BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 68 (72), Numărul 1, 2022
Secţia
CHIMIE şi INGINERIE CHIMICĂ

ASSESSMENT OF THE IMPACT OF CHANGES IN THE COMBUSTION PROCESS IN A BRICK-MAKING PLANT WHICH THE MANUFACTURING MIX CHANGES

BY

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Received: February 23, 2022
Accepted for publication: March 25, 2022

Abstract. In this paper, the influence of the use of two auxiliary raw materials – sawdust and sunflower seed husks – on the oxygen consumption of the air brought in the process and the impact on the combustion products was analyzed on an industrial installation in real working conditions. It has been found that although in the case of recipes that use sunflower seed husks a smaller amount of gas with energy potential is released, it is preferable to use them because the amount of nitrogen oxides exhausted in the chimney of the furnace is lower.

Keywords: brick, waste added, reducing energy consumption, exhaust gases analysis.

1. Introduction

Brick is a ceramic product used as a building material since ancient times and is still appreciated in the construction industry for its mechanical resistance and environmental factors, as well as the aesthetic value of the resulting wall.

An important aspect that contributes to maintaining the value of this product is the ease of procurement of clay raw material – the main constituent.

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During the combustion, the raw material – generally a mixture of clay and other materials (inorganic – sand, power plant ash, organic materials – sawdust, seed husks, sewage sludge etc.) – is transformed into a new material in which mineralogical transformations are similar to those in pyrometamorphism processes, in terms of microstructure, porosity change and liquid phase (Coletti *et al*., 2016).

The analysis of the specialized literature reveals the fact that in the last 40 years it has been possible to successfully use different types of waste in the production of burnt clay bricks. These include mud, ash, polystyrene, kraft paste residues, processed tea waste, rice husks, pineapple leaves, straw, sacks, sawdust, tobacco scraps, grass, paper, cigarette butts etc. The amount of waste added to the burnt clay brick varied between 0.5% and 50%. The advantages obtained by adding the residual sludge consisted in increasing the plasticity and porosity after combustion, leading to the improvement of the thermal conductivity. There were also energy savings, estimated to be up to 40%. However, there are also a number of disadvantages in the use of waste, including the high cost of transporting them, the cost of selecting waste, but also the emissions of gases that may contain noxious substances (carbon monoxide, carbon dioxide, ammonia, monoxide and nitrogen dioxide, in some cases chlorine and fluorine etc.) above the permitted limit (Kadir and Sarani, 2012; Shakir *et al*., 2013).

Binici and Yardim used industrial waste from textile factories, and basaltic pumice stone as additives in the production of burnt clay bricks (Binici and Yardim, 2012). When added up to 10%, these lead to increased resistance to freeze-thaw and to the action of sodium sulphate and sodium nitrate. The compression strength is similar or even better than that of classic bricks (control samples).

Ibrahim and others conducted a laboratory study in which they used sawdust as an alternative to clay to produce new and environmentally friendly bricks (Ibrahim *et al*., 2021). Sawdust was added in order to partially replace zeolite-poor rocks in the Tokaj region (Hungary) in the recipe for the manufacture of bricks obtained by uniaxial dry pressing and burning for three hours in the temperature range of 950-1250°C. Replacement percentages were 0%, 2%, 4%, 6%, 8% and 10% mass. The results obtained confirmed that the inclusion of 8% sawdust leads to a reduction in bulk density from 1.6 [$g \cdot cm^{-3}$] (for the 0% sample) to 1.45 [$g \cdot cm^{-3}$]. It was also found that the porosity increased from 31% for the control sample to 37.37% (for the sample with 8% sawdust), instead, the compression strength was reduced from 14.5 to 6.7 [MPa]. However, the thermal conductivity of the 8% sawdust samples decreased by 37% compared to the control sample. Another important aspect pointed out by the authors is that the heat generated during sawdust combustion can contribute to the heat needs during the manufacturing process, reducing energy consumption (Ibrahim *et al*., 2021).

The reduction in energy consumption during laboratory scale production of bricks made from clay and cigarette butts (with mass percentages of 0%, 0.5%,

1%, 1.5% and 2%) was also analyzed by Kurmus and Mohajerani. Based on energy consumption monitoring during the burning of brick specimens, it was found that for bricks that incorporate 1% cigarette butts, a minimum energy saving of 8% can be achieved (Kurmus and Mohajerani, 2021). There was also a reduction of up to 15.12% in thermal conductivity for this brick compared to traditional ones, respectively a reduction from 0.463 [$W \cdot m^{-1}$] to 0.393 [$W \cdot m^{-1}$]. The authors of the study obtained bricks which incorporate cigarette butts that have a homogeneous distribution of pores. The largest pore sizes of 1.365 [mm] were determined in the case of bricks containing 1.5 and 2% mass of cigarette butts (Kurmus and Mohajerani, 2021).

A substantial increase in porosity and a compression strength of 8.5 [MPa] were obtained by Escalera *et al*. in their study for laboratory-made bricks, from clay to which ash resulted from the burning of walnut shells in Brazil was added (Escalera *et al*., 2015).

Regarding the reduction of thermal conductivity, the best performances were obtained using recycled polystyrene in a percentage of 1.5%. Veiseh and Yousefi found that for bricks containing this waste, the thermal conductivity is a quarter of the value reported for conventional bricks, respectively 0.24 [$W \cdot m^{-1}$] (Veiseh and Yousefi, 2003).

An important aspect that must be carefully evaluated when using different types of waste in the production of burnt clay bricks is the maintenance within the limits permitted by law of the pollutants resulting from the chimney of the burning furnaces (Basegio *et al*., 2002). Basegio and others have established that a maximum percentage of 10% of sludge, along with clay, leads to obtaining bricks with adequate properties, which comply with environmental protection legislation related to the exhaust gases in the chimney of the burning furnace (Basegio *et al*., 2002).The brick manufacturing industry today uses mostly tunnel furnaces which have several technological advantages (continuous flow, high productivity), but also some disadvantages (combustion plants are designed to use a certain manufacturing mix and the limits within which it can be transformed are very slightly permissive).

The realities of the auxiliary raw materials market but also of the energy market (electricity and methane gas) force brick producers to find solutions for an installation designed to operate with a certain manufacturing mix to use alternative mixes to obtain products with similar or improved performance, at reasonable costs. The problem arises in leading the process by managing the chemical reactions that occur in its various phases but also the emissions from the furnace chimneys. These emissions can be an indicator of the performance of the oxidative processes in the furnace (exhaust potential gases such as carbon monoxide, hydrocarbons, etc.).

In order to analyze these aspects, a study was performed on an industrial installation in real working conditions in which determinations were made on the exhaust gases at the furnace chimney, keeping the combustion parameters

constant (mix quantity, combustion parameter settings – methane gas supply, air, pressures, rhythm etc.) in order to assess the influence of the use of two auxiliary raw materials – sawdust and sunflower seed husks – on the oxygen consumption of the air brought into the process and the impact on the combustion products. This study makes important contributions in the development of investment strategies in the maintenance, modernization or refurbishment of the installation.

2. Materials and methods

The same furnace was used in the technological process, in which different mixtures of silicon-based material were loaded. Four types of products obtained in two variants were taken into account: with loads of mixtures consisting of clay + sawdust and clay + sunflower seed husks, for which the average values of gases discharged to the chimney were calculated.

The experimental determinations were performed using a Testo 350 flue gas analyzer equipped with detection and measurement cells specific to the gases of interest (CO, NO_x, C_xH_y, O_2), which were calibrated. For the accuracy of the results, a series of determinations were performed for 15 minutes, with readings from minute to minute, the results taken into account being the arithmetic mean of the 15 readings.

3. Results and discussions

Brick production plants are designed for a certain type of manufacturing mix and a certain type of combustion process. For various reasons, the initial designed and implemented conditions can change radically and the need to maintain and improve product performance, as well as productivity, leads to situations in which new mixtures are introduced on the same installation and, practically, the same combustion curves have to be complied with due to the construction characteristics of the installation. For these reasons, there are often problems with rising costs, waste, but also pollution. To eliminate them, many hours of production are performed in test mode with high costs, but also uncertain results.

In this paper, we propose an analysis of the impact of changes in the combustion process if the original installation is preserved and the manufacturing mix is modified.

To achieve this goal, the exhaust gases at the furnace chimney were analyzed. All the technological characteristics have been kept constant except for the type of auxiliary raw material of an organic nature. By comparing the average values of exhaust gases for different recipes (Table 1) following the combustion process of two mixtures of raw material containing the same percentages of clay, degreaser and auxiliary raw material in variant a) being sawdust (recipe RR) and in variant b) being the sunflower seed husks (RCs recipe), it can be observed that,

practically, at the same hourly tonnage, there is the same oxygen consumption from the air brought in the process, but the impact on the combustion products is different.

Table 1

The influence of the change in the manufacturing mix on the composition of the exhaust gases in the furnace chimney

Monitored Parameter	O_2 [%]	CO [mg·m^{-3}]	CO_2 [%]	NO_x [mg·m^{-3}]	CH_4 [mg·Nm^{-3}]
RR recipe with sawdust / RCs recipe with sunflower seed husks	*1*	*1.03*	*1.02*	*1.35*	*1.45*

Based on the results presented in Table 1, significant differences both from an economic point of view and regarding the potential pollutant can be noticed. Exhausted CH_4 concentrations are 45% higher in the case of the first RR recipe. The amount of exhausted nitrogen oxides is also higher with 35%. These differences are significant, given that the exhaust flows in the industry run into tens of thousands of cubic meters per hour.

The quantities of gas with energy potential obtained in the case of the two types of manufacturing mix were also compared.

Considering the above aspects, the average values obtained for the gases of energy interest were compared under similar process conditions, for the two recipe variants. The results are presented comparatively in Fig. 1. The differences between the exhausted percentage of CO in the case of the two variants of manufacturing mixtures are not significant. Higher amounts of CH_4 are obtained for products 2 and 4 when sawdust is used in the manufacturing mix, compared to the situation where sunflower seed husks are used. For example, based on the monitoring of energy consumption during the burning of small-scale bricks obtained in the laboratory, other researchers (Kurmus and Mohajerani, 2021) have established that for bricks incorporating 1% cigarette butts, a minimum saving of energy of 8% can be achieved.

Interestingly, the combustion process has the same efficiency. In the case of all the analyzed products, according to the results presented in Fig. 2, the values of oxygen consumed in the RR and RCs variants are the same, and the percentage of CO_2 that marks the end of combustion also has close values. From the point of view of the resulting products, the laboratory tests indicated the same performances for the products obtained in both variants.

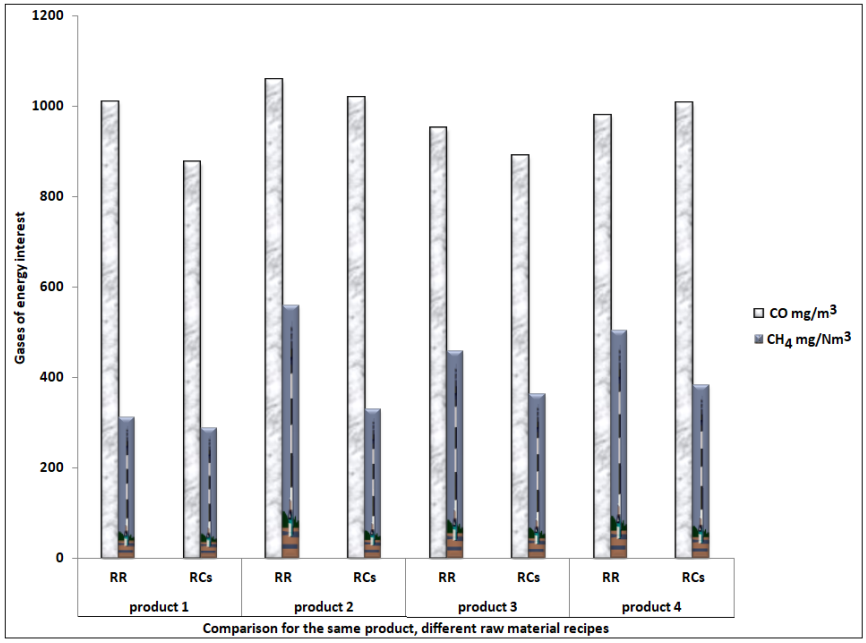

Fig. 1 – Variation of gas concentration with energy potential in which RR is the recipe with sawdust and RCs is the recipe with sunflower seed husks.

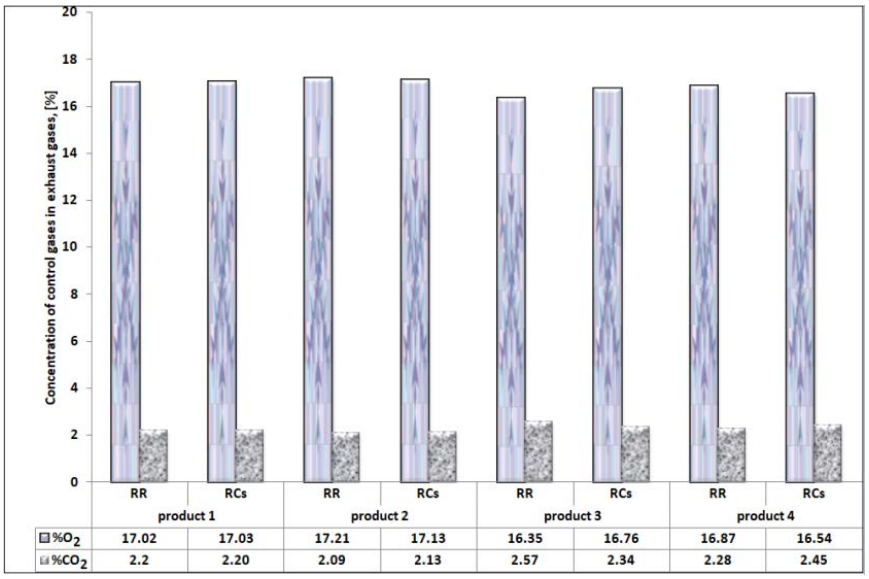

Fig. 2 – Variation of control gas concentration in the case of the two variants of manufacturing mixtures.

Another important indicator is the NO_x concentration in the exhaust gases, developed following the combustion process which, according to the graphical representation in Fig. 3, indicates comparable values in both variants of the manufacturing mix. A slightly larger difference is found for product 4. The amount of NO_x in the exhaust gas is 14% lower in the case of the seed husks recipe compared to the sawdust recipe.

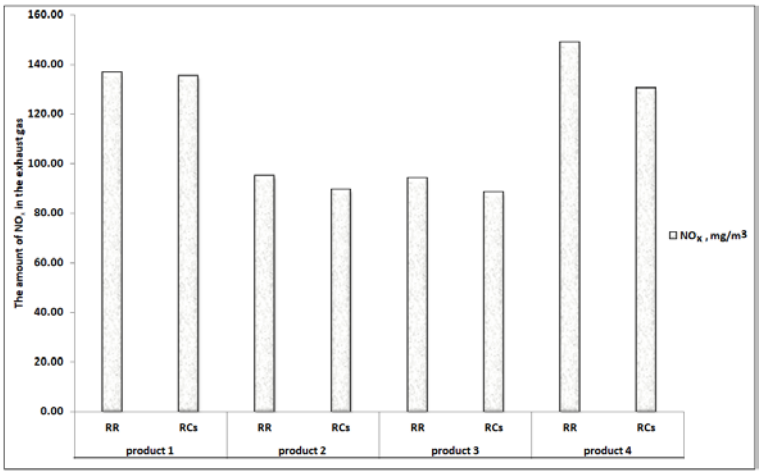

Fig. 3 − The amount of NO_x resulting from the two variants of manufacturing mixes.

4. Conclusions

The study analyzed the influence of the use of two auxiliary raw materials – sawdust and sunflower seed husks– on the consumption of oxygen in the air brought into the process and the impact on combustion products, in an industrial production plant in real working conditions. When analyzing the obtained results, it was found that the recipe containing sawdust tends to generate a higher amount of gas with energy potential in the exhaust gases, but from the point of view of environmental protection, these products have a higher potential to generate pollutant emissions. The process engineers have the mission to find, through test batches, the mix of raw materials that will lead to maintaining and improving the performance of the products, on the same installation, complying with the same combustion curves in advantageous economic conditions and, at the same time, reducing the amount of polluting gas released. Although in the case of recipes that use sunflower seed husks, a smaller amount of gas with energy potential is released, it is preferable to use them because the amount of nitrogen oxides exhausted in the furnace chimney is lower.

Acknowledgements. This work was supported by Exploratory Research Projects PN-III-P4-ID-808, PCE-2020-0551, no. 91/2021, financed by UEFISCDI.

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EVALUAREA IMPACTULUI SCHIMBĂRILOR SURVENITE ÎN PROCESUL DE ARDERE ÎNTR-O INSTALAȚIE DE FABRICARE A CARĂMIZILOR ÎN CARE SE MODIFICĂ MIXUL DE FABRICAȚIE

(Rezumat)

În această lucrare s-a analizat pe o instalație industrială, în condiții reale de lucru, influența utilizării a două materii prime ajutătoare, rumeguș și coji de semințe de floarea soarelui, asupra consumului de oxigen din aerul adus în proces și impactul asupra produselor de ardere. S-a constatat că, deși în cazul rețetelor ce utilizează coji de semințe de floarea soarelui se degajă o cantitate mai mică de gaze cu potențial energetic, este de preferat utilizarea acestora deoarece cantitatea de oxizi de azot purjată la coșul de fum al cuptorului este mai mică.