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Consumption of energy in the manufacturing of ceramic bricks in the metropolitan area of Cúcuta, Colombia

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Abstract. This research determined the consumption of electrical and thermal energy in the manufacturing of ceramic bricks in the metropolitan area of Cúcuta, city located in Colombia, South America. Three bricks manufacturers were selected using extrusion forming technology, artificial drying and tunnel kiln firing in their production system. An inventory of equipment that consumes electrical energy in industrial facilities was made, quantifying the power consumed and relating it to the monthly work hours. In order to estimate the thermal energy demand generated by the coal supplied in the drying and firing stages, we worked under the regime of stationary operation, measuring the mass of coal dosed in the drying and firing cycle, keeping the pressure variables stable and the temperature. We know that by cogeneration, part of the combustion gases of the furnace, are provided as a flow of hot air to the artificial dryer. The demand for electrical energy in the process was 42000kWh/month; while the thermal energy consumption was 998010kWh/month; and the monthly global energy consumption was 1040010kWh. It was concluded that the distribution of consumption was 96% of thermal energy and only 4% is electrical energy; the stages of firing and drying being those of greater energy expenditure.

1. Introduction

The current demands required by the construction market, need that the companies that manufacture ceramic products have the challenge of improving current production systems by incorporating and developing new technologies and designing new products to offer a promise of differential added value. This will allow them to satisfy the requirements of the current market and venture into other potential oriented towards innovation, productivity, competitiveness and environmental protection.

Energy management is a determining factor in the productivity of the industrial sector. It depends on technological development and cultural changes; where in the latter, there are various measures to achieve the rational use of resources. In this context, the challenges for the industry are found in: developing new technologies to generate green energies and process optimization; apply automated systems to control the operation of equipment or systems to reduce consumption of natural resources and use of new materials to reduce losses and CO_2 generation [1].

Energy efficiency is understood as the relationship between the energy output and input energy in a specific process, where the appropriate use of energy is sought, not using it in unnecessary activities and using the minimum possible energy consumption [2].

The manufacturing of ceramic products for construction is characterized by having a high energy consumption and end products with a relatively low added value. This debate about the sustainability of the ceramic industry is based on the protection of the environment and the challenge that this sector has in the efficient use of resources, which forces them to reevaluate their activities, processes and impacts, particularly those related to the rational use of energy [3].

The production of ceramic bricks in Colombia has increased by a third in the last ten years, and regions such as the metropolitan area of Cúcuta stand out for their contribution to this growth. In the last decade the metropolitan area of Cúcuta has been among the main producers of bricks, being the second region in the national production of this products, due to the high concentration of manufacturing companies in this geographical area.

Ceramic bricks manufactured in the metropolitan area of Cúcuta Colombia are classified as: bricks and vertical and horizontal drilling blocks, structural and non-structural [4]; the industries that produce greater volume of these units, are characterized by using in their production processes: dry milling, extrusion molding and firing in tunnel kilns.

As an effect of the expansion of the ceramic industrial sector in the metropolitan area of Cúcuta Colombia, the demand for fossil fuels (coal) for the generation of thermal energy has increased, as well as the consumption of electric energy for the supply of the stages of the productive process; generating the emission of carbon dioxide (CO_2), which is one of the greenhouse gases responsible for climate change and global warming [5].

Energy is one of the main costs of ceramic products for construction, knowing more deeply the thermal and electrical energy consumed in the production stages, it becomes an important tool to develop corporate programs of cost reduction and environmental management [6], which is a challenge for manufacturing companies; for which the study, has allowed to know the energetic consumption for the production of ceramic bricks in the metropolitan area of Cúcuta Colombia, with the purpose of establishing environmental actions oriented to the rational use of energy and reduction of greenhouse gases.

2. Methods

The methodology used to determine the energy consumption in the process of manufacturing ceramic bricks in the metropolitan area of Cúcuta Colombia, was the guide for the implementation of the "Integral Energy Management System", taking only stage 2 as a reference, which it refers to the implementation of the energy management system, applying the definition of the energy monitoring and diagnosis system [7].

2.1. Materials

The equipment used to make measurements in the production processes of the three industrial facilities selected in the investigation were: PCE-PA8000 energy meter to determine the electric consumption, and Mettler Toledo portable analog ramp with a capacity of 200kg to determine the mass of mineral coal used to generate thermal energy in the firing process.

2.2. Diagnosis of electrical energy

Three manufacturing industries of ceramic bricks were selected, taking inventory of equipment that requires electrical energy in the production process and grouping them into the stages of: grinding, mixing, extrusion, drying and firing. Subsequently, the connection points of the energy meter between the current sockets and switches were determined, establishing ten random measurements in working hours for each inventoried equipment. The data reported was presented in units of power measurement in kilowatts kW, which were calculated to units of energy kWh, taking the monthly work time of each equipment analyzed.

To obtain the value of the electrical energy demanded in the process, the expression below was used:

$$E_{\varepsilon=P\times t} \tag{1}$$

Where, E_{ε}=Electric power (kWh), P=Power (kWh), and t=Time (h).

2.3. Diagnosis of thermal energy

The experimental measurements in the three industrial facilities selected for the study were carried out in a steady-state mode, that is, during the measurement of the coal supply in the artificial dryer and tunnel kiln. There were no changes in the pressure and temperature variables of the drying and firing cycle.

The mass of coal used as fuel in the drying and firing stage was measured with the ramp-type industrial scale, before being dosed in the combustion chambers of the dryer and furnace.

The calculation of the thermal energy generated to supply the ceramic bricks manufacturing process was determined with the estimation of the mass of the fuel; and the relation with the calorific value, which was obtained through the next analysis of the coal in the SGS Laboratories. With this information, the value of the thermal energy generated in the drying and firing stage was calculated using the expression:

$$E_{\tau=mc\times cp} \tag{2}$$

Where, $E_{\tau=}$Thermal energy (kWh), mc =coal mass (kg), and cp =Calorific value (Kwh/kg).

3. Results and discussions

3.1. Electric energy consumption

According to the measurement of electrical energy made to the equipment that make up the ceramic industrial facilities in the metropolitan area of Cúcuta, the estimated energy demand required for the manufacture of ceramic bricks is: 42000kWh/month, as shown in the Table 1.

Figure 1 shows the percentage of electricity consumption in the ceramic brick manufacturing process in the metropolitan area of Cúcuta Colombia.

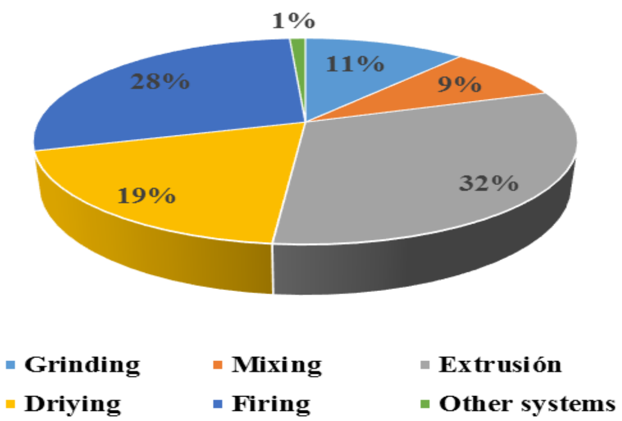

Figure 1. Percentage of electricity consumption in the process stages of ceramic bricks in the metropolitan area of Cúcuta Colombia.

The four stages of the process of manufacturing ceramic bricks in the metropolitan area of Cúcuta with the highest electric power consumption are: extrusion with 32% of the electrical energy consumed in the production plant, preceded by firing with 28%, drying with the 19% and 11% grinding of electricity consumption in industrial facilities. This is because the extrusion operation demands a high power of the forming system; which includes the model and cut of the wet material, where a product with adequate plasticity and compaction must be guaranteed to meet the technical parameters of mechanical resistance to compression that allows defining the capacity of the ceramic product to withstand the load of force axial [4]. While in the firing cycle, the electricity consumption is determined by the ventilation system and recirculation of the air flow [9]; together with the energy provided for the milling and dosing of the coal to the combustion burners of the tunnel kiln.

Table 1. Consumption of electrical energy in the ceramic brick manufacturing process in the metropolitan area of Cúcuta Colombia.

Stage	Machines and devices	Consumption of electric energy (kWh/month)	Total Consumption of electric energy (kWh/month)
Grinding	Feeder box	58	4811
	Conveyor belt 1	209	
	Conveyor belt 2	418	
	Hammer mill 2	3290	
	Bucket elevator	406	
	Vibrotamiz	325	
	Conveyor belt 3	105	
Mixing	Conveyor belt 4	103	3576
	Conveyor belt 5	310	
	Mixer	3163	
Extrusion	Conveyor belt 6	245	13289
	Vacuum pump	1548	
	Extruder	11096	
	Electric cutter	168	
	Conveyor belt 7	232	
Drying	Turbine dryer	1301	7958
	Fan system	3533	
	Drive chain system	596	
	Extractors System	2439	
	Transfer	89	
Firing	Hydraulic Jack	407	11899
	Draft fan	5853	
	Carbojet 1	1304	
	Carbojet 2	1335	
	Winch	9	
	Coal mill	490	
	Conveyor belt for domification of coal	117	
	Pre-furnace fan	2384	
Other systems	Electric board	199	467
	Compression system	268	

3.2. Thermal energy consumption
The monthly fuel demand needed for the artificial drying and firing cycle in the tunnel kiln is: 117000kg of coal, distributed consumption: 41000kg in the drying stage, and 76000kg in the firing operation. According to the analysis of the coal selected for the study, it was estimated that the average calorific value of the coal supplied in the drying and firing operations of the ceramic industry of the metropolitan area of Cúcuta is: 8.53kWh/kg.

Table 2 shows the consumption of thermal energy for the manufacture of ceramic bricks in the metropolitan area of Cúcuta. The consumption of thermal energy in the production process of ceramic bricks in the metropolitan area of Cúcuta is: 998010kWh/month; distributed in the firing stage with 65% and in drying with 35% and can be seen in Figure 2.

Table 2. Consumption of thermal energy in the manufacturing process in the ceramic bricks manufacturing process in the metropolitan area of Cúcuta Colombia.

Stage	Coal mass (Kg/month)	Calorific power (kWh/kg)	Thermic energy consumption (kWh/month)
Drying	41000	8.53	349730
Firing	76000	8.53	648280

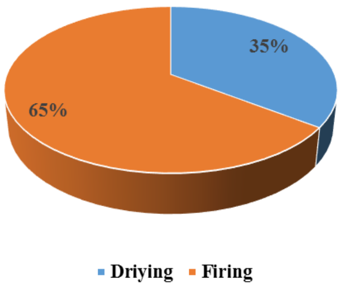

Figure 2. Percentage of thermal energy consumption in the drying and firing stages in the ceramic bricks manufacturing process in the metropolitan area of Cúcuta Colombia.

The thermal energy consumption is greater in the sintering stage, compared to the drying, due to two reasons: the first and the most important, the sintering temperature of the ceramic bricks is: 1050°C [10], while the temperature of the drying process ranges from: 60°C-80°C. In addition, 40% of the combustion gases generated in the firing stage are supplied to the artificial dryer as: hot air flow.

The thermal efficiency of a tunnel kiln is higher than 70%-75%, referred to the heat of combustion and the calorific value of the fuel, being more energy efficient than a Hoffmann kiln, which ranges between 50% and 55%. The same behavior occurs with the chamber dryer that is 45% -55% efficient, while that of a tunnel dryer is greater than 70% [11].

If we compare the thermal energy consumption for the manufacture of ceramic bricks in the metropolitan area of Cúcuta in Colombia, with respect to the energy demands of the ceramic tile industries in Spain and Brazil, it is observed that in both countries 92% The final energy demand required for the manufacture of ceramic tiles corresponds to thermal energy [12], while at the local level the thermal energy consumption is 96% in the manufacture of ceramic bricks.

Figure 3 shows the relationship of electrical and thermal energy consumed in the process of manufacturing ceramic bricks in the metropolitan area of Cúcuta in Colombia.

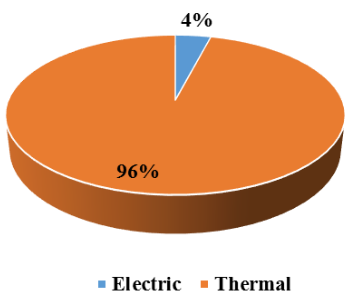

Figure 3. Percentage of thermal and electrical energy consumption in the manufacture of ceramic bricks in the metropolitan area of Cúcuta Colombia.

In addition, the overall energy efficiency (electrical and thermal) in the Spanish and Brazilian ceramics industry compared to that of the region is higher due to the type of technology and automation of the production plants and the characteristics of the products produced, specifically by the volumes and types of manufactured products that optimize the rational use of energy, measurement and control of energy losses, and cogeneration systems with high yields.

The manufacturers of ceramic bricks in the metropolitan area of Cúcuta, are not alien to the changes and current and prospective development of industry and services, in an open and globalized economy, which makes the regional ceramic industry require actions aimed at reduce costs and increase competitiveness, through the efficient use of energy as a fundamental tool to achieve a balance between economy and environment, maintaining the level of business profitability; knowing that at present the companies have seen how the energetics have gone from being a marginal factor in their cost structure to constitute an important item in them [13].

The diagnosis of energy consumption for the manufacture of ceramic bricks in the metropolitan area of Cúcuta was made using the traditional method of energy audit, if compared with the exergy concept, it would be possible to determine with more precision the performance of the analyzed process. In effect, conventional energy analyzes, which are based on the first principle of thermodynamics, actually constitute a simple energy accounting. On the contrary, the exergy analysis based on the second principle of thermodynamics takes into account not only the quantity of energy but its quality. This allows to define the efficiency with greater rigor [14].

4. Conclusions

The consumption of thermal energy is significantly greater than the demand for electricity for the manufacturing of ceramic bricks in the metropolitan area of Cúcuta, Colombia with a ratio of 24:1 in energy demand, being less efficient than the processes of the Spanish and Brazilian ceramic industry. The process is characterized by the concentration of energy expenditure in the firing and drying stage, becoming the biggest challenges to establish environmental management strategies.

The knowledge of the electrical and thermal consumption in the manufacturing of ceramic bricks, will allow taking corrective actions related to the operating conditions, the cycle of use of equipment and the technological change, with the aim of orienting the actions to the efficient use of energy, reduction of production costs and greater control over the atmospheric emissions generated.

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