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Increasing the Effectiveness of Fireclay Bricks Production

Katarina Culkova[1]*, Andrea Rosova[2] and Katarina Teplicka[1]*

[1]*Department of Earth Sources, Technical University of Kosice, Slovakia*

[2]*Institute of Logistics, Technical University of Kosice, Slovakia*

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***Corresponding author**: Katarina Culkova, Katarina Teplicka, Department of Earth Sources, Technical University of Kosice, Letna, Slovakia

Abstract

Bricks are a widely used construction and building material around the world. A wide variety of waste materials have been studied to produce bricks with different methods, but the obstacle is the absence of relevant standards, and the slow acceptance of waste materials-based bricks by industry and public. The aim of the paper is to find out the way for increasing of effective production of fire clay. For better idea of production process operation for fireclay bricks simulation model had been constructed in program Tecnomatix Plant Simulation. The results show possible speeding up and increasing production volume, cost and gas consumption, decreasing with total more effective operation during fireclay bricks production.

Keywords: Production process; Fireclay bricks; Logistics; Production effectiveness

Introduction

Bricks are a widely used construction and building material around the world. Conventional bricks are produced from clay with high temperature kiln firing or from ordinary Portland cement (OPC) concrete. The worldwide trend is characterized by increasingly rapid growth of consumption. The consumption leaves in its trail a massive amount of solid, liquid and gaseous waste. With the growing shortage of raw materials on the one hand and an increasing threat to the environment on the other hand, an increasing need for more sophisticated and efficient use of wastes [1]. A wide variety of waste materials have been studied to produce bricks with different methods, but the obstacle is the absence of relevant standards, and the slow acceptance of waste materials-based bricks by industry and public [2]. For example, Azhar et. al [3] characterized clay bricks produced by the addition of the two agricultural waste materials, which on the other hand can protect environment [3]. Furthermore, the additions of wastes have reduced the unit weight of bricks which decrease the overall weight of the structure leading to economical construction.

The next waste material for bricks production can be fly ash, originated by geopolymerization. It presents secondary products, rising during coal burning, as slag [4]. Geopolymer are characterized as nets of mineral molecules, connected by covalent relations, rising by creation of long chains and connection of four-membered silicon atoms and trivalent aluminum in combination with oxygen. For geopolymer creation any material can be used, consisting of the mentioned elements in amorphous way, for example kaolinite, clay, andesite, etc. Classical high-temperature fly ash (class F fly ash according to ASTM C618) is the most important and fly ash from fluidized technology (class C fly ash) is the second group. Utilization of these products in ceramic technology means a reduction of raw material costs and it helps to reduce adverse environmental impact [5].

Elmaghraby et. al [6] studied the suitability of some waste kaolinite sand as grog for bricks and concretes [6]. They confirmed chemical and phase composition on fireclay with total impurity oxide contents (TIOC) less than 3.0 %, while silica is with TIOC less than 0.5 %. The microstructure of fireclay shows predominant mullite crystals, bonded by silicate phases as confirmed by XRD, whereas silica phases are the main components of the third sample with minor intercalation of mullite phase. It is concluded that fireclay is fired at 1500°C and can be used as grog for brick and concrete manufacture in industrial furnaces up to 1400°C.

Velasco et. al [7] studies the addition of kindling from vine shoots in the production of fireclay bricks to achieve a better insulation of the building´s enclosure and a new way for recycling vine shoots, a waste which is widely produced in vineyards [7].

The influence of kindling addition on the thermal and mechanical properties of the fired clay bricks and the added waste has improved bricks conductivity properties by reducing it up to 62% compared to the brick made without any waste.

Cultrone et. al [8] studied two types of raw clay with a composition representative of that used in brick-making industry: one contains notable amounts of carbonates, with a grain size of under 1mm, and the other is predominantly quarzitic and lacking in carbonates, demonstrating that the presence or absence of carbonates strongly influences the porosity development and, therefore, the brick texture and physical-mechanical properties [8]. The carbonates in the raw clay promote the formation of fissures and of pores under 1μm in size when the bricks are fired between 800 and 1000°C. The absence of carbonates results in a continuous reduction in porosity and a significant increase in the pore fraction with a radius (r) >1μm as the firing temperature rises and smaller pores coalesce.

The next material can be lithomarge clay underlying bauxite deposits; it is non-plastic and therefore cannot be used to produce ceramic bodies. Properties such as bulk density, apparent porosity, linear firing shrinkage, and compressive strength were investigated by Andrews et. al [9]. The results show the properties measured depends on both the temperature and dwell time. The optimum compressive strength of such bricks could be achieved either by firing at 1350°C for 120 minutes or at 1400°C for 30 minutes.

Experimental

The biggest producer of refractory materials is China that in present time produces 66% of whole world production. In the EU area there is 10% of production, in USA - 4%, India - 3%, Japan - 2%, Latin America – 2% and 13% in other countries (Figure 1) [10]. China, as biggest producer, in comparison with the world is illustrated by Table 1, which speaks about the production of refractory materials during the analyzed period. Among biggest producers of refractory materials in the world belong companies, mentioned in Table 2.

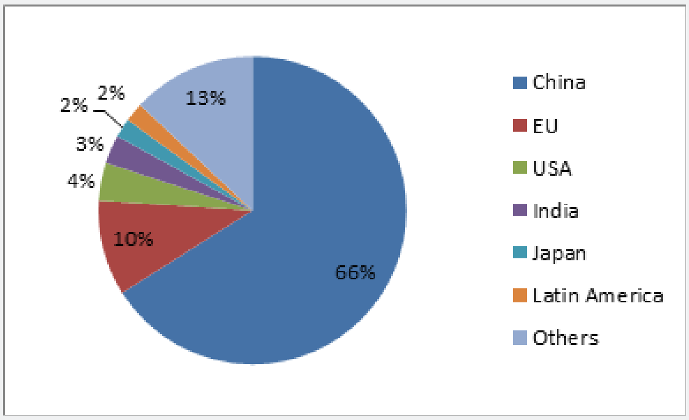

Figure 1: Rate of refractory material production in the world during 2015 – 2019 Source: [10].

Table 1: Production of refractory materials in China and worldwide in 2015 – 2019.

	Production (mil. t)					Change (%)
	2013	2014	2015	2016	2017	2017/2013
Worldwide	41	38	40	45	43	5
China	24,7	25	25,4	29,5	28,2	14

Table 2: Biggest producers of refractory materials in the world.

Company	Turnover (EUR)
RHI	1 836 000 000
Vesuvius	1 812 000 000
Magnesita	941 000 000
Pohang Refractories	890 000 000
Shinagava	819 000 000
Krosaki Harima Co.	818 000 000

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Materials and Methods

The aim of the paper is to find out the way for increasing effective production of fire clay. For achievement of the results we used systematic analysis, applying systematic approach, where the problem is structured to the individual subsystems and elements, which are analyzed, compared with theory and relations are determined for the creation of a model for the system [11]. Such approach is used for solving of complex organizations, economic and technical problems, solving of reengineering tasks and suggestions of new system and projects [12].

The object of searching is a company providing refractory material in the area of metallurgical services and at the same time it produces progressive refractory materials. Products of the company have a realization and application in the metallurgy, concrete industry, shaft and rotation furnaces and construction industry [13].

The company recorded in 2009 considerable decrease of sales, caused by the financial crisis of the period. In 2010-2011 volume of sale reversed to the previous values in 2008. In the next years (2012) till present time there was recorded repeated significant decrease of sale due to the following reasons:

a) Increasing the life cycle of the products, which means, consumption of refractory material is decreased.

b) Change of used materials and Technologies (for example, change of building material with refractory concrete that is cheaper).

For a better idea of production process operation for the fireclay bricks simulation model had been constructed in program Tecnomatix Plant Simulation. Model of the production process in fire clay plant serves as an assumption for creation of simulation.

Results and Discussion

First step presented the construction of the basic model, consisting of individual input materials, reservoirs, equipment, transporting track and tunnel carriages. With an aim to produce demanded products there is a necessary input material would be supplied with stocks and stored in the reservoirs. After storage there are necessary individual input materials would be adapted to the necessary humidity (clay) to the necessary fraction (grain stickiness). A humidity adaptation of the clay goes in clay dryer and grain fraction in the individual mills. After such adaptation materials are prepared to shuffler, in which input materials are mixed to demanded mixture. After control of mixture quality, the mixture is transported to mills, where there is forming to demand shape by the way of proper forms and wrings. After shaping bricks are transported to tunnel carriage, which help to transport extrusion to tunnel calefactory, in which there is drying process to exact necessary residual humidity. After drying tunnel carriages are transported to tunnel furnace, where there are single bricks burning. After burning final products are produced. Such products are transported in stocks for control of quality. In case quality of products meets the norms, product is storage in stock of final products, prepared for an expedition to the consumer. Due to the high production capacity of fire clay plant burning of the material presents main narrow space of whole production process for effective production of limited volume.

For creation of 5 tons of mixture, this equals capacity possibilities of shuffler per hour and for production of common fireclay brick 3 tons of shale and 2 tons of clay are necessary. Capacity of equipment for production of such product is balanced yet to the press, where capacity is at original form using by 61, 6% lower in comparing with other equipment (Table 3).

Table 3: Performance of equipment during fireclay bricks production

Equipment / Activity	Performance
Milling of shale	3 t/hour
Clay drying	5 t/hour
Milling of clay	2 t/hour
Shuffler for mixture creation	5 t/hour
Press	1,92 t/hour

One pressing cycle during pressing common fire clay takes 30 seconds. In case we use present using way of pressing, which means with 4 holes, during one pressing cycle 4 moldings are pressed. One molding weights 4 kg, therefore during one pressing cycle 16 kg of building materials is pressed. At the continuous production for 24 hours, it means press would produce 46 080kg of building materials (calculated without time loss during material transport) (Figure 2).

At the suggested change for increasing of holes number from 4 to 6 the same pressing cycle could produce 6 moldings with 24kg weight. The capacity of the press could by this way increase to 57, 6% against original 38, 4%. At the production for 24 hours, it could produce 69 120 kg of building materials (calculated without time loss during material transport). With 6 holes using production would increase by 50% (Figure 3).

If the principle of increasing of holes number would be applied to most molds, it could have a positive impact to the production increasing and by this way also cost decreasing due to the shortening of the time for tunnel furnace operation. The results from production after increasing of holes number for

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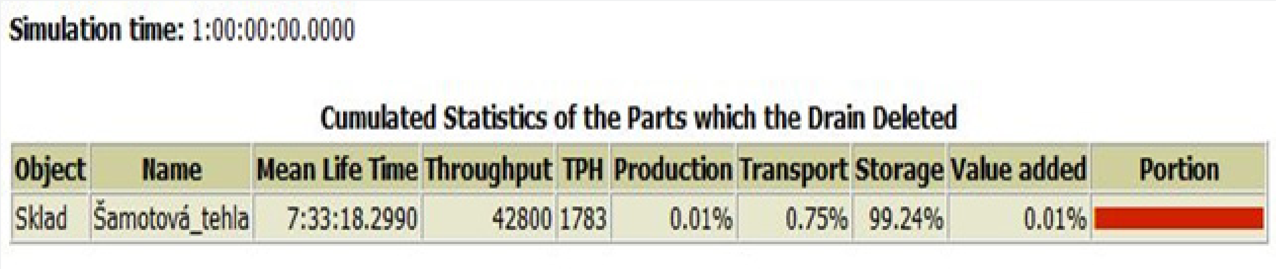
mostly used pressing molds are illustrated by Table 4. At the establishment of multi holes molds production per day could increase approximately by 40%. Due to the mentioned there is possible to decrease the number of dummies to tunnel furnace in the frame of the planed cycle from 42 tons to 30 tons.

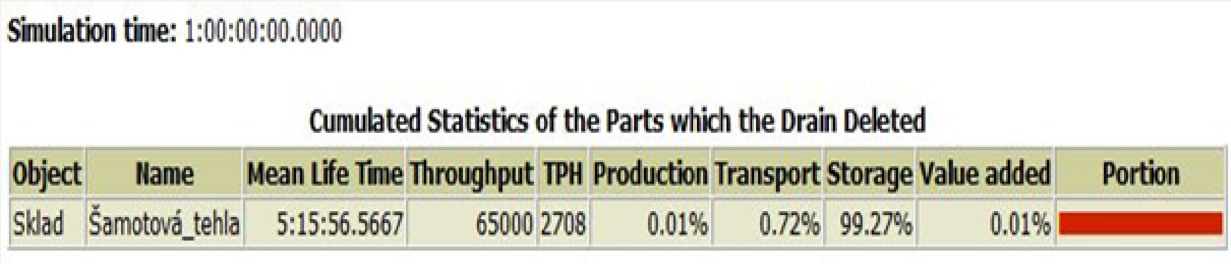


Simulation time: 1:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sklad	Šamotová_tehla	7:33:18.2990	42800	1783	0.01%	0.75%	99.24%	0.01%	

Figure 2: Statistic data of fireclay production during 24 hours with 4 holes using.



Simulation time: 1:00:00:00.0000

Cumulated Statistics of the Parts which the Drain Deleted

Object	Name	Mean Life Time	Throughput	TPH	Production	Transport	Storage	Value added	Portion
Sklad	Šamotová_tehla	5:15:56.5667	65000	2708	0.01%	0.72%	99.27%	0.01%	

Figure 3: Statistic data of fireclay production during 24 hours with 6 holes using.

Due to the limited production, the production is assumed for managing the campaign of building materials burning in tunnel furnace. Due to the capacity of firing, there is necessary to increase production intensity in the mill in a shorter time with the aim to limit using of dummy wagon for holding demanded trend of pressing in tunnel furnace. Decreasing dummy wagon number contributes to decreasing gas consumption for building material firing, which is directly reflecting in cost decreasing. Dummy wagon presents tunnel wagon, charged with building materials that are not intended for the client. Such wagon serves for holding of necessary temperature in tunnel furnace and for balance of temperature differences at the various materials firing. The temperature in tunnel furnace has changed since every type of product demands different firing temperature. The goal is to decrease the number of dummy wagons from average 42 tons to 30 tons. It could enable the firing of higher volume of building materials. By decreasing of dummies number firing of building materials will be more intensive from an average 184, 16 tons to 204, 63 tons in week. Together with dummies it could present 234, 64 tons per week against former average 226, 29 tons per week (Table 5).

Table 4: Results of production after increasing of hole number in pressing mold. Source: [13].

Mold (position)	Present production (t/day)	Operation after molds adaptation (t/day)	Difference
LP230/5	8	10	2
+3KK	5	8	3
C-30	4	8	4
15-0	9	11	2
C25	8	11	3
Sum	34	48	14

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Table 5: Total volume of firing with dummies. Source: [13].

	2015	2016	2017	Average (2015-2017)	Tons/week	Goal per week
Dummies (tons)	2105,00	1435,00	1515,00	1685,00	42,13	30,00
Firing production (tons)	6006,58	7741,58	8351,45	7366,53	184,16	204,63
Sum (tons)	8111,58	9176,58	9866,45	9051,53	226,29	234,64

After decreasing dummies number, the next goal is to shorten time for materials, firing from present average 40 weeks per year to 36 weeks per year. It could present decreasing gas consumption from average 2 324 732 m^3 to 2 092 259 m^3, which means consumption would decrease by 231 350 m^3 of gas. When expressed in MWh, it presents consumption decreasing from present 24 973 MWh to 22 476 MWh, which means consumption decreasing by 2 497 MWh. Financial statement means that cost would decrease from present average 712 469€ to 641 222€, meaning saving of 71 247 €. In gas consumption, expressed by m3 per 1 ton it would be the same as average at the similar volume of firing material, which means at 7 367 tons there would be decreased from presently average 315,68 m3/t to 284 m3/t, which means saving 31,58 m^3/t (Table 6).

Table 6: Gas consumption without dummies.

Gas	MJ	2015	2016	2017	Ø (2015-2017)	36 weeks	Saving per 4 weeks
Firing time	Week	32	43	44	40	-	-
Average unit price	EUR/MWh	316,802	284,563	261,022	261,022	261,022	-
Consumption	m^3	1 984 148	2 598 836	2 427 211	2 324 732	2 092 259	-231 350
Consumption	MWh	20 826	27 893	26 201	24 973	22 476	-2 497
Consumption	EUR	659 781	793 728	683 897	712 469	641 222	-71 247
Value of firing materials	T	6 007	7 742	8 351	7 367	7 367	-
Consumption per material	m^3/t	324,34	335,70	290,63	315,68	284,00	-31,58
Consumption per material	MWh/t	3,47	3,60	3,14	3,39	3,05	-0,34

When expressed in MWh/t, there would be decrease from average 3,39 MWh/t to 3,05 MWh/t, presenting saving 0,34 MWh/t (Figure 4). For 36 weeks campaign annual cost for tunnel furnace consumption would decrease by 10% (Table 7).

Table 7: Contribution of suggested measurements.

Suggested measure-ments	Contribution		Negative impacts
	Economic	Others	
Application of multi holes molds	- speeding up the production, which could enable to produce yet by 40-60% more products, which means shortening of operation time in tunnel furnace with positive impact to cost decreasing.	-speeding up production process. - decreasing of narrow space in mill – its influence to production process. - more effective using of mill equip-ment.	-High investment cost per production of new mold types.
Decreasing of dummy wagons number	-Decreasing of annual cost of gas consumption, neces-sary for heating of tunnel furnace by 10 % (71 247€)	- shortening of time during produc-tion campaign, necessary for firing of demanded volume of materials per year from 40 to 36 weeks. - Lower volume of emissions to air. -more effective operation of tunnel furnace.	

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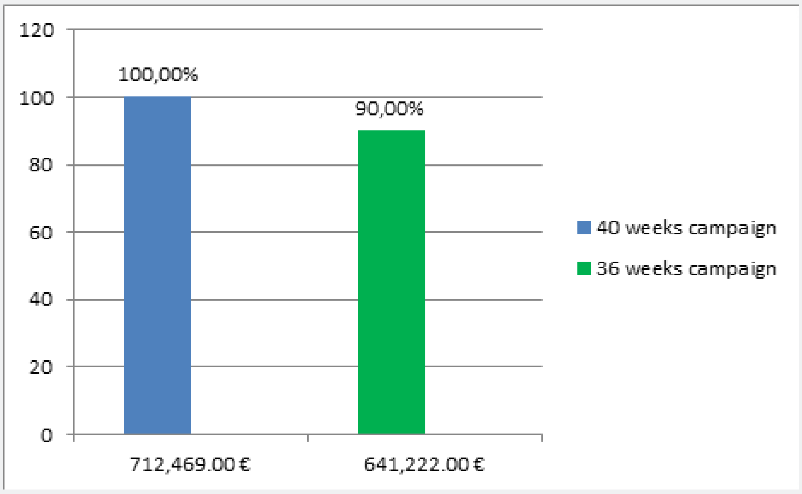

Figure 4: Comparing between 40- and 36-weeks campaign.

Conclusion

Production of refractory materials has a long tradition in the whole world. Fire clay building materials belong among the most common types of refractory materials. They present universal materials that are successfully using almost all types of lining of heating units, since they resist properly against rapid temperature changes and increased temperature conditions.

Any company that wants to be successful must achieve several goals. The main goals are profit increasing, improving production processes, cost decreasing and effectiveness increasing. Due to the high production capacity of fire clay plant burning of the material presents main narrow space of whole production process for effective production of limited volume. The production is assumed for managing the campaign of building materials burning in a tunnel furnace. Due to the capacity of firing, there is necessary to increase production intensity in the mill in a shorter time with the aim to limit using of dummies wagons for holding demanded trend of pressing in tunnel furnace. Decreasing dummy wagons number contributes to decreasing gas consumption for building material firing, which is directly reflected in cost decreasing.

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References

1. Malindžáková M, Straka M, Rosová A, Kaňuchová M, Trebuňa P (2015) Modeling the process for incineration of municipal waste. Przemysl Chemiczny 94(8): 1260.
2. Zhang L (2013) Production of bricks from waste materials - A review. Construction and Building Materials 47: 643-655.
3. Azhar SM, Minhaj SK, Abbas S (2017) Clay bricks prepared with sugarcane bagasse and rice husk ash – A sustainable solution. MATEC Web of Conferences, 120, Article No 030011.
4. Vilamová Š, Piecha M (2016) Economic evaluation of using of geopolymer from coal fly ash in the industry. Acta Montanistica Slovaca 21(2): 139-145.
5. Vodová L, Lang K, Tvrdík L, Kovář P (2016) Experiences of using alternative raw materilas in manufacturing of refractory materials. China´s Refractories 25(1): 7-12.
6. Elmaghraby MS, Ismail AIM (2016) Utilization of Some Egyption Waste Kaolinitic Sand as Grog for Bricks and Concrete. Silicon 8(2): 299-307.
7. Velasco PM, Ortiz MPM, Giró MAM, Melia DM, Rehbein JH (2015) Development of sustainable fired clay bricks by adding kindling from vine shoot: Study of thermal and mechanical properties. Applied Clay Science 107: 156-164.
8. Cultrone G, Sebastian E, Elert K, De la Torre MJ, Cazalla O, et al. (2004) Influence of mineralogy and firing temperature on the porosity of bricks. Journal of the European Ceramic Society 24(3): 547-564.
9. Andrews A, Gawu SKY, Olubambi PA (2015) Fireclay bricks produced from lithomargic clay. Journal of Ceramic Processing Research 16(1): 37-40.
10. (2020) IPC Refractories, ltd.
11. Malindžáková M, Caganová D, Rosová A, Malindžák D (2016) Risk analysis causing downtimes in production process of hot rolling mill. Smart City 360 - 2nd EAI International Summit 14 February 2017 2nd EAI International Summit, Smart City 360, Code 130980.
12. Bednárová L, Liberko I (2008) Application of benchmarking in organizations for fire clay bricks production. Acta Montanistica Slovaca 13(4): 502-511.
13. (2020) RMS, a.s. Košice.

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