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Energetic and exergetic assessment of a trass mill process in a cement plant

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ABSTRACT

Cement production has become one of the most intensive energy industries in the world. For producing it, addition materials have been widely used in cement factories. The main objective of this study is to assess the performance of a trass mill in a cement plant based on the actual operational data using energy and exergy analysis method. In this regard, the values for energy consumption and losses throughout the production process are described. In the process, the overall exergy efficiencies are found to be slightly less than the corresponding energy efficiencies; e.g. 74% and 10.68% for energy and exergy efficiency, respectively. Using energy recovery systems, waste heat energy may be captured, while energy and exergy efficiency values can be improved to 84% and 48%, respectively. It may also be concluded that the analyses reported here will provide the investigators with knowledge about how effectively and efficiently a sector uses its energy resources.

1. Introduction

The cement industry is one of the industrial sectors, which consume the greatest amount of energy in the world and it has occupied a significant place among the other sectors in the last decade. According to the researchers, the world cement production has been increasing 50% during this period. If this cement production rises at about the same ratio, the energy consumption and costs will increase relatively in this sector [1].

There have been many studies about the cement sector. Among them, there are very important and deductive papers, showing both energy approach to the cement industry and the potentials and means of improvement in energy consumption of cement industry. Schuer et al. [2] gave energy consumption values and described the energy saving methods and potentials for German Cement Industry. The study consisted of two parts, namely electrical energy saving methods and thermal energy saving methods. They gave obtained results in the form of energy flow diagrams. Koreneos et al. [3] presented their studying about exergy analysis of the cement and concrete production in Greece. Worell et al. [4] performed an in-depth analysis of the US cement industry, identifying carbon dioxide saving, cost-effective energy efficiency measures and potentials between 1970 and 1997. They gave the energy efficiency improvement and carbon dioxide emission reductions in the production of cement in the US cement industry. Khurana et al. [5] to examine energy balance and cogeneration for a cement plant in India conducted another study. According their study, the primary efficiency of the process is about 50% and the remaining 35% of the energy is lost with the flue gases and the hot air, and energy recovery from these streams would improve the overall efficiency of the system. Camdali et al. [6] carried out energy and exergy analyses for a dry system rotary burner with pre-calcinations in a cement plant of an important cement producer in Turkey, using actual operational data. They found that energy and exergy efficiency values for rotary burner were 85% and 64%, respectively. Engin and Ari [7] performed an energy audit analysis of a dry type rotary kiln system with a capacity 600-ton clinker per day working in a cement plant in Turkey. They found that about 40% of the total input energy was being lost through hot flue gas (19.15%), cooler stack (5.61%) and kiln shell (15.11% convection plus radiation).

Energy efficiency is an important component of a company's environmental strategy. End-of-pipe solutions can be expensive and inefficient while energy efficiency can often be an inexpensive opportunity to reduce criteria and other pollutant emissions. Energy efficiency can be an effective strategy to work towards the so-called "triple bottom line" that focuses on the social, economic, and environmental aspects of a business [8]. Studies conducted on exergy analysis of industrial processes are a few in numbers, compared to studies on energy, while the number of such studies (i.e., [9–15]) has recently increased rapidly. In other words, many

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Nomenclature

$\dot{E}$	energy rate (kJ/h)
$\dot{E}x$	exergy rate (kJ/h)
h	specific enthalpy (kJ/kg)
$\dot{I}$	irreversibility rate, exergy consumption rate (kJ/h)
$\dot{m}$	mass flow rate (kg/s)
$\dot{Q}$	heat transfer rate (kJ/h)
W	shaft work, work (kJ)
$\dot{W}$	work rate or power (kJ/h)
s	entropy (kJ/kg K)
$\dot{S}$	entropy rate (kJ/h)
T	temperature (K)
C_p	specific heat capacity (kJ/kg K)
η_i	energy (first law) efficiency (%)
η_{ii}	exergy (second law) efficiency (%)
ψ	flow exergy (kJ/kg)

Indices

in	input
out	output
k	boundary
gen	generation
dest	destroyed
la	leaking air
g	gas
lim	limestone
t	trass
h,lim	humidity of limestone
h,t	humidity of trass
lim,s	limestone from separator
t,s	trass from separator
h,s	humidity from separator
stm	steam
h	humidity
0	dead state or reference environment
1	temperature of material

Abbreviation

TM	trass mill

researchers have been aware of advantages introduced by the second law analysis in the way to improve energy efficiency of processes [4].

All of the studies based upon the cement sector either to define the general situation or to examine the rotary burner process on the production line. In Turkey, for cement production the dry system with pre-calcine is used. In this kind of system, energy consumption on the production line is very high in each step of the process. In the production process, energy consumption needs to be investigation at every point. In here, we focused on Trass Mill (TM) existed on the production line. This study is important as the first investigation based on energy and exergy analysis on TM. As the method; energy and exergy analyses for TM have been carried out according to the 1st and 2nd law of thermodynamics and energy and exergy efficiencies have been calculated. The present study consists of five sections. The first section presents the sector situation, energy and exergy concepts and objective of this study. Definition of the cement production and TM process is presented in the second section. The third part gives methodology; the mass, energy and exergy analysis equations. The fourth part offers results of energy and exergy analyses, their efficiencies and diagrams. The last part gives the results obtained and suggestions to improve the efficiency.

2. System description

Cement production is a high-energy consumption and involves the chemical combination of calcium carbonates (limestone), silica, alumina, iron ore, and small amounts of other materials, chemically altered through intense heat to form a compound with binding properties. Fig. 1 shows the main steps in a cement production. The process of cement manufacture can be divided mainly into three basic steps, namely (i) preparation of raw materials, (ii) preprocessing to produce clinker, and (iii) grinding and blending clinker with other products to make cement.

Some materials are need while blending of clinker in the cement kiln after getting clinker. These materials are trass and limestone. Chemical formula of the trass is $Ca(OH_2)$. $Ca(OH_2)$ comes out as a product which has characteristic of hydraulic connection as a result of chemical reactions. After reaction with water, $Ca(OH)_2$ causes harm in the hardened concrete. Added trass provides mechanical, physical and chemical improvement in concrete and prevents to be damages. Limestone is the other used additional material. Effect of the included silicate, alumina and calcium ferrites in the cement, limestone adjusts the level of hardening. TM prepares these additional materials for the cement production line in the factory. Fig. 2 shows the flow scheme of TM. As can be seen from this figure, limestone, trass and gas coming from the cooler are mixed. TM removes humidity of the limestone and trass. Same time, both materials are grinded to a desired dimension with the steel marble in the mill. Trass and limestone came into the stock silos after passing from separator helping with transporter gas. Gas exhausts to the atmosphere by a fan after filtering. The operation hours of a TM in the cement factory change completely according to the demand on the cement to be product. In the cement factory where the data of this study were taken on 15 September 2004, the TM was operated for 5 h. In the calculations, an average of this 5 h operation was used.

3. Method and theoretical analysis

The energy balance is the basic method of process investigation and energy analysis is a traditional approach to estimating various energy conversion processes. Energy analyses, based on the first law of thermodynamics, are used reducing heat losses or enhance heat recovery. They do not give any information on the degradation of energy that occurs in the process. For industrial processes, exergy analysis is a powerful concept and the modern thermodynamic method used as an advanced tool. It is also a tool for identifying the types, locations and magnitudes of thermal losses. Identification and quantification of these losses allow us to evaluate and improve the design of thermodynamic systems [9].

Exergy is a measured for quality of mass and energy streams. Rosen and Dincer [16] have reported that examining the relation among exergy and energy and the environment make it clear that exergy directly relate to sustainable development. The concept of exergy provides an estimate of the minimum theoretical resource requirement (requirement for energy and material) of a process. This, in turn, provides information on the maximum savings achieved by making use of new technology and new processes.

New technology and new processes do not come about by themselves. By providing a deeper insight, the exergy concept provides a better foundation for improvement and for calculating expected savings [17].

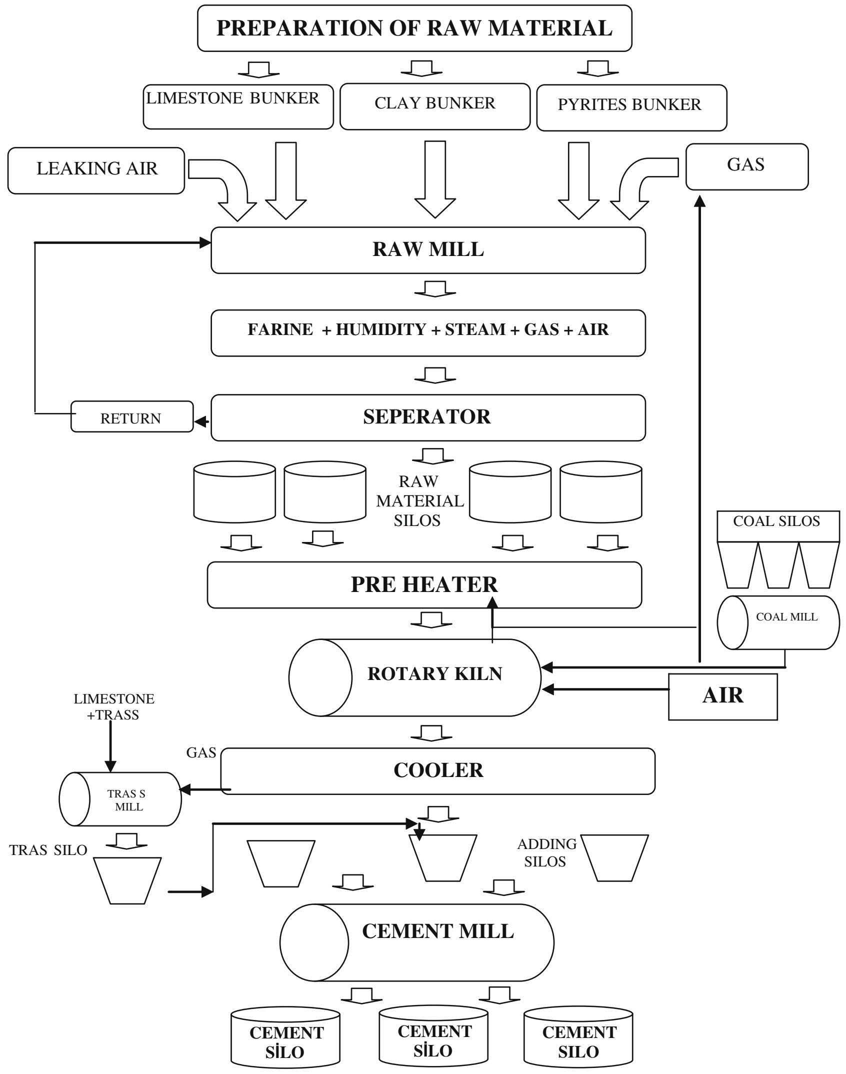

Fig. 1. Flow diagram of cement production line.

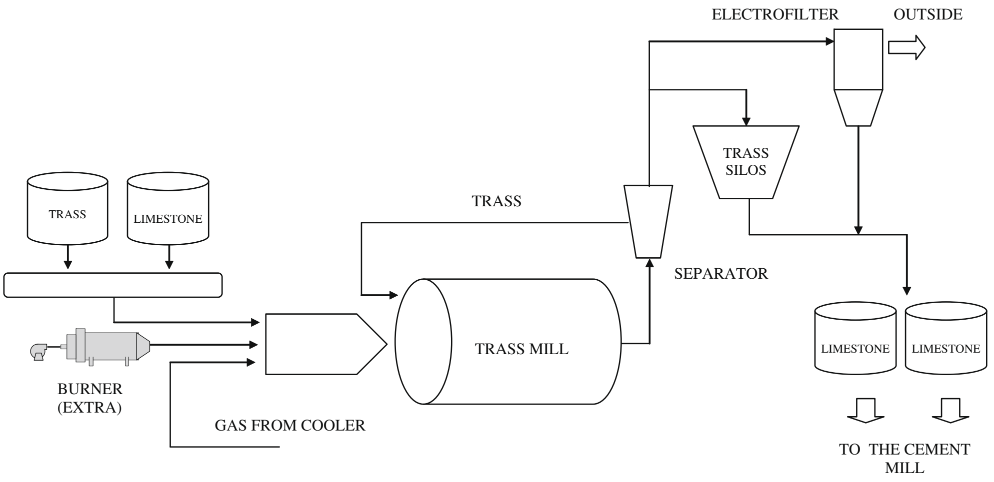

Fig. 2. Trass mill flow schema.

For a general steady state, steady-flow process, the following balance equations are applied to find the work and heat interactions, the rate of exergy decrease, the rate of irreversibility and the energy and exergy efficiencies [17–19]. The mass balance equation is in the rate form as below:

$$\sum \dot{m}_{\mathrm{in}} = \sum \dot{m}_{\mathrm{out}} \tag{1}$$

where $\dot{m}$ is the mass flow rate, and the subscript in stands for inlet and out for outlet.

The general energy balance is can be explained follows:

$$\sum \dot{E}_{\mathrm{in}} = \sum \dot{E}_{\mathrm{out}} \tag{2}$$

$$\dot{Q} + \sum \dot{m}_{\mathrm{in}} h_{\mathrm{in}} = \dot{W} + \sum \dot{m}_{\mathrm{out}} h_{\mathrm{out}} \tag{3}$$

where $\dot{E}_{\mathrm{in}}$ is the rate of net energy transfer in, $\dot{E}_{\mathrm{out}}$ is the rate of net energy transfer out by heat, work and mass, $\dot{Q} = \dot{Q}_{net,\mathrm{in}} = \dot{Q}_{\mathrm{in}} - \dot{Q}_{\mathrm{out}}$ is the rate of net heat input, $\dot{W} = \dot{W}_{net,\mathrm{out}} = \dot{W}_{\mathrm{out}} - \dot{W}_{\mathrm{in}}$ is the rate of net work output, and h is the enthalpy per unit mass [15].

Assuming no changes in kinetic and potential energies with any heat or work transfers, the energy balance given in Eq. (3) is simplified to flow enthalpies only:

$$\sum \dot{m}_{\mathrm{in}} h_{\mathrm{in}} = \sum \dot{m}_{\mathrm{out}} h_{\mathrm{out}} \tag{4}$$

The energy efficiency defines as the ratio between the amounts of energy output and the amount of input energy to system. This expressions is the basic form of the energy efficiency system and it is defined as

$$\eta_i = \frac{\sum \dot{E}_{\mathrm{out}}}{\sum \dot{E}_{i_n}} \tag{5}$$

The general exergy balance for a ideal system is

$$\sum \dot{E}x_{\mathrm{in}} - \sum \dot{E}x_{\mathrm{out}} = \Delta \dot{E}x_{system} \text{ or}$$

$$\sum \left(1 - \frac{T_0}{T_{\mathrm{k}}}\right) \dot{Q}_{\mathrm{k}} - \dot{W} + \sum \dot{m}_{\mathrm{in}} \psi_{\mathrm{in}} - \sum \dot{m}_{\mathrm{out}} \psi_{\mathrm{out}} = \Delta \dot{E}x_{system} \tag{6}$$

where $\dot{Q}_{\mathrm{k}}$ is the heat transfer rate through the boundary at temperature T_{k} at location k,$\dot{W}$ is the work rate. ψ is the flow exergy, which defined as physical exergy [18]. Physical exergy is the work obtainable by taking the substance through reversible processes from its initial state temperature T_0 and the pressure P_0 of the environment and may be expressed as follows [12,13]:

$$\psi = (h - h_0) - T_0(s - s_0) \tag{7}$$

where h is the specific enthalpy and s is the specific entropy and the subscript zero indicates properties at the dead state. The exergy destroyed or the irreversibility is as follows:

$$\dot{I} = \dot{E}x_{\mathrm{dest}} = T_0 \dot{S}_{\mathrm{gen}} \tag{8}$$

where $\dot{S}_{\mathrm{gen}}$ is the rate of entropy, while the subscript "0" denotes conditions of the reference environment [18]. Different ways of formulating exergetic efficiency proposed in the literature have been given in more detail elsewhere [14,20,21]. The exergy efficiency expresses all exergy input as used exergy, and all exergy output as utilized exergy. Therefore, the exergy efficiency η_{ii} is as follows:

$$\eta_{ii_1} = \frac{\dot{E}x_{\mathrm{out}}}{\dot{E}x_{\mathrm{in}}} \tag{9}$$

Often, there is a part of the output exergy that is unused, i.e. an exergy wasted, $\dot{E}x_{\mathrm{waste}}$ to the environment. In this case, exergy efficiency is as follows [21]:

$$\eta_{ii_1} = \frac{\dot{E}x_{\mathrm{out}} - \dot{E}x_{\mathrm{waste}}}{\dot{E}x_{\mathrm{in}}} \tag{10}$$

The rational efficiency defined, by Kotas [11] and Cornelissen [20], as the ratio of the desired exergy output to the exergy used namely is below:

$$\eta_{ii_2} = \frac{\dot{E}x_{desired,output}}{\dot{E}x_{used}} \tag{11}$$

where $\dot{E}x_{desired,output}$ is all exergy transfer rate from the system, which must be regarded as constituting the desired output, plus any by-product that is produced by the system, while $\dot{E}x_{used}$ is the required exergy input rate for the process to be performed. The exergy efficiency given in Eq. (9) may also be expressed as follows [22]:

$$\eta_{ii_3} = \frac{Desired\ exergetic\ effect}{Exergy\ used\ to\ drive\ the\ process} = \frac{Product}{Fuel} \tag{12}$$

To define the exergetic efficiency both a *product* and a *fuel* for the analyzed system are identified. The product represents the desired result of the system (power, steam, some combination of power and steam, etc.), while the fuel represents the resources expended to generate the product and is not necessarily restricted to being an actual fuel such as a natural gas, oil, or coal. Both the product and the fuel are expressed in terms of exergy [23].

4. Results and discussion

In this section, the energy and exergy analyses in the TM which contributes to quality of the cement are performed using the First and Second Law of Thermodynamics. The specific heat capacity, the mass balance, the temperature, the pressure values and the constant specific heat of the input and output materials were firstly determined for the energy and exergy analysis of the TM.

$$\sum \dot{m}_{\mathrm{in}} = \sum \dot{m}_{\mathrm{out}} \tag{13}$$

$$\begin{aligned} &\dot{m}_{\mathrm{la}} + \dot{m}_{\mathrm{g}} + \dot{m}_{\mathrm{lim}} + \dot{m}_{\mathrm{t}} + \dot{m}_{\mathrm{h,lim}} + \dot{m}_{\mathrm{h,t}} + \dot{m}_{\mathrm{h},rs} + \dot{m}_{\mathrm{t,s}} + \dot{m}_{\mathrm{lim,s}} \\ &\quad = \dot{m}_{\mathrm{lim}} + \dot{m}_{\mathrm{g}} + \dot{m}_{\mathrm{stm}} + \dot{m}_{\mathrm{t}} + \dot{m}_{\mathrm{h}} \end{aligned} \tag{14}$$

In the mass analysis, a balance has been set between input and output material in the TM. Limestone and trass having the humidity rate of 20%, coming from the material silos go into the TM. The gas coming from the cooler, having the temperature of 874 K, also go into the mill. Temperature of gas decreases to 586 K because of the heat losses from pipes, fan and multi-cyclone lost. Furthermore, the trass not having suitable size and leaving from TM go back to the mill from the separator. The ratio of the trass returned from the separator, having the temperature of 348 K, is average 40%. Since the whole system runs in vacuum, leaking air enters into the mill from environment. In the mill, the materials mixed and dried go out as the trass having humidity rate 2.28%, after grinding.

Table 1 shows the mass and the temperature values of the input and output material in the TM. The specific heat capacity of the each input and output material for analyses is needed to be know. To find the specific heat capacity (C_p), it is referred the empiric correlation below which practices upon the Kirchhoff law. The total specific heat capacity of each material has been calculated by using the mass flows of each material's components.

$$C_p = a + bT + cT^2 + dT^3 \tag{15}$$

where a, b, c and d are the constants for raw material and T represents temperature of the component. The constants belonging to component of the input material relates the sources [24,25]. The specific heat capacity of the leaking air has been calculated and given in Table 2 with dependent on elementary analysis.

According to first law of the thermodynamics, the TM is an open system, having a continuous flow and the following assumptions are made for the energy analysis:

Table 1
Mass and energy balance of trass mill.

No.	Input material	C_p (kJ/kg K)	T_1 (K)	$\dot{m}$ (kg/h)	Q_h (kJ/h)	Output material	C_p (kJ/kg K)	T_1 (K)	$\dot{m}$ (kg/h)	Q_h (kJ/h)
1	Leaking air	1.05	295	7700	2 385 075	Trass	0.98	354	23 252	8 025 739.16
2	Gas	1.11	586	31 579	20 541 180.03	Gas	1.06	354	39 279	14 739 227.15
3	Limestone	0.83	295	2514	615 776.2	Steam	1.96	354	4 373	3034 689.64
4	Trass	0.94	295	15 709	4 356 130.1	Limestone	0.89	354	3722	1 172 833.77
5	Trass from separator	0.975	348	7697	2 611 745.84	Humidity	4.19	354	543	805 521.72
6	Limestone from separator	0.88	348	1 232	378 668.19	Heat losses				9 751 821.12
7	Humidity from separator	4.18	348	182	265 093.59					
8	Limestone humidity	4.18	295	628	775 284.50					
9	Trass humidity	4.18	295	3927	4 842 719.10					
10	Shaft work	–	–	–	758 160					
	Total			71 171	37 529 832.56				71 171	37 529 832.56

Table 2
Calculation of the specific heat capacity of the leaking air.

Material	T (K)	Components	Percentage mass distribution (%)	Mass flow rate (kg/h)	$C_{pcomp.}$ (kJ/kg K)	$M^{*}C_{pcomp.}$	C_{pair} (kJ/kg K)
Leaking air	295	N_2	77.37	3909.51	1.041	4069.80	1.053
	295	O_2	20.76	1049.00	0.925	970.33	
	295	CO_2	0.03	1.52	0.846	1.28	
	295	Ar	0.92	46.49	4.97	231.04	
	295	H_2O	0.01	0.51	4.181	2.11	
	295	Others	0.91	45.98	1.007	46.30	
Total				5053.00	5320.87		

- The system is a steady state in a steady flow process.
- Kinetic and potential energy changes of input and output materials are ignored as their values very small.
- Electrical energy produces shaft work.
- Energy losses happening in the pipeline connections among units are ignored.

Calculation of the energy balance of the TM is made by using Eqs. (2)–(4) and the analysis results are given in Table 1. It is seen from the obtained results that the unit energy input is 527.32 kJ/kg into the mill. The main heat source in the process is the gas returned from the cooler and the unit input heat is 650.47 kJ/kg. Fig. 3 illustrates the energy flow of TM. In addition, Table 3 gives the enthalpies of the each chemicals components entering and leaving from the TM. The energy balance presented in Table 1 indicates relatively good consistency between the total heat input and the total heat output. Energy efficiency of TM is the ratio between the amount of energy output and input into the TM The energy efficiency value is determined by using Eq. (5) and it is found to be 74% depending on the data of the mill. Fig. 4 shows the results of these energy analyses, helping with the Sankey diagram of TM.

Exergy analysis applied to the process is accepted as an open system under the steady-state conditions. First, it is necessary to define the parameters of the environment for exergy analysis of

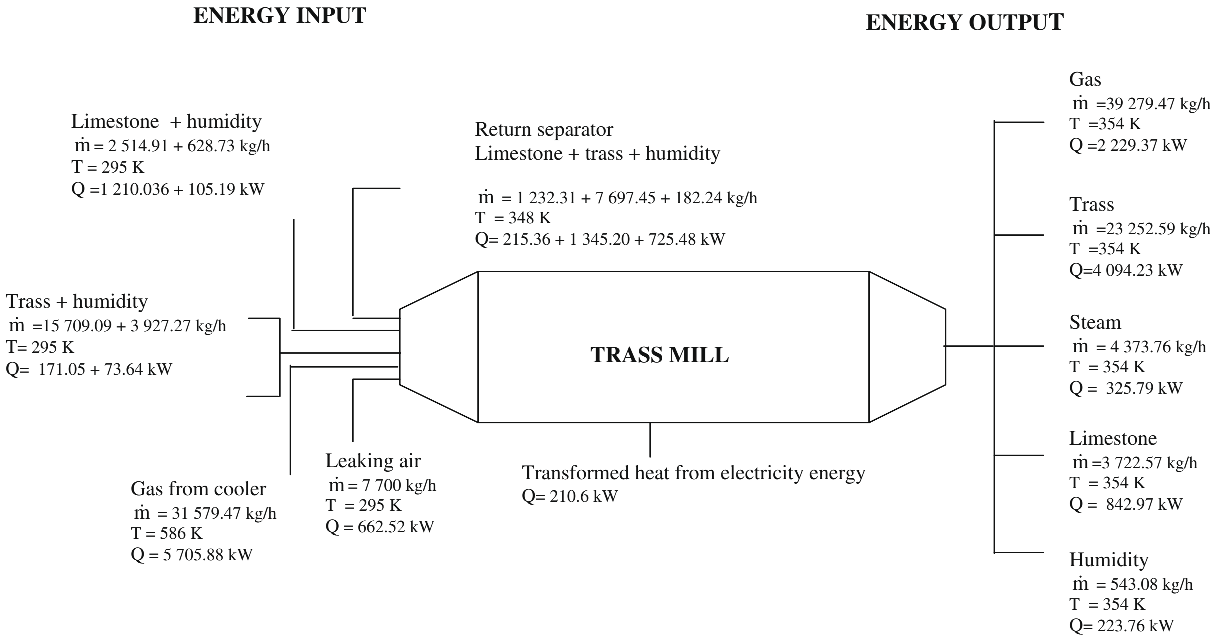

Fig. 3. Energy flow diagram of trass mill.

Table 3
Enthalpy balance of trass mill.

No.	Input material	C_p (kJ/kg K)	T_1 (K)	$\dot{m}$ (kg/h)	ΔH^a (kJ/h)	Output material	C_p (kJ/kg K)	T_1 (K)	$\dot{m}$ (kg/h)	ΔH (kJ/h)
1	Leaking air	1.05	295	7700	0	Trass	0.98	354	23 252	1 337 623.19
2	Gas	1.11	586	31 579	10 200 483.6	Gas	1.06	354	39 279	2 456 537.86
3	Limestone	0.83	295	2514	0	Steam	1.96	354	4373	505 781.61
4	Trass	0.94	295	15 709	0	Limestone	0.89	354	3722	195 472.29
5	Trass from separator	0.975	348	7697	397 765.89	Humidity	4.19	354	543	134 253.62
6	Limestone from separator	0.88	348	1232	57 670.73					
7	Humidity from separator	4.18	348	182	40 373.45					
8	Limestone humidity	4.18	295	628	0					
9	Trass humidity	4.18	295	3927	0					

$T_0 = 295$ K.

[a] $\Delta S = S - S_0$, S: entropy of the material at T_1, S_0: entropy of the material at dead state.

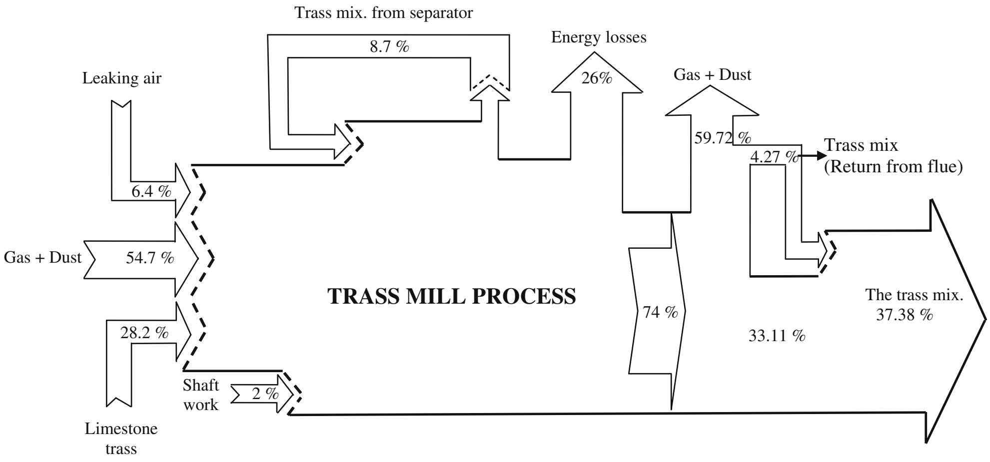

Fig. 4. Sankey diagram of trass mill.

Table 4
Entropy balance of trass mill ($T_0 = 295$ K).

No.	Input material	C_p (kJ/kg K)	T_1 (K)	$\dot{m}$ (kg/h)	ΔS^a (kJ/K)	Output material	C_p (kJ/kg K)	T_1 (K)	$\dot{m}$ (kg/h)	ΔS (kJ/K)
1	Leaking air	1.05	295	7700	0	Trass	0.98	354	23 252	4126.23
2	Gas	1.11	586	31 579	24 046.5	Gas	1.06	354	39 279	7577.79
3	Limestone	0.83	295	2514	0	Steam	1.96	354	4373	1560.21
4	Trass	0.94	295	15 709	0	Limestone	0.89	354	3722	602.98
5	Trass from separator	0.975	348	7697	1238.33	Humidity	4.19	354	543	414.14
6	Limestone from separator	0.88	348	1232	179.54					
7	Humidity from separator	4.18	348	182	125.69					
8	Limestone humidity	4.18	295	628	0					
9	Trass humidity	4.18	295	3 927	0					

[a] $\Delta S = S - S_0$, S: entropy of the material at T_1, S_0: entropy of the material at dead state.

the process. Reference temperature and pressure values were 295 K and 101.325 kPa, respectively. As the mass balance of the trass mill contains the non-chemical reaction, they have a covered atomic balance. Consequently, the chemical exergy of this unit has not been calculated in the process. In the exergy analysis of the process, the following assumptions are made:

- The effect of the pressure is neglected on the enthalpy and entropy characteristics of the input and output materials.
- Pipe gases are ideal gas mixture.
- Processes are always in a constant flow state. The exergy values of the kinetic and potential energy of the input and output materials are very small, that is why we ignored them.
- The effect of chemical exergy is neglected since the drying process lacked a chemical reaction thus, only the physical exergy is calculated.

Using these assumptions, the exergy analysis has been made by using Eqs. (6) and (7) and the exergy efficiencies have been calculated for the TM. Tables 3 and 5 show exergy analyses and efficiency results. Tables 3 and 4 give the enthalpy and the entropy balance of TM, respectively, and the exergy balance of TM is listed in Table 5.

Exergy efficiency for TM is found as the ratio between the amount of output and input exergy into the mill [24]. The exergy efficiency is calculated by using Eqs. (11) and (12) and found to

Table 5
Exergy balance in trass mill.

No.	Input material	ΔH (kJ/h)	ΔS (kJ/K)	ψ (kJ/h)	Output material	ΔH (kJ/h)	ΔS (kJ/K)	ψ (kJ/h)
1	Leaking air	0	0	0	Trass	1.337623	4126	120386.09
2	Gas	10200483	24046	3106765.85	Gas	2456537	7577	221088.41
3	Limestone	0	0	0	Steam	505781	1560	45520.34
4	Trass	0	0	0	Limestone	195472	602	17592.51
5	Trass from separator	397765	1238	32459.2	Humidity	134253	414	12082.83
6	Limestone from separator	57670	179	4706.15				
7	Humidity from separator	40373	125	3294.63				
8	Limestone humidity	0	0	0				
9	Trass humidity	0	0	0				
10	Shaft work			758160				
	Total			3905385.82				416670.17

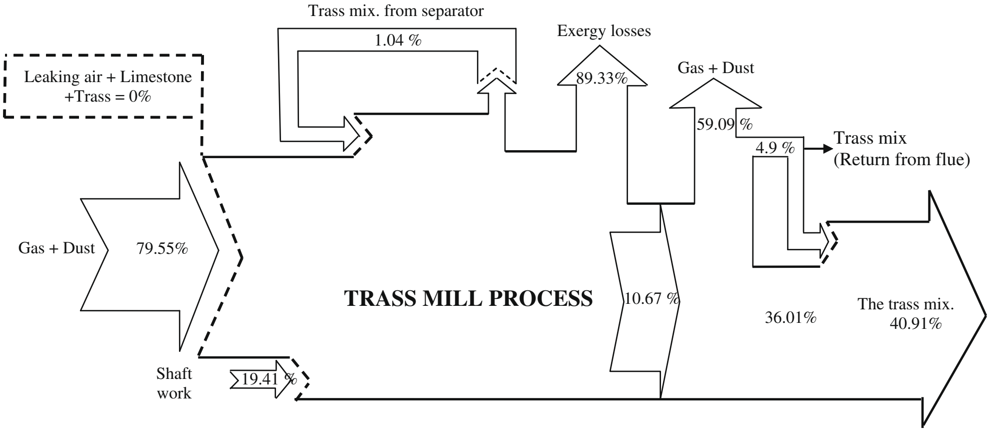

Fig. 5. Grassmann diagram of trass mill.

be 10.68% depending on the data of the mill. Fig. 5 shows the results of these exergy analyses by the Grossman diagram.

5. Conclusions

The main conclusion drawn from the present study is summarized below:

(a) Exergy analysis is a powerful tool used successfully and effectively in the design, simulation and performance evaluation of thermal systems as well as for estimating energy utilization efficiencies of countries or societies.

(b) The energy and exergy efficiency values are found to be 74% and 10.67%, respectively, for the TM.

(c) Operation of the TM spends a lot of energy. Gas at high temperature goes to the TM to reduce the humidity of the output material. So, energy losses decrease the efficiency of the TM. The primary efficiency of the process is about 74% and the 26% of the remaining energy lost with heat losses. In this system, energy recovery may be realized from hot flue gasses and heat losses. However, the temperature of the gasses should not be dropped below the limit values for energy recovery from the flue hot gasses. If the energy recovery rate of heat losses would be 40%, this rate could be increased about 14% for the whole TM process. Thus, energy efficiency of the system is to be arisen from 74% to 84%.

(d) In the TM, exergy losses have been calculated about 89% and the exergy losses are exhausted due to the irreversibility. Firstly, the hot gas temperature must be checked out continuously in order to reduce the losses. Furthermore, the exergy losses could be decreased to 33% using the energy recovery system established before the mill unit. Usable exergy rate of the hot gasses and steam going up the flue gas are 4%. If this improvement could be made, exergy efficiency of the system would go up to about 48% except for the gains obtained by the insulation. To increase the efficiency, realistic evaluations on the TM can be made after studies on the exergoeconomic analyses and improvements of using waste energy.

(e) This study indicates that exergy utilization at the TM was even worse than energy utilization. That is, this process represents a big potential for increasing the exergy efficiency. It is clear that a conscious and planned effort need to improve exergy utilization in TM. Considering the existence of energy-efficient technologies in the similar sectors, the major problem is delivering these technologies to consumers or using effective energy-efficiency delivery mechanisms.

Absolutely, studies on the efficiency analyses, according to Second Law of Thermodynamics, have increased the efficiency in the production line of the cement factory. Determinations of the energy saving potential, improving and dating of the production technology will provide in an inevitable manner the energy and financial saving at an important ratio in Turkey having highly energy costs.

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