace the modern precalciner rotary kiln process and to become the main stream technique of cement clinkering process in low carbon economy times.

1. Introduction

Coal is a kind of carbon-based solid fossil fuels used as heating agent and reactant in manufacturing industries widely. The burning modes in these cases can be classified as follows (Table 1).

Among all the modes, the compact internal burning (CIB) is an emerging technique getting more and more applications in recent years.

Historically, the cement shaft kiln process was a technique developed parallelly with the cement rotary kiln process. Since 1970's, with the emergence of dry precalciner rotary kiln process, the shaft kiln process was not able to win in competition with it and had been eliminated by cement industry. Howevxer, the cement shaft kiln process is still applied in some countries, particularly, in China and India.

As a technical upgrade of the existing cement shaft kiln process, cement clinkering process with compact internal burning of Carbon (CCP–CIBC process) is a new technique in developing. It retains the basic reaction principle of the shaft kiln process with respect to gas–solid counterflow contact in a vertical moving bed, adopts dry briquetting instead of originally used wet pelletizing for preparing the kiln feed and adds afterburning power generation for the exhaust heat utilization. The process flow is shown as Fig. 1 [1].

This paper demonstrates the potential benefit and risk of the CCP–CIBC process as follows.

2. Technical demonstration

2.1. The heat consumption of clinkering and exhaust heat utilization

2.1.1. Differences between the CCP–CIBC process and the existing cement shaft kiln process (Table 2)

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Table 1
Carbon burning modes in manufacturing industries.

	External burning (EB)	Internal burning (IB)		
		Compact (CIB)	Packed (PIB)	Fluidization (FIB)
Feature	Carbon burning process occurs outside the other reactants	Carbon burning process occurs inside the other reactants with powdery (particulate) state		
Use	Rotary kiln process, Blast furnace process, lime shaft kiln process	CCP–CIBC process, various non-blast furnace iron-reduction processes	Existing cement shaft kiln process, various rotary hearth furnace process	Precalcining sub-process of cement precalciner kiln process

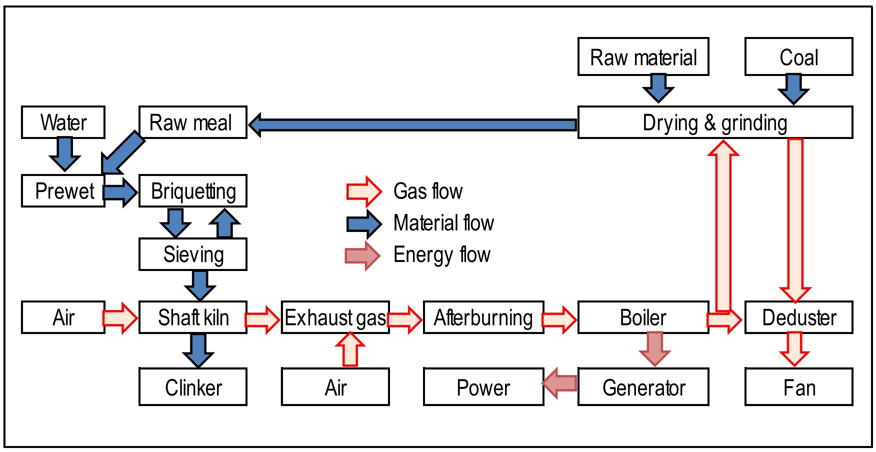

Fig. 1. CCP–CIBC process flow diagram.

2.1.2. Prediction of the specific clinkering heat consumption for the CCP–CIBC process on the basis of operating result from the existing cement shaft kiln

The CCP–CIBC process consists of clinker production and power generation. The energy effect is divided into two parts of the specific clinkering heat consumption and the specific electricity output accordingly. Both the efficiencies are evaluated with the kiln bed surface as the subsystem boundary. The heat content in the exhaust gas stream from kiln surface no longer reckons in the specific clinkering heat consumption.

The heat balance result, based on the data from a thermodynamic measurement in a Ø3.8 × 8.6 m new type of cement shaft kiln (so called JT kiln [2], an innovation result developed by Jiantong Cement in China) with 21.17 t/h production output in Oct. 2007, is listed in Table 3. The predicted values of the expenditure items corresponding to the CCP–CIBC process (for the clinkering part) are shown as figures with bracket in the table.

It could be seen from the table that, most part of the vaporization heat (615.6–125.6 = 490 Kj/Kg) and the chemically unburning heat (631 Kj/Kg) is transferred to the sensible heat of the exhaust gas and the heat content in the exhaust gas rises up to more than 1260 Kj/Kg as the CCP–CIBC process with a specific heat input 3350 Kj/Kg-clinker (800 kcal/Kg-clinker) is adopted.

For the CCP–CIBC process, the specific clinkering heat consumption, totally 2093 Kj/Kg (500 kcal/Kg), consists of clinker formation heat 1 (1723 Kj/Kg), water vaporization heat 2 (126 Kj/Kg), clinker sensible heat 3 (84 Kj/Kg), carbon residue heat 4 (147 Kj/Kg) of clinker and kiln wall emission 5 (21 Kj/Kg), among which, Item 5 keeps the same as that of the existing process. Items 2, 3 and 4 correspond with shaping moisture 3%, clinker output temperature 100 °C and carbon residue content 0.4% in the clinker product respectively. Item 4 value is based on a set of electric furnace test results with the coal-containing cement raw meal pellets (CCRPs) [3]. The prediction aforementioned is considered as reasonable.

Table 2
Differences between the CCP–CIBC process and the existing cement shaft kiln process.

	CCP–CIBC process	Existing cement shaft kiln process
Kiln feed preparation	Dry briquetting with high pressure; shaping moisture: <3%; the pellets possess single size of 30–40 mm, good mechanical strength and high thermal stability.	Wet pelletizing; pellet moisture of 15%; wide size distribution with maximum size 10–20 mm; the pellets possess a poor mechanical strength
Kiln body	It is enveloped by vertical inner walls, the cross section is in the shape of rectangle with corners rounded and with area of 20–200 m^2, the kiln body height is 3–5 m.	The upper part is in the shape of reverse cone, the main body is cylindrical with the maximum inner diameter of 6 m, the kiln body height is 8–10 m.
Exhaust gas treatment	The exhaust gas with 2–3% CO content and 500–700 °C temperature flows through afterburning zone with the secondary combustion, is reburnt to 850–900 °C and used to produce steam for power generation.	The CO-containing exhaust gas with 100 ~ 300 °C temperature is emitted to atmosphere directly.