IOŚ-PIB OCHRONA ŚRODOWISKA I ZASOBÓW NATURALNYCH
ENVIRONMENTAL PROTECTION AND NATURAL RESOURCES 2014
DE GRUYTER OPEN
VOL. 25 NO 2(60): 35–38
DOI 10.2478/oszn-2014-0013

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Using alternative fuels in the production of cement

Wykorzystanie paliw alternatywnych przy produkcji cementu

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Keywords: alternative fuels, clinker, cement kiln, environmental protection
Słowa kluczowe: paliwa alternatywne, klinkier, piec cementowy, ochrona środowiska

Abstract

The paper presents a modern approach to environmental protection in a cement plant. The possibilities of using alternative fuels are discussed along with the consequences of using them. The authors describe the feeding systems of impregnated and shredded solid fuels and tyres, as well as of liquid fuels. The basic parameters of alternative fuels used are also discussed.

Streszczenie

W artykule przedstawiono nowoczesne podejście do ochrony środowiska w zakładzie produkcyjnym cementu. Omówiono możliwości wykorzystania paliw alternatywnych oraz konsekwencji ich stosowania. Autorzy scharakteryzowali instalacje podawania paliw alternatywnych stałych – impregnowanych, rozdrobnionych oraz opon, a także paliw płynnych. Omówiono też podstawowe parametry stosowanych paliw alternatywnych.

1. INTRODUCTION

Searching for new sources of energy, economical management of natural resources and construction of modern processing lines are examples of actions aimed at reducing the impact of industrial processes on the natural environment. This article presents an example of a new approach to environmental protection issues adopted in a cement production plant.

The presented plant is an example of a modern, thriving facility. Protection of the natural environment and human health has become its watchword. Striving to comply with the strict laws expressed in the directives of the European Union, the company board has introduced a number of modifications to both the system of work and the manufacturing process. The plant has implemented quality management system ISO 9001:2000. Thanks to huge investments made in recent years, the environmental impact of the cement industry has been reduced to a minimum. This article analyses several processing installations that are mainly aimed at reducing the adverse impact of emissions of harmful substances and compounds into the atmosphere, as well as the use of alternative fuels as substitutes for conventional fuels.

2. USING ALTERNATIVE FUELS

Clinker, the basic material used for cement production, is produced in a cement kiln fed with mineral raw materials in the form of a suitably prepared mealy substance comprising mainly limestone, marl, clay, chalk, diatomaceous earth and quartz sand. Apart from the aforementioned mineral raw materials, a cement kiln also needs to be supplied with huge amounts of heat energy. In order to bake clinker, the necessary amount of heat energy is approximately 3140–3780 kJ/kg. This energy is generated by burning fine coal, low-quality fuel oil (mazut), furnace oil, natural gas and, increasingly, alternative fuels. These fuels are obtained through the recycling process of wastes with suitable calorific value. Cement plants use, among others, wastes in the form of:

- plastics,
- waste paper,
- waste oil and solvents,
- waste rubber and tyres,
- waste from the textile industry,
- dried sludge from wastewater plants,
- plant and animal waste [Mokrzycki and Uliasz-Bocheńczyk 2005].

Characteristics of clinker production processes, which are mainly based on high temperatures inside the kiln, enable the use of alternative fuels [Moses P.M. Chinyama 2011].

Working conditions prevailing in the cement kiln meet the requirements of the Regulation of the Minister of Economy of 21 March 2002 (Journal of Laws of 2002 No. 37, item. 339) on the process of thermal treatment of waste. Fig. 1 presents a section through a kiln, with thermal zones indicated.

The highest temperature is observed in the flame zone and reaches up to 2000°C. Wastes generated while burning alternative fuels, i.e. ashes, react with the baked raw material, as a result of which clinker is produced. It must be noted that the kiln's size is very advantageous. In case of a breakdown or stoppage, the heat capacity stored in the kiln lining is so great that it enables easy afterburning of alternative fuels and the harmful compounds included therein; thus, no environmental pollution occurs. Both the flue gas residence time and the temperature of the combustion chamber exceed the requirements of the Regulation.

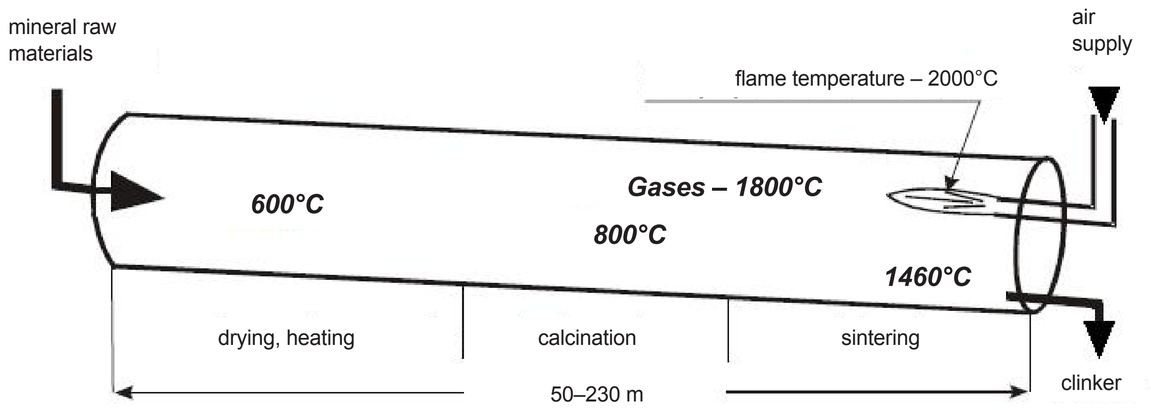

Fig. 1. Distribution of thermal zones along the rotary kiln

Apart from issues related with conditions present inside the kiln, the use of alternative fuels is also possible thanks to modern installations designed for the storage and feeding of fuels, as well as dedusting installations and intensified control over the feeding of this kind of fuel.
Use of alternative fuels basically offers the following advantages:
- reduced use of oil and conventional fuels,
- management and utilisation of wastes,
- energy recovery,
- protection of the natural environment,
- high availability of certain groups of alternative fuels, in particular solid fuels.

Basic drawbacks related to using alternative fuels include:
- increased costs resulting from managing supplied wastes,
- increased costs resulting from the need to build storage facilities and to adapt or construct new fuel feeding lines,
- some compounds generated during fuel combustion, e.g. ZnO, lower the strength of baked clinker,
- the need to implement stricter monitoring procedures over the resulting clinker,
- the lower calorific value compared with petroleum fuels,
- the risk that sinter and slag will build up inside the kiln, mainly due to the presence of chlorine, sodium and potassium compounds.

In 2011, more than 1.4 million metric tons of clinker were produced in the cement plant; at this production level, demand for coal supply reached approximately 210,000 metric tons. Thanks to the use of substitutes for conventional fuels, whose share in total heat balance for 2011 reached 52%, it was possible to save more than 109,000 metric tons of coal, which also contributed to the reduction of emissions of CO_2, CO, SO_2, SO and other harmful substances into the atmosphere.
For an alternative fuel to be used in the cement industry, it must comply with the relevant requirements (Table 1), which the Ministry of the Environment regulates, in particular Regulation of 22 April 2011 on the installation emission standards (Journal of Laws of 2011 No. 95, item. 558).

3. DESCRIPTION OF ALTERNATIVE FUEL FEEDING INSTALLATIONS IN CEMENT KILNS

The presented plant uses feeding installations for three kinds of solid alternative fuels: solid alternative fuel, shredded or PAS-r (abbreviation of the Polish term: Paliwo Alternatywne Stałe – rozdrobnione); solid alternative fuel, impregnated or PAS-i (abbreviation of the Polish term: Paliwo Alternatywne Stałe – impregnowane); and

Table 1. Requirements for alternative fuels

Substance	Emission standards in mg/m^3_u (for dioxins and furans in mg/m^3_u) the presence of 10% oxygen in the flue gas (m^3_u for T = 273K, p = 101,3 kPa)
Total dust	30
HCl	10
HF	1
NOx for existing installations NOx for new installations	800 500
SO_2	50
Organic substances in the form of gases and vapours, expressed as total organic carbon	10
CO	2000
Cd + Tl	0.05
Hg	0.05
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V	0.5
Dioxins and furans	0.1

tyres, as well as feeding installations for two kinds of liquid alternative fuels, CLIF and UTIL.
All types of solid alternative fuels are transported from producers as a mixture ready for use.
The following criteria are taken into consideration in supplying a specific alternative fuel: calorific value, chlorine content, sulphur content, PCB content, heavy metal content (mercury, cadmium, thallium) and, apart from this, auto-ignition point, moisture level, ash content, particle size distribution, and so on [Mokrzycki and colleagues 2003, Kurczabiński 1997].
Parameters of alternative fuel must comply with the quality criteria set by the cement contained in Table 2 [www.polskicement.pl].
There is a possibility of derogation from the above-mentioned parameters, depending on the specific arrangements with the leading cement plant.

3.1. Description of PAS-r feeding installation

PAS-r fuel comes in the form of a dry granulate with a maximum particle size up to 12 mm. This kind of fuel is produced mainly by shredding plastic elements, e.g. polyurethane packaging, laminates, and wastes such as paper, cardboard, foils, textiles, tapes, cables, abrasives, and so on. The material obtained directly via the shredding process constitutes fuel suitable for burning. In 2011, more than 72,000 metric tons of PAS-r fuel were used.
This kind of fuel is unloaded from the trucks directly into the storage area, which is divided into three parts, each provided with an independent installation designed for transporting the material. This solution enables the simultaneous unloading of fuel from trucks, transporting the material from the storage area and possible repairing of the equipment, without any need for interrupting the feeding of fuel to the kilns.
Suspended push-plate conveyors take material from the chosen box and transport it to a buffer container with a capacity of approximately 30 m^3. From this container, fuel is moved by means of a screw conveyor, which then transports the material to the belt conveyors, which are capable of weighing the material. Once weighed, the fuel is transferred to a cyclone feeder, and then pneumatically fed via pipelines through a blowpipe to the cement kiln. The basic parameters of the PAS-r fuel are presented in Table 3.

3.2. Description of PAS-i feeding installation

PAS-i (impregnated) fuel is a homogeneous mixture of solid wastes and watery wastes with sawdust or other carriers, e.g. tobacco wastes. PAS-i fuels also include animal wastes, e.g. bone meal and different types of impregnates and animal fat.
In terms of quantity, PAS-i fuel is the second-ranked fuel used in the cement plant. In 2011, more than 44,000 metric tons of this fuel was used.
Fuel is delivered to the plant on tipper trucks. The capacity of the storage area is 1800 m^3 of fuel. A dosing station made of two buffer containers is located outside the storage area. The material is transported from this area to these containers using a loader, and then, by means of a screw conveyor and belt conveyors, to successive containers located within the kilns. In the case of kilns 1 and 2, fuel is fed via the kiln's inlet; for kiln 3, it is fed though the blowpipe.
The basic parameters of the PAS-i fuel are presented in Table 4.

3.3. Description of the feeding installation for liquid alternative fuels

UTIL and CLIF alternative fuels belong to the group of liquid fuels. In 2011, only 871.5 metric tons of these fuels were used as they are not readily available. The major advantage of liquid fuels lies in their high calorific value, which exceeds 25 MJ/kg; therefore, cement plant manufactures are very interested in this kind of fuel.
Liquid fuels are made mainly of waste oils and liquid petrochemical waste that can no longer be used. Fuel is delivered in tankers

Table 2. Preferred parameters for alternative fuels

Parameter	The value of the preferred alternative fuels in the state of delivery
Moisture content, %	<20
Caloric value, MJ/kg	>15
Ash content, %	Not defined by the nature of the waste
Sulphur content, %	<1

Table 3. Basic parameters of PAS-r fuel

Average calorific value	16,602 kJ/kg
Average humidity	19.4%
Ash content	16.9%
Chlorine content	0.9%
Sulphur content	0.3%
Coal content	40.6%

Table 4. Basic parameters of PAS-i fuel

Average calorific value	12,736 kJ/kg
Average humidity	28.9%
Ash content	12.6%
Chlorine content	0.2%
Sulphur content	0.4%
Coal content	31.0%

from which it is pumped out to two intermediate tanks, each with a capacity of 120 m^3 each. From these intermediate tanks, fuel is directly transported to the kilns via hydraulic installations with a number of rotodynamic pumps.

4. SUMMARY

Under the provisions of the Directive of the European Parliament and of the Council of 5 April 2006 on waste, storage is considered the least desirable method of waste management. In order to avoid waste storage, considerable quantities of waste can be used for energy purposes. One of the programmes aimed at environmental protection consists of sustainable use of natural resources and waste management. The use of the so-called alternative fuels, i.e. waste that has high calorific value, is a perfect example of an action contributing to the aforementioned goal.

Conventional fuel resources have been depleted; therefore, there is an urgent need to find substitutes. Dynamic economic growth in the twentieth century has resulted in a rapid increase in energy consumption. Consequently, a number of energy-related and environmental problems occurred. Excessive demand for energy and the need to protect the environment have led to the introduction of many legal restrictions. For this reason, alternative fuels have attracted great attention in terms of their potential as substitutes for conventional fuels. This trend is particularly visible in industrial plants, where huge amounts of energy are used. Data presented in the professional literature show that the share of alternative fuels on the fuel market has been constantly increasing [Hjorth 1998]. The sale of cement by different manufacturers and percentage use of alternative fuels in the years 2009 and 2011 are presented in Table 5 [Rahman et al. 2013].

Apart from purely economical aspects and the almost limitless availability of some alternative fuels, definite ecological advantages must also be borne in mind. Data collected in the analysed cement plant in 2011 show that the share of alternative fuels in the total energy balance reached approximately 52%. This enabled the plant to avoid combustion of more than 109,000 metric tons of coal. Considering that altogether in the analysed year 2011, 73,000 metric tons of PAS-r fuel with a specific gravity of 0.27 ton/m^3 and 44,000 metric tons of PAS-i fuel with a specific gravity of 0.49 ton/m^3 were used, it can be concluded that during a 12-month period more than 360,000 m^3 of waste was utilised.

Estimates can be carried out for all cement plants operating in Poland. Assuming an average production of cement on the Polish market of 15 million tons and that the average consumption of heat to burn a ton of clinker is 3.5 GJ, we get the required amount of heat Q = 52,500,000 GJ. Assuming that the proportion of the heat of combustion of a variety alternative fuels having an average calorific value 16 GJ/tonne is 50%, receive 1640,000 tons of waste per year, which can be destroyed only in cement in Poland. The result depends on many factors, among others, the situation on the market of cement and the volume of production.

Thanks to the modern approach to environmental protection issues, legislation required by the European Union and growing social awareness, these tremendous quantities of waste are not stored on dumping sites or even in our households and do not contaminate the land or pollute air and thus do not cause harmful degradation of the natural environment.

Table 5. Sales of cement and percentage use of alternative fuels

Company	Sales of cement (million tons)		Percentage of thermal energy from alternative fuel	
	2009	**2011**	**2009**	**2011**
Holcim Group	131.9	144.3	12.0	12.2
Cemex Group	72.0	75.0	16.4	24.7
Heidelberg Group	79.3	87.8	22.7	21.2
Italcementi Group	55.7	51.5	5.4	5.8
Lafarge Group	149.4	160	10.9	13.0

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