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# A LIME PRODUCTION OF THE FLUIDIZED BED BOILER'S ENERGY AND EXERGY ANALYSE

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## ABSTRACT

In this study, it was calculated energy and exergy analysis of a lime production for the fluidized bed boiler by a case of sugar factory. The aim of this study is to show calculation of the energy and exergy analysis of a lime production for the fluidized bed boiler, and to determine a lime mass quantity for the factory process. This factory is a sugar factory that has got many heat processes for the sugar raw filtration and defection. The production of lime mass was found 1.2973 [kg/s]. The production of lime (CaO) energy result was found 4121.92 [kW] and exergy result was found 2766.97 [kW]. Energy (CaO) quality was found 0.671.

***Keywords:*** *CaO, lime production, fluidized bed boiler, energy and exergy analysis*

## INTRODUCTION

Nowadays, a lime production is to come significant for the fluidized bed boiler that products energy for the factory processes. These processes are steam for the food process and turbine for electric energy. This sugar factory produced approximately 400,000 [t] sugar last year. This plant is very huge sugar factory in Turkey. So, this factory was selected in this work.

In this study, we analysed the energy and exergy of a lime production for the fluidized bed boiler for the sugar factory. Our study was composed by this theory.

There are several similar studies in this research area. Gutierrez et al. [1] designed a device for the analysis of energy and exergy usage of the lime. Energy recovery resources from mineral carbonation process in coal fired power plant was performed by Moazzem et al. [2]. Exergy-based indicators to appraise the possibilities to decrease fuel consumption in lime production was researched by Gutierrez and Vandecasteele [3]. Energy of lime production was calculated for the sugar factory by Taner [4]. Energy and exergy analysis of the lime production was investigated for the raw juice purification process by Taner and Sivrioglu [5]. Limestone-$SO_2$ reactivity in a circulating fluidized bed was researched by Büyükgüner [6]. The stability evaluation of lime mud was explored for biodiesel production by Li et al. [7]. Pina et al. [8] and Casas et al. [9] showed lime preparation in juice treatment process. Maravic et al. [10] remarked this work that variances promoted to crucial diminish in limestone. Gul and Harasek et al. [11] indicated that sugar juice purification in order to avoid or to decrease the use of lime. Ensinas et al. [12] determined that lime is used in juice treatment process. Ensinas et al. [13] defined most irreversibility generation is carry on chemical reactions, primary in the turbine power plant and separately in the juice clarification unit, particularly in all limes processes. Souza Dias et al. [14] indicated that lime can be added along to the juice treatment for a second heating. Therefore, investigation of the similar studies as follow; Gutierrez et al. [1] found lime mass 0.91 [kg/s] in Kiln No 1 and 4.03 [kW] in Kiln No 2. In other study, Ensinas et al. [13] found lime production mass 0.22 [kg/s]. In this study, lime (CaO) production energy was found 4,121.92 [kW]. Gutierrez et al. [1] found lime energy 2,603 [kW] in Kiln No 1 and 10,277 [kW] in Kiln No 2. In this study, lime (CaO) mass quantity was found approximately 1.30 [kg/s]. Gutierrez et al. [1] found exergy destruction 1,227 [kW] in Kiln No 1 and 5,492 [kW] in Kiln No 2. In other study, Ensinas et al. [13] found lime production exergy 428 [kW]. In this study, lime (CaO) production exergy was found 2,766.975 [kW].

## METHOD AND MATERIAL

Lime production is very important structure for the sugar production processes. Calcium oxide (CaO), widely defines as lime, is an energy mass product [1]. Mhemdi et al. [15] determined that the juices quality is very significant parameter in sugar processing influencing on the lime purification technology. So, lime production

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energy should be calculated very carefully for processes of sugar factory. Energy and exergy analysis was prepared for this study. Mass and energy balances were used to calculate the energy of lime production.

Firstly, it was calculated lime production energy step by step. Energy and exergy calculations of lime productions are prepared according to the following formulas [4, 6]. Quantity of CaO is calculated as follow:

$$m_{CaO} = m_{Ca(OH)2} \ \% \ CaO \tag{1}$$

where $m_{CaO}$ is a lime mass flow, [kg/s]. $m_{Ca(OH)2}$ is mass flow, [kg/s]. % CaO is a lime percentage, [%]. Energy of lime (CaO) production can be calculated as follow:

$$En_{CaO} = m_{CaO} \times h_{CaO} \tag{2}$$

where $En_{CaO}$ is a lime production energy, [W]. $m_{CaO}$ is a lime mass flow, [kg/s]. $h_{CaO}$ is a lime production entalphy, [kJ/kg]. Exergy of lime (CaO) production can be calculated as follow:

$$Ex_{CaO} = m_{CaO} \times \psi_{CaO} \tag{3}$$

where $Ex_{CaO}$ is a lime production exergy, [W]. $m_{CaO}$ is a lime mass flow, [kg/s]. $\psi_{CaO}$ is a lime specific exergy, [kJ/kg]. Unit of lime energy consumption can be calculated as follow:

$$en = En \ / \ m_{CaO} \tag{4}$$

where CaO is a lime. $en_{CaO}$ is unit of lime energy consumption, [kJ/kg]. Energy quality of lime production can be calculated as follow:

$$\Theta_{CaO} = Ex_{CaO} \ / \ En_{CaO} \tag{5}$$

where $\Theta_{CaO}$ is energy quality of lime production.

## RESULTS AND DISCUSSION

Data were taken from factory lime production. Accordingly, data of $Ca(OH)_2$ was taken 200 [t/d] from factory. Percentage of CaO (lime) was assumed % 56 [4, 6]. Lime (CaO) mass quantity can be found as follow:

$m_{CaO}$ = 112 [t/d]=4.67 [t/h]=4,670 [kg/h] = 1.2973 [kg/s]

$n_{CaO}$ is taken as 56,08 [g/mol].

Entalphy of CaO (lime) value was taken 177,940 [kJ/kmol] and 3177.5 [kJ/kg] from Kotas [4, 6, 7]. This assumption was taken from literature and then lime production energy and exergy were calculated. The result of lime production energy and exergy was shown step by step. Lime (CaO) production energy was calculated from Eq. 2 as follow:

$$En_{CaO} = m_{CaO} \times h_{CaO} \tag{6}$$

$En_{CaO}$ = 14,838,925 [kJ/h]=4,121.92 [kJ/s]=4,121.92 [kW]

Exergy of lime (CaO) production was taken 119,620 [kJ/kmol] and 2,133 [kJ/kg] [4, 6, 7]. Lime (CaO) production exergy was calculated from Eq. 3 as follow:

$$Ex_{CaO} = m_{CaO} \times \psi_{CaO} \tag{7}$$

$Ex_{CaO}$ =9,961,110 [kJ/h]=2,766.975 [kJ/s]=2,766.975 [kW]

Unit of lime energy consumption was calculated from Eq. 4 as follow:

$$en = En_{CaO} \ / \ m_{CaO} \tag{8}$$

en = 4,121.92 / 1.2973 =3,177.5 [kJ/kg]

Energy quality of lime production was calculated from Eq. 5 as follow:

$$\Theta_{CaO} = Ex_{CaO} / En_{CaO} \tag{9}$$

$\Theta = 0.671$

This value is very optimum when similar study [1] compares to this study. In this study, lime (CaO) mass quantity was found approximately 1.30 [kg/s]. Gutierrez et al. [1] found lime mass 0.91 [kg/s] in Kiln No 1 and 4.03 [kW] in Kiln No 2. In other study, Ensinas et al. [13] found lime production mass 0.22 [kg/s]. In this study, lime (CaO) production energy was found 4,121.92 [kW]. Gutierrez et al. [1] found lime energy 2,603 [kW] in Kiln No 1 and 10,277 [kW] in Kiln No 2. By this way, this study posed that lime production is very important for the fluidized bed boiler. This study also indicated that lime production mass quantity was more sufficient than the other some studies.

In this study, lime (CaO) production exergy was found 2,766.975 [kW]. Gutierrez et al. [1] found exergy destruction 1,227 [kW] in Kiln No 1 and 5,492 [kW] in Kiln No 2. In other study, Ensinas et al. [13] found lime production exergy 428 [kW]. This study showed that lime production has got an average exergy from previous studies when these studies compare to our study.

When similar studies were investigated, some values were seemed that unit of lime production energy consumption and energy quality were not calculated. In this study, unit of lime energy consumption and energy quality also were calculated. In this study, unit of lime energy consumption was found 3,177.5 [kJ/kg]. Finally, energy quality of lime production was found 0.671.

## CONCLUSION

These results showed that energy of lime production can be used efficiently for the sugar factory. This factory is a sugar factory that has got many heat processes for the sugar raw filtration and defection. The production of lime mass was found 1.2973 [kg/s]. The production of lime (CaO) energy result was found 4121.92 [kW] and exergy result was found 2766.97 [kW]. Energy (CaO) quality was found 0.671. These results are very sufficient to see the lime production energy and exergy values. The main addition of this study to literature is to pose importance of the lime production mass and energy for the fluidized bed boiler.

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## NOMENCLATURE

$En_{CaO}$ Lime production energy, [W]
$en_{CaO}$ Unit of lime energy consumption, [kJ/kg]
$Ex_{CaO}$ Lime production exergy, [W]
$h_{CaO}$ Lime production entalphy, [kJ/kg]
$m_{CaO}$ Lime mass flow, [kg/s]
$m_{Ca(OH)2}$ Mass flow, [kg/s]
$\psi_{CaO}$ Lime specific exergy, [kJ/kg]
$\Theta_{CaO}$ Energy quality of lime production, [-]
% CaO Lime percentage, [%]

**Abbreviations**

CaO Calcium Oxide (Lime)

d Day
h Hour
s Second
t Tonnes
W Watt

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