Review on Practices of Waste Fuels in Cement Manufacture Plant

Ahsan Ali[1], Gouraw Beohar[2]
[1]*Research Scholar, Department of mechanical Engineering, SRIT, Jabalpur*
[2] *Professor, Department of mechanical Engineering, SRIT, Jabalpur*

***Abstract* - Ordinary Portland Cement is the most common type of cement manufactured today and how to produce it from coal as well as alternate fuel, will be the focus of this review paper. Portland Cement can be used directly as is, or mixed with different additives i.e. slag or fly ash, to form composite cements with various properties. Clinker design makes a great role for combustion of fuel. To provide the energy required for the clinker phase transition, different types of fossil and alternative fuels like biomass, rubber MSW etc are commonly fired through the main burner. Thus, there is a need to find out the applicability of alternative fuel in India cement plant. The objective of the present review paper is: To gain improved methodical and technical facts on the combustion of Municipal Solid Waste as alternative fuels in the cement rotary kiln.**

***Index Terms* - Municipal Solid Waste, alternative fuels, Cement rotary kiln. FEA etc.**

I.INTRODUCTION

The carbon in fossil fuels contributes to ~0.29 kg of CO_2/kg clinker at the prevailing level of fuel efficiency. Fuel costs keep increasing year after year, influencing the costs of production of cement. Therefore, from this angle also substitutes or alternatives which have commercially usable heat value, which produce a lesser quantum of greenhouse gas (GHG) and which are cheaper are proposals worth considering.

The burden of waste generation in our planet is on a massively increasing trend as the economies keep on flourishing and industries keep on developing in different countries and regions. According to the World Bank data, the global generation of wastes in 2016 was a little > 2.0 billion tonnes, which is likely to increase to 2.6 billion tonnes in 2030 and to 3.4 billion tonnes in 2050. In the first decade of this century, the modes of waste disposal in the developing countries were primarily open dumping and burning, while the developed countries took recourse to landfilling, recycling, incineration and composting.

The burden of waste generation in our planet is on a massively increasing trend as the economies keep on flourishing and industries keep on developing in different countries and regions. According to the World Bank data, the global generation of wastes in 2016 was a little >2.0 billion tonnes, which is likely to increase to 2.6 billion tonnes in 2030 and to 3.4 billion tonnes in 2050. In the first decade of this century, the modes of waste disposal in the developing countries were primarily open dumping and burning, while the developed countries took recourse to landfilling, recycling, incineration and composting. It is a matter of interesting coincidence that the top ten solid waste generating countries in 2016 included the first three cement-producing countries of the world, viz., China, India, and the United States as well as some other relatively large cement-producing countries, such as Brazil, Indonesia, Russia, Mexico, Germany, and Japan. Hence, the cement plants with their high-temperature kiln systems and suitable product chemistry turned out to be an appropriate solution to the problem of waste management in most cases. In fact the use of alternative fuels and raw materials (AFR) in the cement production process, which was initiated in the nineteen eighties in some countries essentially as a cost saving measure, pushed the industry into a premier position worldwide as the provider of the most eco-friendly disposal of different kinds of agricultural and industrial waste. Further, in the last decade the plant operational strategy with AFR has been recognized as a potential tool for minimizing the emission of greenhouse gases, and particularly of CO2, from the cement plants. This paradigmatic shift in the cement production process has been possible due to significant technological improvements in the design and engineering of collection, transportation, treatment, distribution, storage and feeding of AFR in large capacity modern cement plants.

1.1 Sources and Types of Alternative Fuels

The selection of fuel for the cement production is an important parameter for the cement plant, especially since the fuel often makes up a significant cost of the plant operation. Before a fuel is selected it is important to consider the following three parameters [39]:

- Costs, e.g. fuel purchase, availability, fuel handling, maintenance.
- Product quality, e.g. impacted by unburnt particles in the clinker
- Environmental impact, e.g. CO_2, CO, and NOX emissions

The non-biogenic waste materials, originating from manufacturing and other industrial processes but not from actions of living organisms, may not necessarily be biodegradable but they contain organic compounds that provide heat and energy on combustion. The renewable biofuels derived in the form of ethanol and diesel from naturally oil-rich edible and non-edible plants form another potential source of alternative fuels [3].

1.2 Biomass Residues

The woodchips and pellets, particularly originating from the construction and demolition waste, are extensively available in India. Rice husk is available in large volume in some of the Asian countries. The cement plants in India are reportedly meeting > 15% of their total thermal need with the help of rice husk.

Coffee husk, sunflower shell, oil palm husk, sugar cane stalk and bagasse, groundnut shell, bamboo dust, etc. are examples of other biomass residues that are used in different countries. It is important to note that the availability of biomass residues is seasonal and region-specific. Hence, the experience of its use is essentially local. Drying is an important process requirement for using biomass, as the freshly cut wood has a low heating value due to high moisture content. The drying process can be either natural or forced with the help of waste heat from the cement plants.

It may be relevant to mention here that the fixed carbon content of biomass residues is generally below 45% but they possess high volatile matter. As a result, they have low calorific value but easy burning characteristics. The ash content of rice husk is much higher than that of other biomass residues. Further, the sugar cane bagasse often shows high phosphorus content (0.7–1.0%). Because of such variations, it is always preferable to evaluate various biomass residues in respect of their sulphur, chlorine, alkali, phosphorus and ash contents before using them in the combustion process.

1.3 Cement Production

The main raw materials used for cement production are naturally occurring limestone, shale, and sand, which are sources of $CaCO_3$, SiO_2, Fe_2O_3, and Al_2O_3.The materials are normally mined in a quarry, which should ideally be placed close to the cement factory, to reduce transportation costs. Raw materials that are relatively dry are usually preferred since removing excess water requires large amounts of energy. Figure 2-1 provides an overview of the different processes in the cement plant after the raw materials have been mined and crushed.

As the raw meal reaches temperatures around 700 °C the calcium carbonate begins to decompose forming calcium oxide. The reaction is highly endothermic and consumes around 60 % of the thermal energy required in the cement process. The energy for calcination is provided by combustion of fuels in the calciner, where the raw meal reaches temperatures between 800 and 900 °C and up to 95 % of the calcium carbonate is converted. Around 50 % of the CO_2 emissions from cement manufacture are due to the decomposition of calcium carbonate.

From the calciner the material is admitted to the cement kiln where it is heated further and undergoes the reactions that gives the cement its characteristic attributes. In the kiln the materials partly melt and form nodules known as clinker.

After the reactions in the kiln, the clinker is quickly cooled by ambient air in the clinker cooler. The preheated air from the cooler reaches temperatures of 1000°C and is used as secondary air for the combustion process in the kiln. Excess air from the cooler is used as combustion air in the calciner, so-called tertiary air.

The cooled clinker is transported to storage until it is needed. The clinker typically has a size of 3-25 mm and needs to be grinded to smaller and more uniform particle size in order to increase the reaction rate of the cement. During the milling different additives such as gypsum, coal fly ash, or sand can be added to the cement in order to control the setting time of the cement. The additives might replace a substantial amount of cement clinker in the finished cement and can reduce the energy requirement and CO_2 emissions of the manufacturing process.

1.4 The Cement Rotary Kiln

The formation of cement clinker occurs in the rotary kiln. Figure 1.2 shows a rotary kiln and a grate cooler indicating the main temperature zones in the kiln. The cement rotary kiln is essentially a long cylindrical tube that acts as a large counter-current heat exchanger. At one end the raw materials, preheated and calcined in the cyclone tower, are admitted at around 900 °C. At the other end of the kiln, fuel is being fired through the burner, to heat the material in the kiln to a maximum temperature of around 1450°C. The kiln is composed of an outer steel shell, which is lined with refractory material that acts as thermal insulator and protects the outer shell. The type of refractory bricks varies along the length of the kiln depending on the temperature of the material and gas. In the hot parts of the kilns, where the clinker melts, a coating is formed on top of the refractory, which further helps insulate and protect the kiln walls.

The kiln is typically 50-100 meters long with diameters between 3 and 7 meters. Old wet kilns are long with L/d around 30, while modern pre-calciner kilns are shorter with L/d around 10-15. The kiln is tilted at 1-3° and rotates at 1-4 rpm to facilitate the movement of the raw materials from one end to the other. The residence time of the raw materials is typically 20-40 minutes with 10-15 minutes in the burning zone, the hottest part of the kiln. The residence time of the gasses is around 5-10 seconds. Typical production capacities are around 3,000 ton/day, but the largest kiln in the world has a capacity of 13,000 ton/day.

Several different types of air are relevant for the combustion process in the cement kiln. Primary air is injected through the burner and can be divided into transport air, axial air, and swirl air (also called radial or tangential air). The transport air is used to pneumatically inject the fuel into the kiln at velocities around 30 m/s. The axial and swirl air are used to control the flame shape. The primary air constitutes around 5-15 % of the air required to combust the fuel. Older generations of burners may have used up to around 30 % primary air.

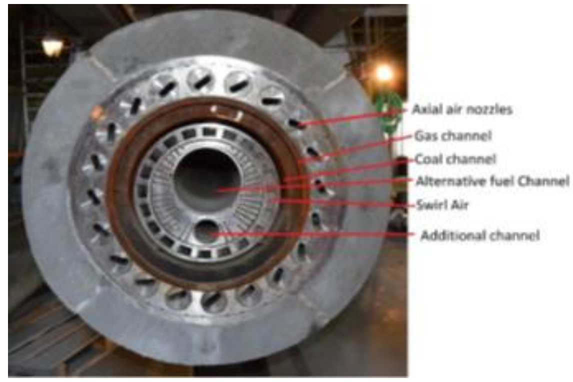

Figure 1.1 Kiln Burner

II-LITERATURE REVIEW

C. Pieper et. al. (2020) presents CFD simulation of a commercial scale revolving klin for concrete clinker creation. The fuel for the klin fire is a blend of pulverized coal and a Refuse Derived Fuel (RDF). In the research propelled models were created to fittingly portray the warm change attributes and optimal design of non-round RDF particles. The models depend on point-by-point fuel parameters investigations (e.g., flight and ignition attributes, physical and substance fuel properties) of major RDF divisions, similar to plastic foils, 3D plastic particles, paper and cardboard and materials. The procedures in the clinker inside the kiln are estimated utilizing a basic one-dimensional model that figures heat and mass transfer with the gas stage and the subsequent synthetic mineralogical responses in the solid bed. Calculation results of the one-dimensional model were compared to measurements obtained from a semi-industrial laboratory rotary kiln.

The research done by Galina S. Nyashina et. al. (2019) is depending on the search of a lot of manufacturing divisions (coal handling, wood preparing, transport, oil, and water treatment) so as to distinguish the sum and kind of explosive waste appropriate for combustion.

The principal explosion and combustion parameters of these wastes have been tentatively developed from their immediate individual combustion in the original form and as a major aspect of a slurry dependent on wastewater. It has been built up that a lot of parameters permit waste fuel blends to rival coal residue and fuel oil with a natural bit of leeway. The test results acquired are the reason for the improvement of helpful innovations for the sheltered and proficient burning of waste from various ventures.

The objective of study present by Chaouki Ghenai et. al. (2019) is to explore the combustion execution and discharge qualities of SPL as alternatively fuel in the concrete industry. The aim was to create maintainable procedure frameworks by utilizing solid waste materials, for example, SPL from the Aluminium industry as a fuel in the concrete industry. The proximate (moisture, volatile, fixed carbon, and ash contents) and ultimate (C, H, O, N, S) analysis with higher heating value (MJ/kg) of the crude and treated SPL materials are resolved first. The outcomes show that the last treated fuel can be utilized as elective fuel in the concrete industry to dislodge coal fuel and lessen the toxin outflows from the combustor in the concrete industry.

The article given by Anjan Chatterjee et. al. (2019) focused around combustible waste materials utilized in clinker making through 'co-preparing', which is considered as the most suitable methods for vitality and asset recuperation and the resultant decrease in the utilization of traditional energizes without disabling the quality and properties of clinker and cement. It is relevant to make reference to here that the investigations identifying with the material structure and the designing parts of co-preparing of elective powers are definitely more bottomless in the distributed writing than on their impacts on the procedure and properties of clinker. Consequently, the study depends more working on it studies and preliminary information of the creators, notwithstanding the data accessible in the writing.

Zsofia Fodor et. al. (2012) gives a brief review on the use of waste as an elective fuel, usually mentioned to as Waste-to-Energy (WTE). The study encloses a broad survey of the literature available in this field with proportional analysis of different methodologies and procedures. The fundamental highlights and properties of metropolitan and modern waste have been breaking down as these can change essentially from area to area and year to year.

The paper talks about the applicability and constraints of present and creating WTE advancements just as new and rising WTE advances and the ongoing improvements in the plan of for delivering warmth, force and powers. Systems that are considered incorporate criteria for innovation choice, together with the methodology that conform to the natural EC guidelines Best Available and Best Applicable Techniques (BREFs).

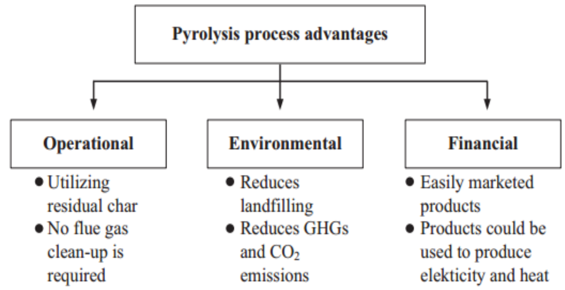

Figure 2.1 Pyrolysis process advantages (reported at Zsofia Fodor et al.2012)

III-CONCLUSION

To provide the energy required for the clinker phase transition, different types of fossil and alternative fuels are commonly fired through the main burner. In this work, CFD simulations of a cement rotary kiln, which include advanced models for RDF combustion and a 3D-model for modelling the clinker bed, are presented. The Municipal solid wastes is used as alternative fuel in combination with coal.

The following observation have been made after the review of previous research:

1. It has been observed that as the jet air temperature increases the kiln temperature also increases. The increment follows the polynomial curve of second order.
2. It has been observed that the fuel particle sizes influence the drying and devolatilization inside the kiln during the combustion process within a very short time.
3. The different fuel like biomass, rubber, industrial wastes and other waste can also be used as alternate fuel.
4. The design of the kiln burner should also be examined for better performance.
5. Fuel cost, environmental impact, and potential impact on the kiln process are some of the factors that should be considered in further investigation.

REFERENCES

[1] Azad Rahman, M.G. Rasul, M.M.K. Khan, S. Sharma, “Impact of alternative fuels on the

cement manufacturing plant performance: an overview", Procedia Eng. 56 (2013) 393–400

[2] Andile B. Maqhuzu, Kunio Yoshikawa, Fumitake Takahashi, "The effect of coal alternative fuel from municipal solid wastes employing hydrothermal carbonization on atmospheric pollutant emissions in Zimbabwe" Science of the Total Environment 668 (2019) pp.743–759

[3] Anjan Chatterjee, Tongbo Sui, "Alternative fuels - Effects on clinker process and properties" Cement and Concrete Research 123 (2019) 105777

[4] Christopher Csernyei, Anthony G. Straatman, "Numerical modeling of a rotary cement kiln with improvements to shell cooling" International Journal of Heat and Mass Transfer (2016) pp. 610–621

[5] Chaouki Ghenai, Abrar Inayat, Abdallah Shanableh, Eman Al-Sarairah, Isam Janajreh "Combustion and emissions analysis of Spent Pot lining (SPL) as alternative fuel in cement industry" Science of the Total Environment 684 (2019) pp. 519–526

[6] C. Pieper, B. Liedmann, S. Wirtz, V. Scherer,"Interaction of the combustion of refuse derived fuel with the clinker bed in rotary cement kilns: A numerical study" Fuel 266 (2020).

[7] E. Mastorakos, A. Massias, C.D. Tsakiroglou, D.A. Goussis, V.N. Burganos, A.C. Payatakes, "CFD predictions for cement kilns including flame modelling, heat transfer and clinker chemistry" Applied Mathematical Modelling 23 (1999) pp.55-76

[8] Fayza S. Hashem, Taha A. Razek, Hani A. Mashout "Rubber and plastic wastes as alternative refused fuel in cement industry" Construction and Building Materials 212 (2019) 275–282

[9] Galina S. Nyashina, Ksenia Yu. Vershinina, Nikita E. Shlegel, Pavel A. Strizhak,"Effective incineration of fuel-waste slurries from several related industries" Environmental Research 176 (2019).

[10] Prashant Sharma, Bhupendra Gupta, Arun Kumar Sharma, Hemant Parmar, Prashant Baredar, "Municipal Solid Waste in combination with coal as alternative fuel for cement plant: Energy Feasibility Analysis", APGRES 2019

[11] Chase, M.W., Jr., NIST-JANAF Themochemical Tables, Fourth Edition, J. Phys. Chem. Ref. Data, Monograph 9, 1998, 1-1951.