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Investigation of the Effect to Lime Quality of Kiln Conditions

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Abstract

People think limestone calcination reaction is a very simple and straight-forward reaction. However, numerous critical variables effect to lime burning operations, such as limestone quality, fuel and kiln burning conditions etc. The factors and variables that affect the burning (calcination) of limestone must be considered in the selection, design and optimization of the kiln equipment. Limestone burning in a vertical kiln often presents complex problems which can be solved from the conception by consideration of the prevailing factors that determine the progress of calcination reactions. The evaluation of the influence of these factors on the progress of the burning of Çelemli limestone (Adana Turkey) in a vertical shaft lime kiln (four Maerz kilns) is the thrust of this study. Çelemli limestone is proper for lime production that is higher than 97% $CaCO_3$ and low impurities, but lime quality seems differences due to burning conditions in the kilns.

In this study, the effects of chemical kinetics, calcination temperature, calcination time, effect of pressure and flow conditions in the kiln were evaluated.

Keywords: Limestone, Lime, Calcination, Maerz vertical shaft lime kiln

INTRODUCTION

People think limestone calcination reaction is a very simple and straight-forward reaction. However, numerous critical variables effect to lime burning operations, such as limestone quality, fuel and kiln burning conditions etc. The factors and variables that affect the burning (calcination) of limestone must be considered in the selection, design and optimization of the kiln equipment.

Several factors affect the quality of lime (CaO), i.e.: characteristics of the limestone, calcination temperature, pressure acquired in kilns, rate of calcination and fuel quality.

Lime namely calcium oxide is usually made by thermal decomposition of materials such as limestone that contains calcium carbonate. Calcium carbonate ($CaCO_3$), namely limestone is sedimentary rock type and the most abundant mineral in the earth crust [1]. Limestones display the following conditions, alone or in combination, are prone to decrepitation; coarse crystallinity, friability, foliation, excessive calcite veining, microfracturing, highly porous and thinly bedded. Impurities in limestone change the carbonate mineralogy of limestone and its physical characteristics such as color, brightness, specific gravity, hardness, and decomposition properties [1,2].

The main chemical property of limestone is its thermal decomposition, known as calcination, during which lime (CaO) and carbon dioxide are produced.

The calcination reaction is endothermic (Eq. 1):

$$CaCO_3 \leftrightarrow CaO + CO_2 \quad \Delta H=182.1 \text{ kj mol}^{-1} \qquad (1)$$

When calcination takes place (Eq. 1), the product calcium oxide weighs only 56% of the parent carbonate. The reaction only begins when the temperature is above the dissociation temperature of the carbonates in the limestone.

At the beginning of the 20th century, the $CaCO_3$ decomposition temperature determined as 898 °C at 1 atm in a 100% CO_2 environment. However, some studies this temperature is 902.5 °C [3-5]. Kılıç [6] is reported 600 °C and attributed to the CO_2 of $CaCO_3$ that is initiated at 682-691 °C and completed at 944-961 °C by DTA-TG in nitrogen atmosphere.

This accomplished by heating the material, a process called calcination or lime burning, to liberate a molecule a CO_2, leaving CaO. This process is reversible since once the quick lime (CaO) product has cooled it immediately absorbs CO_2 from kiln atmosfer air. Until after enough time, it is completely converted back to calcium carbonate.

The internal structure of a rock having open and closed pores in its texture affects its heat transfer. The specimen comprises a dense carbonate core surrounded by porous oxide layer. The changes in pore structure also play a significant role on the calcination and the reactivity of a calcined limestone is strongly dependent on its chemical, physical and structural properties, which in turn are highly dependent on heat treatment conditions.

In the good calcination process, limestone should be approximately consisting of 97% $CaCO_3$ and low impurities. Impurities such as iron, magnesium and aluminum oxides tend to lead to lower surface areas in the limestones and calcines [7].

Lime properties, lime production and limestone burning in a vertical kiln often presents complex problems which can be solved from the conception by consideration of the prevailing factors that determine the progress of calcination reactions. The evaluation of the influence of these factors on the progress of the burning of Çelemli limestone (Adana, Turkey) in a vertical shaft lime kiln (four Maerz kilns) is the thrust of this study.

MATERIALS and METHODS

Lime producing conditions of 4 units, petroleum coke fed to the kiln, each Maerz kilns lime production capacity of 250 ton/day in Adana were investigated (Figure 1-3).

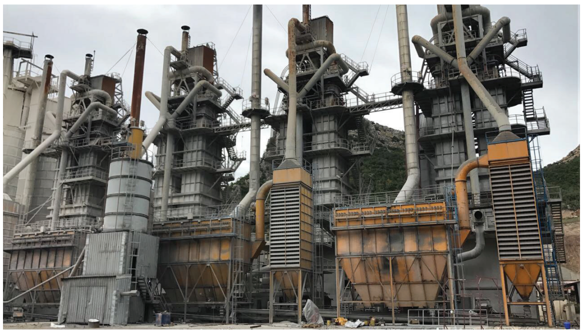

Figure 1. Maerz kilns

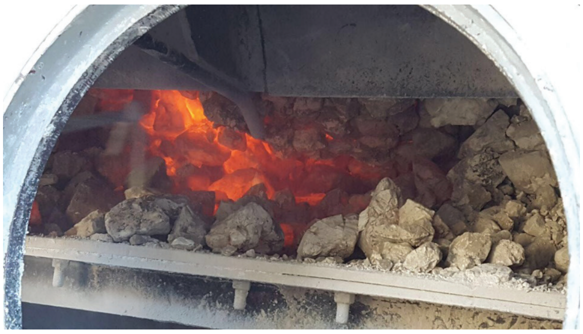

Figure 2. A sight of lime in the kiln calcining zone

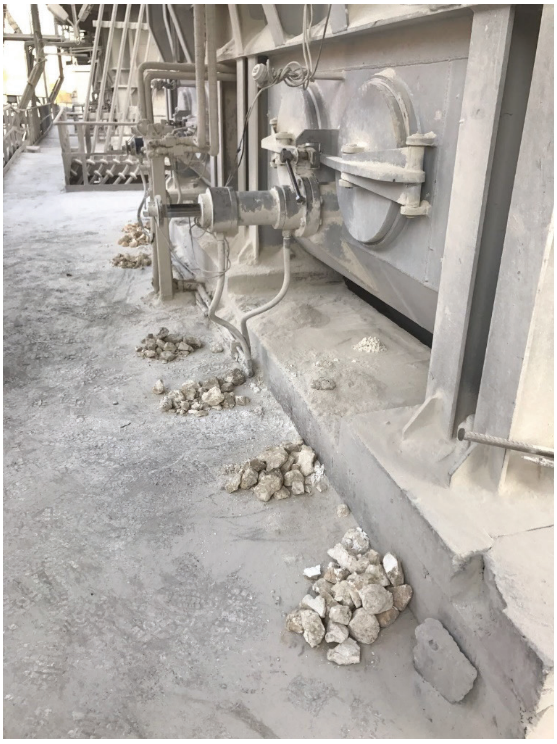

Figure 3. Lime

RESULTS and DISCUSSION

According to chemical analysis results; limestone is very pure with an average $CaCO_3$ content higher than 97% (CaO: 54.90%). The impurities (MgO, Fe_2O_3, Al_2O_3 and SiO_2) are very low (MgO: 0.74%, Fe_2O_3: 0.10%, Al_2O_3: 0.08%, SiO_2: 0.55%). Limestone and lime (CaO) is good quality and reactivity.

Maerz kiln operation parameters are given Table 1. Detailed lime production parameters for a kiln is given Table 2. These parameters are proper for the producing of good quality lime. Lime an fuel (petrol coke) analyses results are shown Table 3.

Table 1. Maerz kiln operating values

	Kiln 1	Kiln 2	Kiln 3	Kiln 4
Lime production (ton/day)	260	260	260	260
Spesific temperature value (kcal/kg)	860	870	860	830
Cooling air (m³/h)	0.7	0.65	0.65	0.75
Air coefficient	1.13	1.13	1.13	1.13
Lime ratio	1.68	1.68	1.68	1.68
Flue gas velocity (m/sn)	5.2	4.3	4.6	4.1

CONCLUSIONS

Limestone contains sufficiently high percentages of the main oxide i.e. calcium oxide. The temperature dependent it was observed that direct effect on the rate of reaction and limestone chemical properties, porosity and micro-cracks, and on the rate of reaction.

Limestone has compact texture, low porosity, high CaO and low impurity and good thermal conductivity. Chemical analysis results are show that limestone and lime (CaO) is good quality and reactivity.

The results indicate that higher the kiln calcination temperature, the more reactive the produced the lime. Concerning the lime the quality is related to its impurities and microstructure, which is, in turn, related to microstructural characteristics of the limestone (texture, grain size, porosity).

Kiln operating parameters are sufficient due to lime will have a good quality and high reaction.

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Table 2. Maerz Kiln (Number 4 Kiln)

Fuel consumption (ton)	Fuel fineness (+90 µm %)	Moisture of fuel (%)	Limestone feed (ton)	Lime production (ton)	Kiln waiting time (min)	ACaO (%)	LoI (%)	Flue gas temperature shaft 1 and 2	Spesific energy (kcal/kg)	Teoric kiln capasity (ton)
23.87	23.05	0.20	423	252	61	88.79	4.43	118 116	825	260
24.83	23.56	0.40	421	250	49	87.64	4.10	130 119	835	260
24.71	26.85	0.40	421	250	57	90.45	2.53	133 130	840	260
25.22	24.95	0.50	425	253	44	93.67	2.23	131 130	840	260
25.03	27.68	0.30	425	253	51	93.11	2.59	132 133	840	260
25.90	27.48	0.40	429	255	49	93.02	1.90	130 130	835	260
25.13	24.87	0.50	433	257	33	88.84	3.08	132 128	835	265

Table 3. Analysis results of lime and petrolcoke

Kilns	**Analysis results of lime**		**Analysis results of petrolcoke**			
	CaO (%)	LoI (%)	Moisture (%)	Finess (%)	Ash (%)	Volatile material (%)
1	89.65	2.93	0.60	19.46	0.64	11.37
2	88.55	3.17	0.50	16.75	0.78	11.14
3	92.97	1.93	0.50	18.24	0.62	11.10
4	90.20	2.93	0.30	25.93	0.64	10.47

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