Increasing Energy Efficiency in Indian Cement Manufacturing

Synopsis :

The cement industry is among the most energy intensive industries around the world and is therefore, quite rightly, the focus of global strategies to reduce energy requirements. Richard Woosnam of Fairport Engineering examines how the use of a variety of alternative fuels can improve energy efficiency in the Indian cement sector by adopting different strategies for kiln firing and electrical energy generation.

A cement kiln requires a significant amount of thermal energy that is traditionally delivered by fossil fuels, mainly coal and pet-coke. The European average figure (for 2010) was 3,733 $MJ_{(th)}$/Te (888.8$kcal_{(th)}$/kg) but nowadays modern energy efficient kilns have reduced the thermal energy demand to around 3,300 $MJ_{(th)}$/Te (785.7 $kcal_{(th)}$/kg) using pre-heater kilns and a dry process. Older long dry kilns use approximately 33% more energy (than 3.300 $MJ_{(th)}$/Te), while wet processes typically consume in excess of 80-85% more energy than pre-heater kilns. Indian data indicates that the typical thermal energy to pyro-process cement raw materials to clinker is of the order of 650-750 $kcal_{(th)}$/kg [4]. Comparing this data indicates that India typically uses less energy per tonne to manufacture cement. However, it is known that Europe (and in particular the UK) uses more Alternative Fuels (AF) via thermal substitution in the kiln. If this could be introduced into Indian cement manufacture the potential savings are significant and profitability could be increased as the cost of traditional fuels is saved as a minimum..

The electrical energy consumed in making cement is also of significance and can be sub-divided in to various parts of the process as shown below in Table 1. This needs to be related to a broad general assumption that a modern cement plant uses 110 -120 $kWh_{(e)}$/tonne[1] to produce 1 tonne of finished and packed cement.

Proportion of electrical energy	Process Step
~38-40%	Cement Grinding
~22-24%	Raw Material Grinding
~20-22%	Clinker Production (including grinding of fuels)
~3-6%	Raw Material Homogenisation
~3-5%	Raw Material Extraction
~5%	All types of conveying and packaging
Total 100%	

Table 1 - Approximate Electrical Energy Split by Cement Production Process Step

The UK produces some 10 Mt/a of cement quite energy efficiently using Best Available Techniques (BAT), even though the cement plants are generally older than found in Asia. Countries like India produce considerably more cement. In FY 2016[2] India produced over 282.8 Mt/a of cement and this is forecast to grow to around 400 Mt/a this year, an annual growth rate of 9.7%; with further increases in production predicted to nearly 500 Mt/a production by 2020. The electrical demand for increased capacity of all cement process would add approximately 41.4% power demand by FY17 (compared to FY2016) if growth is accurately forecast, and more than 60.7% increased power demand by 2020. A huge increase that will require significant investment in power infrastructure. While many cement plants in India have some Captive Power Plants (CPP), this increase in production will also increase the amount of emissions; especially if this energy demand is provided by coal and/or pet-coke..

In reality much of this requirement for additional energy, thermal and electrical, can be met by using AF's and increasing Thermal Substitution Rates (TSR). In Europe AF's are regularly used to provide up to 65% of the energy required in kiln firing and even up to 100% TSR has occurred; comparatively in Asia, and India in particular, the use of AF is around 4% and often less than 1.5%. Biomass fired alternative generating plants are only just beginning to become the norm in Europe but increasingly providing electrical energy to their national grids. In the UK some major power stations like Drax, Ferrybridge and Lynemouth now use predominantly biomass (wood pellet and refuse derived fuels) as their fuel of choice.

AF's have come a long way since their early use in the European cement industry. Originally the first AF's were described as RDF (refuse derived fuel). These fuels were originally quite crudely produced from Municipal Solid Waste (MSW) and often came with high levels of moisture that often led to poor firing in the cement kilns. Over time the waste was subjected to more sophisticated treatment in a so called Material Recovery Facility (MRF) where better quality fuels were produced called Solid Recovered Fuel (SRF). Nowadays these facilities have become largely semi-automated and are a corner stone of TSR within a variety of industries.

To facilitate the increased use of AF the UK government supported a 'Demonstrator Technology Programme' to encourage the building of state of the art facilities that otherwise would have been viewed as new and too commercially speculative for normal financing channels. Orchid Bioenergy a member of the same group as Fairport Engineering, harnessed this support to build a MSW processing plant that successfully operated for a number of years. This provided the first batches of SRF to several cement plants for initial trials and subsequent adoption as AF material. One novel and patented feature of the Orchid Bioenergy process was the control of the moisture in the finished product. Moisture levels in the product were in the range typically of 12 -18% (on a w/w basis) raising the Gross Calorific Values to 18 to 15 MJ/kg typically. This was proven to be an excellent and reliable AF with which to feed to cement kilns via new, uprated burners.

A major enabling step in this transition from RDF to SRF was the legislative taxation by the UK government of waste disposal on the basis of 'The Polluter Pays', A Landfill Tax was instigated, which monetised the process of disposal of 'wastes'. This is currently not adopted in India but the Indian government has set up a scheme (Perform Achieve Trade) to incentivise the saving of energy, which is another step forward on the road to driving down the energy requirements of industry globally. Ironically many cement plants in the UK today earn as much by "co-processing" waste compared to their primary function of producing cement !!

Other AF materials used during this period in the UK for both thermal and electrical energy substitution included Pelletised Sewage Pellets (PSP) dried to around 6% moisture (GCV 15.6MJ/kg), Meat and Bone Meal (MBM) GCV of ~16.2MJ/kg, and rubber tyres from road vehicles with a GCV of 35.6MJ/kg, that is greater than coal (GCV 30MJ/kg). These fuels also have lower embedded Nitrogen and most have a lower Sulphur content (with the exception of tyres) than traditional carbon fuels. Consequently use of AF can lower the emissions from cement plants compared to the traditional fuels and also save energy. To demonstrate how the use of AF could compare to traditional fuels the following table examines various key parameters.

	Fuel	**Nitrogen Content %**	**Sulphur Content %**	**Nett CV (MJ/kg)**	**Estimated Global Availability (Mt/yr.)**	**Estimated Global Heat Value (PJ /yr.)**	**Coal Equivalent – Mt/yr.** (calculated at 25.3MJ/kg)
Alternative Fuels	SRF	0.7	0.17	15.5	1,400	21,700	614.4
	MBM	7.52	0.38	16.2	7	113	3.15
	Sewage Sludge (PSP)	0.84	0.12	15.8	18.5	292	8.12
	Tyre Rubber	0.43	1.54	35.6	5	178	4.94
Normal Fuel	Pet Coke	1.71	4.0	33.7	60	2022	N/A
	Bituminous Coal	1.2	1.3	25.3	6200	156,860	N/A

Figure 1 – Comparison of types of Alternative Fuels with traditional fuels for NCV versus embedded Sulphur and Nitrogen.
Note – Pelletised Sewage Sludge (PSP) is pre-dried to 6% moisture (w/w basis) prior to feeding so as to maximise its Nett C.V., and at that moisture content should have no odours.

Waste streams may also include organic material naturally containing moisture, so that subsequent processes for maximum energy production may include, Cellulosic Alcohol Fermentation / Bio-Digestion followed by Anaerobic Digestion of the resultant solid discharge to maximise energy production. These wet processes can be followed by thermal drying of the resultant digestate (using recovered waste heat from the process) then combustion of the dried digestate fraction, for final recovery of the remaining of the chemical energy.

The alcohol produced in fermentation makes an excellent Secondary Liquid Fuel (SLF) for the kiln, while the biogas produced from digestion provides bio-methane for firing in the kiln and/or partial drying of the digestate. Any recovered waste heat from the cement process will supply all the remaining heat for the final drying of the digestate to make an AF typically with 15-18 MJ/kg NCV. In this manner all the chemical energy in the AF can be converted into thermal energy and the resultant ash is also incorporated in the clinker as an Alternative Raw Material (ARM).

As can be seen AF can be solid material such as RDF or SRF, or further improved to make Tertiary Alternative Fuels (TAF), or additionally liquids known in the UK as Secondary Liquid Fuels (SLF) can be used as feedstocks for pyro-processing. These SLF's typically have high calorific values and can make excellent fuels for cement kilns, if handled appropriately via a suitable burner train. TAF's have lower glass, stones (all abrasive materials) and a finer particle size to improve combustion properties and typically use recovered waste heat to dry immediately prior to dosing to the upgraded burner.

The use of AF's can be incorporated into most cement plants relatively easily, dependent upon the existing layout and spatial separation of the process components. Heat can be recovered from clinker cooling and/or other process stages, where there is excess process heat to be gainfully recovered and re-purposed. Simple surveys can identify opportunities for energy saving and recovery which can be analysed and placed in order of payback (according to Corporate Investment Rules) when compared to PAT goals and energy gains attained so far. In this manner the cement manufacturers will gain a financial saving each year, plus further saving under the PAT Scheme. India gains because they can re-purpose the power for other uses including Industry and/or socio-economic purposes.

References

1) A critical review on energy use and savings in the cement industry written by N.A Madlool, R Saidur, M.S, Hossain, N.A.Rahim covering cement production in China. India, USA, Mexico, Japan, Italy, Spain and Brazil published May 2011.

2) FY = Financial Year according to Indian Government norms i.e. 1st April – Mar 31st following calendar year

3) GNR Reference CEMBUREAU- 'Thermal Energy Efficiency in Brief' article paras1, 2 & 3. And GNR Project reporting CO2 www.wbcsdcement.org/GNR-2014/index.html region EU28

4) Figures given at KEP presentation 2016 November 7 at 12:50 New Delhi.