Bulletin

ALTERNATIVE FUELS USAGE IN CEMENT KILN

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STOCHIOMETRIC CALCULATIONS FOR DIFFERENT TYPES OF ALTERNATIVE FUELS

ABSTRACT

Co-processing is the use of waste as raw material or fuel, or both to replace natural mineral resources and fossil fuels such as coal. This paper investigates air requirement for complete combustion of different types of alternate fuels in cement kiln and exhaust gas volumes of different fuels to be handled by preheater fan.The purpose of this paper is to discuss the stochiometric air calculations for alternative fuels and increased usage of same in cement industry there by reducing fossil fuel consumption in cement industry.

Cement production is a very energy consuming process; in India the industry's average thermal energy consumption was 725 kcal/kg of clinker and average electrical energy consumption was 80 kWh/tonne of cement[1]. To meet the thermal energy requirement of the system, most of the cement plants in India utilize coal as a fuel, which may be imported or purchased in India.

The range of coal requirement for the cement industry during the different years of 12th plan period is assessed to be in the range of 63-96 million tonnes (46-70 million tonnes for cement production and 18-27 million tonnes for captive power). Post 2007, no new linkage has been granted to any cement manufacturer. Even in cases where linkage has been granted, actual supply against such linkages is less. Thus, unless the linkage coal is quickly increased the fuel supply gap shall put upward pressure on cement production costs[2]

Many European countries and other foreign countries utilizes waste as AFR in cement kiln, which not only benefit in cost savings for replacing the coal but also conserve the fossil fuels and reduce the overall carbon emissions.

While using different types of fuels in the system the air requirement vary depends on the ultimate analysis of the fuel. Some plants are forced to reduce the kiln feed rate due to high exhaust gas flow rates, due to characteristic of the fuel.

This paper aims to provide the overall air requirement and exhaust gas volumes for different types of alternative fuels (AF). This also includes a model for calculating the air required for combustion and exhaust gas volumes for one of the alternate fuel in detail.

This calculation sheet will help to identify different types of fuels suitable to individual cement plants based on the characteristics of fuel and Pre heater fan capacity to handle the volume of the exhaust gases.

The values taken are typical and representative and to be used if no value is available. To have accuracy it is always preferred to have the correct sample and analysis for the fuel to be used.

ULTIMATE ANALYSIS OF DIFFERENT ALTERNATIVE FUELS

	Ultimate analysis	Unit	Coconut shell	Paddy husk	Saw dust	Rice Husk
1	Moisture	%	13.95	10.79	7.98	-
2	Ash	%	3.52	16.73	1.73	-
3	Carbon	%	44.95	33.95	48.55	34.72
4	Hydrogen	%	4.99	5.01	6.99	3.44
5	Oxygen	%	31.94	32.52	33.85	29.67
6	Nitrogen	%	0.56	0.91	0.8	0.45
7	Sulphur	%	0.08	0.09	0.1	0.05

STOICHIOMETRIC REQUIREMENTS FOR COMBUSTION REACTIONS

Carbon, Hydrogen, Sulphur combines with oxygen to form Carbon dioxide, Water vapour and Sulphur dioxide. Following Reactions happen in fuel combustion and all are exothermic reactions which release heat.

$C + O_2$ ---------------------------- > CO_2

$2H_2 + O_2$ ---------------------------- > $2H_2O$

$S + O_2$ ---------------------------- > SO_2

Molecular mass or molecular weight refers to the mass of a molecule. 1 kmol of a gas occupies 22.4 Nm^3 at 0^oC & 1 atm.

Molecular weight of Hydrogen - 2 Kg/Kg mole

Molecular weight of Sulphur - 32 Kg/Kg mole

Molecular weight of Carbon - 12 Kg/Kg mole

Molecular Weight of Oxygen - 16 Kg/Kg mole

Therefore 12 Kg of Carbon requires 32 Kg of Oxygen to form 44 Kg of Carbon dioxide.

Therefore 1 Kg of Carbon requires (32/12) Kg of Oxygen
- 2.7 Kg of oxygen

Similarly for other reactions 4 Kg of Hydrogen requires 32 Kg of Oxygen to form 36 Kg of kg of water

Therefore 1 Kg of Hydrogen requires (32/4) Kg of Oxygen
- 8 Kg of oxygen

32 Kg of Sulphur requires 32 Kg of Oxygen to form 64 Kg of Sulphur dioxide

phur requires 32 Kg of Oxygen to form 64 Kg of Sulphur dioxide

Therefore 1 Kg of Sulphur requires (32/32) Kg of Oxygen - 1 Kg of oxygen

We can take an example of Coconut shell as a fuel and consider a sample of 100 Kg fuel.

One kg of Carbon requires 2.7 kg of oxygen therefore

44.95 Kg of Carbon requires 44.95*2.7 Kg Oxygen

One kg of Hydrogen requires 8 Kg of Oxygen therefore

4.99 kg of Hydrogen requires 4.99*8 Kg of Oxygen

One kg of Sulphur requires 1 kg of oxygen therefore 0.88 kg of Sulphur requires 0.88*1 Kg of Oxygen.

Total Oxygen requirement
- [(44.95*2.7) + (4.99*8) + (0.88*1)] - Oxygen in fuel
- 161.36 -31.94
- 129.42 Kg oxygen / 100 kg of fuel

Atmospheric air is supplied for combustion through primary air fan and cooler and this air is a mixture of mainly Oxygen and Nitrogen and small traces of Argon, Carbon dioxide, Water vapour etc. We know that air contains 23% of Oxygen by weight. Therefore the weight of the air supplied is

- 129.42/0.23
= 562.7 kg of air / 100 kg of fuel

Theoretical air required
- 562.7/100
- 5.63 Kg of air/kg of fuel

Density of air
- 1.29 Kg/Nm^3
- 4.36 Nm^3/kg of fueL

STOICHIOMETRIC AIR REQUIRED FOR COMPLETE COMBUSTION OF DIFFERENT FUELS

	Unit	Coconut shell	Paddy husk	Saw dust	Rice Husk
	100 kg of fuel requires				
Carbon	Kg	121.36	91.66	131.08	93.74
Hydrogen	Kg	39.92	40.08	55.92	27.52
Sulphur	Kg	0.08	0.09	0.1	0.05
Total oxygen required	**Kg**	**161.36**	**131.83**	**187.10**	**121.31**
Oxygen in fuel	Kg	31.94	32.52	33.85	29.67
Additional oxygen required	Kg	129.42	99.31	153.20	91.64
Dry air required	Kg of air/100 kg of fuel	562.7	431.8	666.30	398.5
Theoretical air requirement	**kg of air/kg of fuel**	**5.63**	**4.32**	**6.66**	**3.98**
	Nm^3/kg of fuel	**4.36**	**3.35**	**5.17**	**3.09**

CALCULATING THEORETICAL VOLUME OF EXHAUST GASES

Here also we can take an example of Coconut shell as a fuel

Assume Kiln inlet Oxygen	-	1.5 %
Excess air in the exit gases	-	100*((1.5)/(21-1.5))
	-	7.7 %
Therefore actual air	-	5.63 Kg of air/kg of fuel* 1.077
	-	6.1 Kg of air/ kg of fuel
Carbon content in the fuel	-	44.95 %
	-	(44.95/100)*(44/12)
	-	1.648 kg / kg fuel
Hydrogen content in the fuel	-	4.99 %
	-	(4.99/100)*(44/12)
	-	1.648 kg / kg fuel
Sulphur content in the fuel	-	0.88 %
	-	(0.88/100)*(64/32)
	-	0.0016 kg / kg of fuel
Nitrogen content in the fuel	-	0.56 %
	-	(0.56/100) + (0.77*6.1)
	-	4.67 kg / kg of fuel

Oxygen content in the exhaust gas

	-	(6.1-5.63)*(23/100)
	-	0.100 Kg/Kg fuel
Total combustion gases	-	6.87 Kg/Kg of fuel

Total combustion gas volume in Nm^3

Density of CO_2	-	(44/22.4) = 1.964 Kg/Nm^3
	-	[1.648 (kg/ kg of fuel)] / [1.964 Kg/Nm^3]
	-	0.839 Nm^3 / kg fuel
Density of H_2O	-	(18/22.4) = 0.804 Kg/Nm^3
Density of SO_2	-	(64/22.4) = 2.85 Kg/Nm^3
Density of N_2	-	(28/22.4) = 1.25 Kg/Nm^3
Density of O_2	-	(32/22.4) = 1.42 Kg/Nm^3

Similarly for other constituents

H_2O	-	0.558 Nm^3/ Kg fuel
N_2	-	0.00056 Nm^3/ Kg fuel
O_2	-	0.070 Nm^3/Kg fuel
Total combustion gases	-	5.21 Nm^3/ Kg of fuel

STOICHIOMETRIC AIR REQUIRED FOR COMPLETE COMBUSTION OF DIFFERENT FUELS

S.No		Unit	Coconut shell	Paddy husk	Saw dust	Rice Husk
	Kiln inlet O_2	%	1.5	1.5	1.5	1.5
	Excess air	%	7.7	7.7	7.7	7.7
	Actual air going inside	Kg of air/kg of fuel	6.1	4.7	7.2	4.3
1	CO_2	Kg/kg	1.648	1.245	1.780	1.273
2	H_2O	Kg/kg	0.4491	0.4509	0.6291	0.3096
3	SO_2	Kg/kg	0.0016	0.0018	0.002	0.001
4	N_2	Kg/kg	4.672	3.590	5.242	3.309
5	O_2	Kg/kg	0.100	0.076	0.118	0.070
	Exhaust gas volume	**Kg/kg of fuel**	**6.87**	**5.36**	**8.06**	**4.96**
1	CO_2	Nm^3/kg	0.83	0.63	0.90	0.64
2	H_2O	Nm^3/kg	0.558	0.561	0.782	0.385
3	SO_2	Nm^3/kg	0.00056	0.00063	0.0007	0.00035
4	N_2	Nm^3/kg	3.73	2.87	4.19	2.64
5	O_2	Nm^3/kg	0.070	0.053	0.083	0.049
	Exhaust gas volume	**Nm^3/kg of fuel**	**5.21**	**4.12**	**6.20**	**3.73**
		Nm^3/1000 Kcals	**1.30**	**1.37**	**1.54**	

	Imported coal	Indian Coal	Petcoke	Coconut shell	Paddy Husk	Saw dust
PH gas with excess air(Nm3 / kg clinker)	1.35	1.72	1.42	1.47	1.54	1.68
Increase in preheater gas volume due to AFR compared with Imported Coal (Nm3 / kg clinker)		0.37	0.07	0.12	0.19	0.33
Percentage increase in preheater gas due to AFR compared with Imp Coal (%)		21.5	4.9	8.2	12.3	19.6

PROJECT BACKGROUND

Waste management in India is an increasing concern. India generates about 6.2 million tons of hazardous wastes annually, out of which around 3.09 million tonnes is recyclable, 0.41 Million tons is incinerable and 2.73 million tons is landfillable1. With this kind of increasing quantum of hazardous waste generation, local administration, civic bodies and policy makers are posed with a serious concern of its effective & safe disposal.

Confederation of Indian Industry (CII) in association with cement Manufacturers Association (CMA) is working on an initiative to increase use of "Alternative Fuels & Raw materials (AFR)" in Indian Cement Industry. As a part of the initiative CII is working on the project "Facilitate Development of Framework to Promote Alternate Fuel Utilization in India" and is partially supported by Shakti Sustainable Energy Foundation (SSEF), a part of Climate Works Foundation.

The main objective of this project is to accelerate AFR initiatives and increasing usage of AFR in the Indian Cement Industry through capacity building, data availability and facilitating exchange of waste by working closely with Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs), thereby reducing environmental impacts of waste generation and raw material usage.

All developed nations globally have utilized cement kilns in their countries as an effective option for industrial, municipal and hazardous waste disposal.

CII – SOHRABJI GODREJ GREEN BUSINESS CENTRE

CII – Sohrabji Godrej Green Business Centre (CII – Godrej GBC), a division of Confederation of Indian Industry (CII) is India's premier developmental institution, offering advisory services to the industry on environmental aspects and works in the areas of Green Buildings, Energy Efficiency, Water Management, Renewable Energy, Green Business Incubation and Climate Change activities.

CII Godrej GBC has been actively involved in the Indian energy and environment scene, and works on various activities and projects with the government and industry. Energy audits and energy efficiency related activities conducted by CII Godrej GBC in Indian industry have resulted in annual recurring energy savings of over INR 2,100 million. The initiative entitled Mission on Sustainable Growth, with signatories from 450 Indian companies, has resulted in annual renewable energy power generation of 82.855 million units and annual GHG reductions of 779,337 tons of CO_2, among other benefits.

CII has been closely associated with the Indian cement industry at both technical & policy level. On the technical front, CII has been associated with detailed energy efficiency improvement studies with over 70 cement manufacturing facilities over the last 15 years. Based on these onsite field level studies, CII has a complete understanding of cement operations, energy efficiency and productivity parameters and perspectives of the industry today. At the policy level, CII has a National Cement Council headed by senior industry representative and its membership has representatives from all stakeholder organizations.

References

1- Low-Carbon Technology Roadmap for the Indian Cement Industry

2- Report on working group on cement industry for XII Five Year Plan (2012- 2017)

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