Alternative Fuels for Cement Industry: A Review

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Abstract

Energy costs and environmental standards encouraged cement manufacturers world-wide to evaluate to what extent conventional fuels can be replaced by alternative fuels with processed waste materials. The decisive factors promoting the use of cement kilns for the utilization of wastes (alternative fuels) are: the high incineration temperature, the large area of the furnace, the significant length of the kiln and the alkaline environment inside the kiln. It may further, reduce pollution from cement industry.

Keywords
Alternative fuels; waste; cement kiln; pollution reduction; cost reduction

1. Introduction
Fuels made from waste have been used in many countries for over 10 years. They are used by power plants and various industrial plants using high-temperature processes, including cement plants. The fuels applied can be solid or liquid, made from municipal waste, industrial waste, or their mixtures. Replacement of some conventional fuels with alternative fuels brings both ecological and economic benefits. An industry that is especially suitable for the application of such fuels, from the technological and environmental points of view, is the cement industry. Alternative fuels are used in many cement plants throughout the world. Several cement plants in Poland are using alternative fuels. Among these plants, are Lafarge Concerns that has begun using alternative fuels in the early 1990s, (CMA, 2003). Lafarge plants uses alternative fuels made from waste. The incineration of alternative fuels in cement plants is a safe method for the utilization of waste that is ecologically friendly and profitable for the industrial plants and society alike (Jenkins BG, 1997). The cement industry is an energy intensive industry. The average energy demand for the production of 1 ton of cement is about 3.3. GJ (Feng L, 1995) which corresponds to 120 kg of coal with a calorific value of 27.5 MJ per kg. Energy costs account for 30–40% of the total costs of cement production (Personal communication with Dr. Pandey and Log sheet, Vikram Cement).

2. Cement Manufacturing Process
There are three main steps in the cement manufacturing:

- Preparing raw material, called as “meal” that includes mixing/homogenizing, grinding and preheating (drying).
- Burning of raw meal to form cement clinker in the kiln. The components of the raw meal react at high temperature (900-15000C) in the precalciner and in the rotary kiln, to give cement clinker.
- Finish grinding of clinker and mixing with additives is done after cooling.

Cement manufacturing consists of raw meal grinding, blending, precalcining, clinker burning and cement grinding. In short, limestone and other material containing calcium, silicon, aluminum and iron oxides are crushed and milled into raw meal. This raw meal is blended and is then heated in the pre-heating system to initiate the dissociation of carbonate to calcium oxide and carbon dioxide. An alternative fuel is fed into the preheating system to keep the temperature sufficiently high. The meal then proceeds to the kiln for heating and reaction between calcium oxide and other elements to form calcium silicates and aluminates at a temperature up to 14500C. Primary fuel is used to keep the temperature high enough in the burning zone for the chemical reaction to take place. The reaction product leaves the kiln as a nodular material called clinker. The clinker will be inter-ground with gypsum, limestone and/or ashes to a fine product called cement.

3. Alternative Fuels used in the Cement Plants

Fuels in various countries have been prepared from mixed types of waste in order to ensure the better use of the chemical energy contained in waste. It is now established that processed waste with energy content can be utilized as an energy source. According to the European Cement Association, CEMBUREAU, the figures for the proportion of alternative fuels used in clinker kilns between 1990 and 1998 in particular countries were as follows: Belgium—18%; France—52.4%; Italy—4.1%; Portugal—1.3%; Spain—1%; Sweden—2%; Switzerland—25%; Czech Republic—9.7%; Great Britain—20%; Germany—15%; Poland—1.4% (Cembureau, 1997). The energy content depends mainly on the size of the organic combustible fraction and on the moisture content. To better employ the chemical energy contained in wastes, alternative fuels have been developed which are mixtures of different wastes (Grosse-D, 1996). There are a number of wastes that can be incinerated as fuel in cement kilns. Some of that can be mentioned are: selected combustible fractions of municipal wastes, liquid crude-oil derived wastes, car tires, waste products derived from paint and varnish production, expired medicines from the pharmaceutical industry.

The range of fuels is extremely wide. Traditional kiln fuels are gas, oil or coal. Materials like waste oils, plastics, auto shredded residues, waste tyres and sewage sludge (SS) are often proposed as alternative fuels for the cement industry. Also, all kinds of slaughterhouse residues are offered as fuel too (Pizant J, 1997). To be able to use any of these fuels in a cement factory, it is necessary to know the composition of the fuel. The choice is normally based on price and availability. The energy and ash contents are also important, as are the moisture and volatiles contents (Mokrzycki E, 2003). All kinds of varieties from liquid to solids, powdered or as big lumps can be encountered when dealing with alternative fuels, requiring a flexible fuel feeding system. Somehow, they should all be fed into the burning chamber of the process. It may be fed directly into the burning zone in the kiln itself or into the pre-heating system for dissociating part of the carbonates from the meal before it enters the kiln for clinker formation (Kaantee U, 2004). Table 1, several fuels of interest to the cement industry and their properties are listed. The burning of various types of wastes requires the detailed control and adaptation of technological processes to each type of waste. For this reason, alternative fuels are derived from wastes having similar composition and properties. Figure 1 presents a graph of Time vs. Temp of gas and material flow in the cement manufacturing process based on a common Indian cement plant.

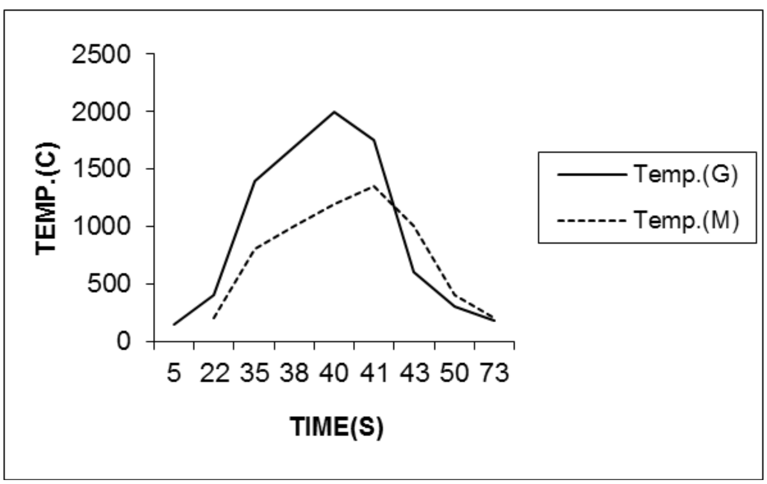

Figure 1: Diagram of the temperatures of gases and materials in a cement kiln

Table 1: Properties of Fuels of Interest to the Cement Industry

Dry, in wt.%	Bituminous coal	Petcoke	Meat and bone meal	Sewage sludge	Car Tyre	Rubber	Petcoke Mix
C	70.6	89.5	42.1	40.5	79.6	87.0	75.1
H	4.3	3.08	5.83	7.0	7.0	7.82	4.20
N	1.2	1.71	7.52	0.84	0.43	0.33	1.70
S	1.3	4.00	0.38	0.12	1.54	0.80	3.00
O	11.8	1.11	15.3	25.2	5.0	1.81	4.90
Cl	0.07	0.20	1.0	-	0.063	-	-
P (P_2O_5 in ash)	0.016	41.2	0.015	0.046	-	-	-
Na (Na_2O in ash)	0.05	-	1.47		0.04	0.9	2.4
K (K_2O in ash)	0.12		0.28		0.038	1.1	2.8
Ca (CaO in ash)	0.18		18.4	1.83	0.53	8.7	11.7
Fe (Fe_2O_3 in ash)	0.31		0.14		0.36	1.7	5.4
Al (Al_2O_3 in ash)	1.07		0.02		0.11	16.6	1.2
Si (SiO_2 in ash)	2.0		0.45		0.94	27.8	55.8
Mg (MgO in ash)	0.08			0.32		1.2	2.6
Ni (NiO in ash)		0.0432			0.018	0.0065	0.044
Hg (mg/kg)		0.05			<0.1		
Pb (PbO in ash)		0.00053			0.004	0.0373	0.0054
Zn (ZnO in ash)		0.00103			1.48	56.6	0.0092
Mn (MnO in ash)						0.021	0.027
V (V_2O_5 in ash)		0.0906				0.0043	0.251
As (mg/kg)					0.7		
Cr (Cr_2O_3 in ash)		0.0013			0.034	0.0008	0.0018
Cd (mg/kg)		0.46			8		
Co (CoO in ash)		0.0001				0.495	0.00017
Ash	11.1	0.50	28.3	17.9	6.35	2.20	11.1
Volatiles	35.9	10.0	64.5	85.0	69.4	66.6	20.0
C-fix	53.0	89.5	7.20	5.00	30.6	31.1	69.2
H_2O (wt.%)	3.0	1.50	8.09	5.20	0.66	0.73	1.30
LHV (MJ/kg)	27.4	33.7	16.2	15.8	35.5	35.6	29.0
HHV (MJ/kg)	28.4					37.3	29.7

(Alsop, 1998)

Initially gas temperature was 1500C in the preheater zone, further it had increased to 6000C in the rotary kiln in almost 20-22 seconds where the combustion process begins and finally it reaches to about 20000C at about 39-41 seconds. When the gas flows through the cooler temperature comes down to 2000C. As gas flow the temperature of material get affected. The temperature of material suddenly rises to 8000C at about 33-35 seconds at the inlet of the rotary kiln and while flowing through the cooler it becomes 1500C. The required time for waste disposal is estimated as 2 seconds.

The use of waste-derived fuel in the process of clinker production also has certain limitations, such as technological limitations related to the volume of waste-derived fuel that may be fed to the kiln. The waste volume depends on the effective incineration surface, i.e. the kiln's length and capacity. The use of waste-derived fuel must not have a negative impact on the kiln running or clinker quality and to environmental safety aspects.
The following properties should be examined before the burning of alternative fuels:

1. Physical state of the fuel (solid, liquid, gaseous)
2. Content of circulating elements (Na, K, Cl, S)
3. Toxicity (organic compounds, heavy metals)
4. Composition and content of ash
5. Content volatiles
6. Calorific value
7. Physical properties (scrap size, density, homogeneity)

8. Grinding properties
9. Humidity content
10. Proportioning technology

As a mixture of various wastes, alternative fuels may be produced in conformity with certain rules as follows:

- The chemical quality of the fuel must meet regulatory standards assuring environmental protection,
- The calorific value must be stable enough to allow the control of the energy supply to the kiln; the objective being to arrive at a fairly homogeneous composition, and
- The physical form must allow easy handling of the material for transportation and a stable, adjustable flow of material in the cement plant.

5. Advantages of Burning Alternative Fuels

Cement furnaces operate on a continuous basis. The temperatures of the materials and their decomposition in the furnace are very stable in time. The large heat capacity of the furnace results in the fact that, even in the event of an emergency shutdown, significant changes in temperature occur only after several minutes, which ensures the complete incineration of the fuels in the case of a furnace failure. The process of fuel combustion in rotary cement furnaces is a non-waste process, as the ash created as a result of incineration is contained in the clinker produced.

A characteristic feature which makes cement furnaces perfect for the application of alternative fuels consists in the alkaline environment allowing one to neutralize and capture acid gas components occurring as a result of fuel combustion before the release of the gas emissions to the air (Mitra A, 2004). The highly effective purification of the gases released from the furnace allows the elimination of heavy metal emissions. These are condensed on dust molecules and, together with the dust captured by the dust-removing devices, are returned back to the process. As a result, they are captured in the clinker.

6. Summary

While cement plants do not themselves produce wastes, they use wastes from other branches of industry as additives or alternative fuels. This is possible owing to the technological conditions in rotary kilns. Many years of experience have shown that the use of wastes as alternative fuels by cement plants is both ecologically and economically justified. The substitution of alternative fuels for fossil fuels will help reduce energy costs, providing a competitive edge for a cement plant using this source of energy. Furthermore, this will reduce the burden of waste disposal considerably. The conditions in rotary kilns, such as high temperature, the high speed of the gas stream and the long particle-storage period, guarantee that the use of alternative fuels is ecologically safe.

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Biography

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