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Industrial Applications of Rotary Kiln in Various Sectors - A Review

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Abstract **- A Rotary kiln is a cylinder which rotates around its cylindrical axis and acts as a device to exchange the heat. The construction, position and alignment of kiln is a essential factor for the smooth operation. Slight inclination with the horizontal axis makes the movement of solid bed towards the discharge head. The operational efficiency of the kiln is based on various parameters like inclination angle, temperature, rotation speed, material flow rate and discharge rate. This paper briefly discusses the various industrial application of the rotary kiln in various sectors considering the vital factors**

Keywords **- Rotary Kiln, Dryer, Incinerator, Pyrolyser, Heat Treatment.**

I. INTRODUCTION

The rotary kiln is a horizontal circular cylinder lined with refractory material supported by support stations and driven via a girth gear and drive train. The drive train consists of DC electrical motors and gear boxes with hydraulic packs which is clearly shown in fig. 1 the kiln cylinder is located at an angle to the horizon and rotates at low revolutions around its longitudinal axis and operates essentially as a heat exchanger, dryer, calcinator and incinerator. The inclination of cylinder makes an axial displacement of the solid bed, which moves towards the discharge end. The rotating cylinder acts simultaneously as a conveying device and stirrer by the use of internal fins which helps to mix and rotate the material in radial direction. Inclination angle of the cylinder, operating temperature, rotating speed, material flow rate and discharge rate are the vital parameters for the performance of the kiln. Kiln control is one of the most vital parts and the kiln is very sensitive for operation. Control of the kiln during its operation the assemblage of various components and process parameters is essential one in the rapid fast developing environment. Kiln is generally used for the processes like activated coal regeneration, lignite degasification, municipal waste disposal, scrap tire recycling, sewage sludge disposal, soil cleaning, waste wood recycling. Indirect heated rotary kilns are used for pyrolysis and thermolysis processes due to the advantages of continuous process, very good blending of the product unlike batch processing and simple plant layouts.

The fig. 1 shows the arrangement of rotary kiln with accessories. Kiln can be used as a rotary dryer to remove water and moisture content from solid substances by introducing hot gases into a drying chamber. Kiln shell should be structurally strong with non-conductor lining and designed to withstand high temperature and prevent the thermal losses of the kiln.

Fig.1. Rotary kiln arrangement

II. APPLICATIONS

A rotary kiln is a cylinder that rotates around its cylindrical axis and essentially operates as a device to exchange heat. The direct heated rotary kiln is broadly used for physical activation. Construction and position alignment of the kiln is very important for all the process. In thermal processing of residual materials with a various origin and predominantly for fire treatment of hazardous wastes rotary kiln are employed. In metallurgy they serve for heating of solid particles like oxide ores reduction, limestone calcination, cleaning of swarfs from machine oil. Furthermore, these units find a large application in the silicate, chemical and pharmaceutical industry also used as an incinerator and pyrolyser in minerals, metallurgical, cement, sugar and food industries. In these sectors they are used mainly for heating and drying of bulk materials with different dimension.

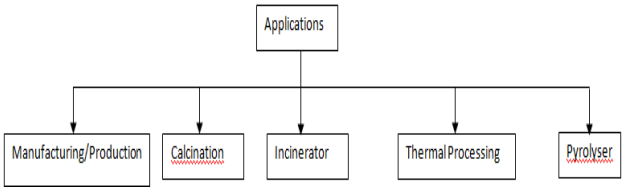

Fig.2. Various industrial applications of rotary kiln

Rotary kilns find its numerous industrial applications in the field of waste lime recovery, proppent manufacture, activated carbon manufacture, sugar industry, food processing, pulp and paper industry, clays, thermal desorption of organic/hazardous wastes, mineral roasting, specialty ceramics, plastic processing, gypsum calcining, Tire pyrolysis, bauxite calcining, pigments, catalysts,phosphate production. The fig. 2 shows the various industrial applications of kiln which are explained in the following sections of this paper in detail.

A. Cement Kiln

In cement manufacturing industry cement clinker is produced from $caco_3$ by using rotary kiln of length 63m and 4.3m in diameter with an average production capacity of 3000tonnes per day. The initial temperature while entering decomposition zone is 850°C then increased to 900°C and 1450°C while entering transition zone and sintering process zone and final temperature of sintering zone is 1300°C [1] and different types of alternative fuels were used in these cement kiln for combustion [2]. In cement kiln chrome-free brick with the addition of TiO_2 is improved all properties as well as the coating ability and corrosion resistance of the brick that exhibit a good thermal stability and an excellent chemical resistance clinker raw meal. This brick has qualities needed in the hot zone of rotary cement kiln [3]. The cement is made of clinker and grinded gypsum and produced from a burned mixture of limestone and clay, for this process rotary kiln is used for making cement clinker. The length of the kiln is 124.4m and inner diameter is 4.2m with 4% slope [4].

B. Calcination

The limestone calcination as energy intensive production process from unhydrated lime is often performed in continuously operating rotary kiln through the chemical reactions takes place in the bed of raw material as well as in the gas phase [5]. Inclined kiln is used to produce sodium metasilicate from Soda – Ash and produce calcined product of lime and dolomite in glass melting [6]. Large amount of Sugar – Ash materials are produced as a by-product in the sugar industry. These materials can be re – cycled with the use of rotary kiln in the lime industry at calcinations temperature in the zone of 950 - 1000°C [7]. According to Les Edwards, Rotary kiln have been used successfully for many years to produce calcined coke for the aluminium industry [8]. Calcinations process is performed in rotary kiln with the temperature around 1350°C. Retention time depends on the size of the limestone as well as calcination temperature. In this calcinations process both vertical and horizontal kilns were used. On vertical kilns, the limestone moves downward and the hot gases flow upward through the limestone. These kilns usually use limestone sizes between 0.13 to 0.2m and operating temperature is between 900 to 1000°C. Vertical kilns are fuel efficient but limited in capacity. On horizontal kilns, the kiln body rotates allowing the limestone to tumble and exposing all of the surfaces to hot gases. These kilns usually use limestone size varying between 0.04 to 0.05m which allows for quick heating and short residence time but the ideal size for calcining limestone is between 0.0125 to 0.02m [9]. Calcinations of limestone has been carried out in a rotary kiln under certain operating variables such as limestone type, feedrate, rotational speed, inclination angle. In this process limestone feedrate has the strongest effect on the temperature and calcinations fields where as inclination angle and rotation speed are relatively less important. The physical parameters of the kiln are 5.5m long, 0.61m OD and 0.406ID. The kiln is lined with 0.092m of plicast tuff-lite over a 0.002m layer of insulating fibre [10]. Kiln is used for the calcination of calcium carbonate (limestone) in the regeneration of Kraft pulping chemicals and in the production of industrial calcium oxide (quicklime) [11].

C. Manufacturing

A rotary kiln is used in iron manufacturing industry which has two zones namely preheating zone and reduction zone and can mix the solid charge as it heats and reduces the simultaneous mixing which helps in the dilution of CO_2 concentration formed around the iron ore particles [12]. In ironmaking plant direct reduction rotary kiln is used for the prereduction of the titani-ferous iron ore. The hot prereduced iron is discharged at a temperature of about 1100˚C in to kiln hoppers [13]. The similar type of rotary kiln is used for making aluminium in aluminium remelting plant from aluminium scrap. The length of the kiln is 4.8m and diameter is 3.5m with 5 to 35° inclination. Aluminium scrap is charged and liquid aluminium is discharged through the front aperture with the melting capacity of 4T aluminium scrap per hour but filling capacity is 8T per hour [14]. Rotary kiln is also used in the production of sarooj with 200kg/hr production capacity by burning specific clay soil that posses adequate quantity of silica, alumina, and iron oxides. The external diameter of the kiln is 1.2m, overall length of the kiln is 3.17m, and operating temperature is 750°C, material feed rate is 200kg/hr with speed of rotation of cylinder is 30rpm [15]. Rotary kiln is also used in pellet induration process, a complex process in pellet production under the premises of the maximum productivity and minimum fuel consumption with sufficient mechanical strength and thermal stability [16]. A pilot rotary kiln, used to manufacture activated carbon from eucalyptus wood, length of the kiln is 3.7m internal and external 0.30m and 0.60m with 2 to 6° slope and rotation speed is 1 to 3 rpm. The processing temperature is between 800-1100°C [17]-[18]. Kiln is used for mixing of glass powder slurries in concrete manufacturing to improve mechanical properties [19]. Kiln is used to supply reburned lime in the recausticizing operation [20]. Tauqeer Abbas.et.al, reviewed that from the flue gases of brick kiln can produce ammonium bicarbonate as a fertilizer for the use of agriculture need and economy [21].

D. Incinerator

Rotary kiln is used as waste incinerator, the cylinder is mounted at an angle of 1-2° and rotates at a speed of 0.2 to 0.3rpm, and diameter is 4.2m and 11.4m length. Two types of hazardous wastes are incinerated in the rotary kiln system having high caloric waste such as waste oil and solvents, with a calorific value of roughly 30MJ/kg and having low caloric waste an average value of 9 to 10MJ/kg. The burning temperature of the waste inside the kiln wall is 1200°C, mixing temperature of 1250°C and solid bed temperature of 3157°C with mass flow rate of 12.5kg/s [22]. Plasma combustion of hazardous medical waste process is done by using kiln with direct motion of burning hazardous medical waste and incandescent gases with the capacity of 150-200kg/hr. About 60% of organic part of the waste burn in this process [23]. According to M.J.Gazquez.et.al rotary kiln is used for the removal of

waste content and trace amount of sulphur from TiO_2 [24]. Rotary kiln is used for refining of used oil generated from automotive industries in this refining process kiln is used as incinerator [25].

E. Thermal Processing

The broad application of the rotary kilns in a variety of industrial branches for thermal processing of residual materials with a different origin and mostly for fire treatment of hazardous wastes [26]. The rotary kilns were used as rotary dryer to remove moisture and water from solid substances (olive stones), primarily by introducing hot gases into a cylinder, it act as a conveying device and stirrer. After the first extraction of olive oil from olive stone, still that contains oil which can be chemically subtracted by the drying process. The processing temperature is 427°C and cylinder inclination is 2°. Around 8 to 10% of moisture gets reduced by this process [27]. Followed by this rotary kiln is used as a dryer for yerba mate heat treatment processing. The length of the kiln is 9.6m and internal diameter is 2.57m, the inclination of the cylinder is 60° with respect to horizontal axis. Material feed rate is 0.282kg/s and processing temperature is 120°C. Rotation speed of the cylinder is 10rpm [28]. D.Peinado.et.al, reviewed that rotary kiln is used as a dryer employed in a hot mix asphalt (HMA) plant for heating and drying of the aggregates. The operating temperature is between 150°C and 200°C [29]. For drying magnesite ore rotary kiln is used as a dryer with operating temperature of 100°C [30].

F. Pyrolyser

The main purpose of a rotary kiln pyrolyser is to convert olive pits into char fated to the production of activated char. The capacity of plant is about 2000kg/hr of wet olive pit, distribution of pyrolysis products as function of the process temperature (50 - 750°C) at fixed biomass with flow rate of 1700kg/hr. operating temperature of 300 - 400°C and higher operating temperature is 800 to 900°C, length of the kiln is 20m and internal diameter is 1.6m [31]. Rotary kiln is used for recycling of waste composite material (thermoset – based polymer composites) collected from the products such as automobiles, wind turbines and aircrafts [32]. Rotary kiln is also used for transforming solid biomass into useful liquid and gaseous fuel in this process rotary kiln act as pyrolyser. The inclination of cylinder is of few degrees, with internal fins which help to mix and rotate the biomass in radial direction. The rotational speed of the cylinder is 10 to 100rpm and reaction temperature is above 350°C [33].

III. Geometrical and Process Parameters of Rotary Kiln

Table 1: Geometrical and process parameters of rotary kilns in various processes

Applications	Length (m)	Inner Diameter (m)	Inclination Angle (degree)	Temperature (°C)
Cement	63-125	4.2-4.3	4% slope	850-1350
Calcinations	5.5	0.406	1-4% slope	950-1450
Aluminium plant	4.8	3.5	5-3.5°	800
Activated Carbon	3.7	0.3	2-6°	800-1100
Incinerator	11.4	4.2	1-2°	3000
Thermal Processing	9.6	2.57	60° Angle	120
Pyrolysis	20	1.6	Adequate	800-900

The pertinent information of rotary kiln is illustrated in the table. 1 based on the review done in this paper. The geometrical size of the kiln is based on the requirement of production capacity. Fig. 3 illustrates the usage level of the rotary kiln in various applications.

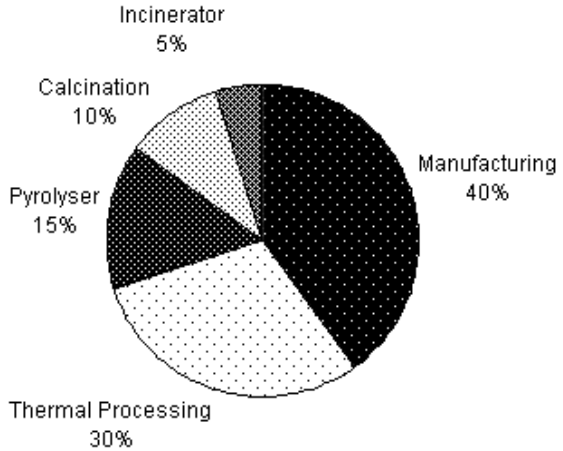

Fig.3. Allocation of application levels

From the review it can be inferred that 40% is used in manufacturing sector, 30% is used in thermal processing applications, 15% is used as a pyrolyser, 10% is used for calcinations and 5% is used as an incinerator.

III. Conclusion

Rotary kiln is widely used in the production of cement clinker, Calcination of limestone, producing activated carbon, sponge iron production, metallurgical, minerals, food and sugar industries, it can also used as an incinerator and heat treatment system (dryer) for the process of liquid and solid hazardous and medical waste, drying olive stone. The vital factors affecting the performance of rotary kiln for various applications is elaborated in a lucid manner. For all the applications, the inclination angle and process temperature plays a main controlling factor for the operation of the kiln.

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