

DOI 10.26886/2414-634X.8(35)2019.3

UDC: 666.942.2

ALTERNATIVE FUELS FOR CEMENT PRODUCTION

A. Bielohrad, process engineer

V. Tokarchuk, PhD of Technical Sciences

National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Kyiv, Ukraine

Different types of fuel which can be recommended for use in cement clinker production are considered. The analysis of specific heat of combustion of selected materials has been carried out, which has allowed to propose tires and plastic waste as the most promising among the possible alternative fuels. The chemical composition of ashes of the proposed types of fuel has been established. High content of iron (III) oxide in ashes from tires combustion and calcium oxide from shredded plastic waste combustion has been observed. The influence of ashes of different types of fuel on a liquid phase formation during the annealing of the Portland cement clinker is considered.

Keywords: Cement production, annealing of clinker, alternative fuel, used tires, plastic waste

Introduction. Fossil fuels, such as coal, oil and natural gas fulfil most energy needs of mankind today. Coal and natural gas are consumed raw, but oil, shale and bituminous sands demand further refinement [1]. This process is power intensive and produces pollutants, which escape to the environment. High price and negative impact on ecosystems stress the need to use renewable and/or alternative types of fuel in many industrial systems and to retire fossil fuels.

Cement is considered to be one of the major construction materials in the world. According to the European Commission, production of one ton of Portland cement clinker requires on average 3.3 GJ of thermal energy and close to 90-120 kWt per one ton of cement. Moreover, by estimate of the international ecological organizations, cement industry accounts for 7 % of global emissions of carbon dioxide (CO₂). Thus, the cement industry is energy-intensive, which drives the high price of the final product, and causes substantial harm to the environment.

The volumes of carbon dioxide emissions could be reduced by replacing some of the clinker components in cement with active mineral additives without altering of the main properties. Such measures are intensively undertaken around the world [2, 3]. It allows not only to reduce emissions of carbon dioxide, but also to drive down the product cost.

It is also possible to reduce product cost and by full or partial retirement of fossil fuels.

The purpose of this article is to perform the analysis of alternative types of fuel for cement production.

It is possible to assess the efficiency of alternative fuel in cement production using two key indicators, which are specific heat of combustion and cost.

Specific heat of combustion is the amount of heat that is produced during the full combustion of a unit of mass of solid fuel, or unit of volume of gaseous fuel [4].

Today, the most widespread type of fuel used in cement production is coal. The selling price of this fuel to the enterprises of the industry is a trade secret, but if one was to use to the data which is provided in various Internet resources, the average asking price is around 3500 UAH per ton, which is significantly higher than the price of waste which can be used as alternative fuel (2275 - 2500 UAH per ton). It should be noted that

according to some projections, the annual growth of coal cost of approximately 10 % is expected in the coming years. The possible growth of the price of waste, which can be used as fuel, has not been considered. Specific heat of combustion of different types of fuel is provided in Table 1.

Table 1

Specific heat of combustion of various types of fuel

Type of fuel	Heat of combustion. KJ/kg
Natural gas	41000 – 49000
Coal	20900 – 30150
Brown coal	10000 – 12000
Fuel oil	38000 – 39800
Used tire	25000 – 34000
Plastic waste	36000 – 42000
Solvents	25000 – 44000
Used oils	10000 – 20000
Residual waste	13000 – 15000
Biogas	36000 – 40000

As Table 1 illustrates - used tires, plastic waste and solvents have the heat of combustion which is disproportionate to heat of combustion of coal and natural gas. The most promising, from our point of view, are the first two types of waste.

Considering that the most widespread fuel presently is coal, the indicators of other fuel materials are compared to indicators of this fuel.

Full combustion of all types of fuel forms ashes, which react with raw materials to form the corresponding clinker minerals and liquid phase. It has been established that the amount of ashes formed during combustion of the selected materials is different (Table 2).

Table 2

Amount of ashes formed at combustion of different types of fuel

Ash content, wt.% at combustion		
Coal	Used tires	Plastic waste
14	15	9

Evidently from the received results, the received amount of ashes which are formed at combustion of coal and such of the used tires is almost identical, while with plastic waste it is significantly lower. This should be considered when calculating raw material mixes for clinker production, but it is more important to consider the chemical composition of ashes (Table 3).

Table 3

Chemical composition of ash of different types of fuel

Fuel type	Content of oxides, wt.%							
	CaO	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	SO ₃	Cl	K ₂ O	Na ₂ O
Coal	12,2	48,8	27,1	4,0	6,2	0,1	1,5	0,1
Used tires	1,1	10,8	1,1	85,9	1,1	0,0	0,0	0,0
Plastic waste	45,4	30,2	10,6	3,3	4,5	1,0	2,5	2,5

The chemical composition of ashes from different fuel materials differs significantly. At combustion of coal, primarily silicon oxide forms in ash (48.8 wt.%) and increased amount of aluminum oxide (27.1 wt.%). Therefore, when using coal as fuel, the ashes will replace some of the aluminosilicate component (clay).

Ashes from combustion of used tires contain primarily iron oxide (85.9 wt.%). It is known that oxide of iron is injected into the mixture of raw

materials to form the liquid phase during clinker annealing process. Thus, the application of used tires as alternative fuel will lead to reduction of iron content in raw materials mix.

Ashes which are formed at combustion of plastic waste almost by half consist of calcium oxide (45.4 wt.%) and by a third from silicon oxide (30.2 wt.%). Both oxides take active part in formation of clinker minerals, therefore they have no negative impact on processes which take place during the annealing of clinker.

Proposed fuel materials contain oxides of sulfur, chlorine and alkaline metals, which are harmful. The highest content of sulfur oxide is in coal ash (6.2 wt.%) and plastic waste ash (4.5 wt.%), which dictates the need for a more careful selection of the ration of fuels, used in production.

Regarding chlorine, its content in products of combustion of each proposed fuel material is insignificant.

Special attention is demanded when using plastic waste as fuel in production of clinker. This is because the alkaline oxides constitute up to 5.0 wt.%, and the regulations on general-purpose cements limit the total amount of such oxides [5]. Considering that alkaline oxides are usually present as part of the clay component of raw materials, said total can be higher than resolved.

Thus, the considered fuel materials (used tires and plastic waste) could be used as alternative fuel in production of Portland cement clinker.

Considering that the chemical composition of ashes which are formed during combustion of the considered fuel materials differs significantly, the quantity of the liquid phase that could form over the course of annealing has been calculated. Based on that, the condition of plastering in the rotating furnace, the amount of clinker fusion and the crystal modifications of main clinker minerals can be anticipated. The quantity of the liquid phase at 1450 °C is calculated by the following formula:

$$\text{Liquid phase, wt. \%} = 2,95 \times Al_2O_3 + 2,2 \times Fe_2O_3 + MgO + K_2O + Na_2O$$

The results are provided in Table 4:

Table 4

The quantity of the liquid phase that could be formed on account of ash

Liquid phase content, wt.%, during combustion		
Coal	Used tires	Plastic waste
0,9	1,9	0,4

Provided calculations confirm that the ashes from combustion of used tires affect formation of the liquid phase the most, and plastic waste the least of all.

Conclusions. Performed analysis of various fuel materials suggests that used tires and plastic waste can be used as alternative fuel in production of Portland cement clinker. Use of such materials would allow to lower energy expenses, as well as preserve natural resources while minimizing the ecological impact of the whole process.

References:

1. Moses P.M. (2011). Alternative Fuels in Cement Manufacturing. Open access peer-reviewed chapter <https://www.intechopen.com/books/alternative-fuel/alternative-fuels-in-cement-manufacturing> (2011, August, 9)
2. Sobol, Kh.S., Markiv, T.E., Sanytsky, M.A., Koguch, G.V. (2003). Influence of active mineral admixtures on the blended cements properties. *Chemistry, technology of substances and their use, no. 488, 274–278.* [in English].
3. Sokoltsov, V.Yu., Tokarchuk, V.V., Sviderskyi V.A. (2015). Hardening peculiarities of blended cements with silicate admixtures of different origin.

Eastern-European Journal of Enterprise Technologies, no. 11(75), 9-14. [in English].

4. Saranchuk V.I. and oth. (2008). *Osnovy khimii i fizyky horiuchykh kopalyn: pidruchnyk [The basics of chemistry and physics of combustible fossil fuels: textbook]*. Donetsk, Skhidny vydavnychy. [in Ukrainian].

5. *Tsementy zahalnobudivelnoho pryznachennia tekhnichni umovy DSTU B V.2.7-46:2010* (Ministerstvo rehionalnoho rozvytku ta budivnytstva Ukrainy). [General Purpose Cement Technical Specifications DSTU B B.2.7-46: 2010 The Ministry of Regional Development of Ukraine]. [in Ukrainian]. (2011).

Citation: A. Bielohrad, V. Tokarchuk (2019). ALTERNATIVE FUELS FOR CEMENT PRODUCTION. *Innovative Solutions in Modern Science*. 8(35). doi: 10.26886/2414-634X.8(35)2019.3

Copyright: A. Bielohrad, V. Tokarchuk ©. 2019. This is an openaccess article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) or licensor are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.