

Energy efficiency and recovery of heat lost in the Industrial Systems

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Abstract. the economic importance of energy is manifested at all levels of farms, the demand for energy is today one of the major challenges of societies, it constitutes an indispensable element to any activity of production, it is for this, the industry has an interest to anticipate and invest in energy efficiency in order to gain competitiveness, this last represents a tremendous lever for performance and economy. The Energy diagnosis allows unveils the potential energy sinks and the discovery of the various sources of energy losses in a manufacturing process or in all system user of energy. Use with the effectiveness of the energy help the industry to meet the challenges of competitiveness.

1. Introduction

The mastery of the future energy demand and conditions of supply is a major political issue for the whole of the planet. It is made all the more difficult that humanity must face a double challenge. The satisfaction of the energy needs of a world population that will continue to grow during the next few decades [1], and with a large share aspires to a social and economic development based on an increased demand for energy. The one posed by the necessary reduction of emissions of greenhouse gases, inherent in the use of fossil fuels and emissions of other gaseous pollutants, which threaten the climatic balances environmental and of the earth. It is the issue of sustainable development, a concept in which the word development is not less important than the idea of responsibility vis-a-vis the future generations that involved the concept of sustainability, in its three dimensions economic, social and environmental.

An energy audit can lead to the discovery of various sources of energy lost in an installation. The consumption of this energy in the industrial sector is extremely concentrated and specific to each branch.

During the operation of a process of production or processing, the heat produced thanks to the energy provided is not used in full. A part of the heat is inevitably lost. It is because of this inevitability that we speak of "heat lost" [2] which can now be recovered. The recovery of the lost heat can respond to the needs of specific heat to the business or to the needs of heat from other companies, or more broadly, a territory, via a network of heat. It can also be converted into electricity for the internal or external use. In different areas in particular the industrialists, the loss of energy is a major shortcoming in the optimization of its use. Its recovery is a very complex task; significant breakthroughs have been achieved in the development of new technologies, the purpose of which is to reduce its consumption and losses that is derived from it.



Knowing that such a loss cannot be avoided, it goes without saying that the innovation in its recovery is needed and that new technologies or techniques are to develop in this direction. The various possibilities of recovery of energy and the reduction of its consumption, lead to the reduction of its cost and the improvement of energy efficiency and to the improvement of the profitability of industries.

The energy optimizations on the processes represent a significant deposit that must be implemented early in the life of a project, in order to reduce in a visible manner the energy consumption and the associated costs, it is appropriate to practice for the management of the energy. These actions provide a profit on the Environmental Plan and on the economic plan. The system of management of the energy is a tool of pilotage allowing putting in place these good practices in an effective and sustainable manner.

Energy efficiency in the industry relies already on a number of clusters of excellence. The development and refinement of technologies allow exploiting a deposit of energy saving high in the industry. For optimal effectiveness, this search for energy performance must be based on a dual approach: global optimization of the performance of the systems and improving the performance of the equipment.

2. Energy consumption in the industry

As soon as the first oil shock in 1973 and 1982 [3], the world was re-accustomed to an energy little expensive, often wasted and not sufficiently valued. Its recent increase, the awareness of its scarcity inescapable and the climate impact point again the need of the mastery of the consumption of energy. With the increase in the long term the price of energies and its volatility, the energy performance of enterprises becomes a factor of competitiveness key: energy efficiency programs allow you to reduce the costs of production, the impact on the environment and identify new capabilities of investment for businesses.

The future of energy and economic development through the improvement of technologies in all areas of the use of energy. In particular, the energy consumption of the utilities and the transverse processes to all industrial sectors represents a significant share. The industry, because its motivation is before any economic, has been the "good pupil" in energy efficiency and important results have been achieved during the last thirty years [3]. However there is still the potential of energy efficiency very significant in this sector consuming 1/3 of energy. In effect, if the energy intensity in the industry has decreased from 2 to 3 per cent per year before 1990, she returned then to decay more moderate 1 per cent per year. The potential of economy of energy with the best existing technologies that is to say, outside technological breakthroughs, is evaluated in 15 to 20% of the consumption of the industry.

The energy consumption is divided into four areas: the transport, the building (residential and tertiary), agriculture, and industry. At the national level, the energy consumption in Morocco is divided in the following manner: 21% of the energy is consumed in the building, 44% in transport, 21% in industry, and 13% in agriculture, after ADEREE (National Agency for the development of renewable energy and energy efficiency).

Although the period of analysis is relatively short (10 years) of the consumption of energy by sector, we can certainly consider that the share of transport increases and that of the industry decreases on the long term.

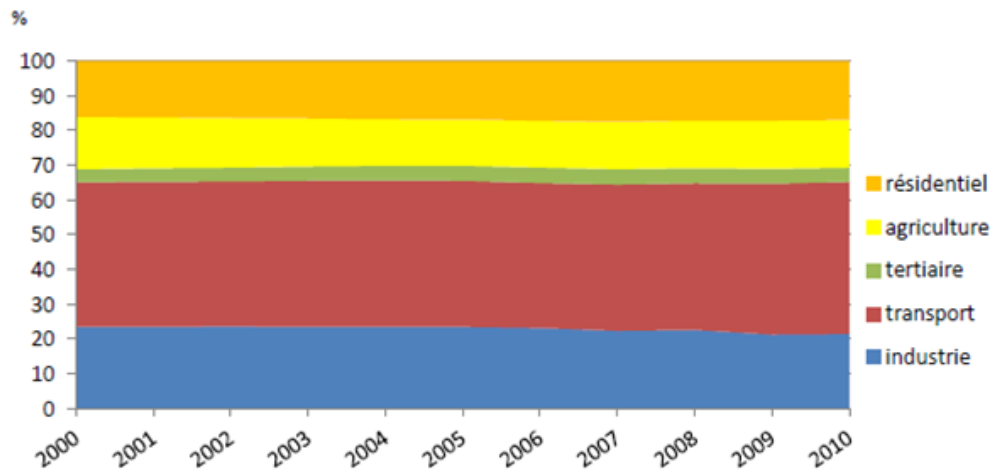


Figure 1. Energy consumption Moroccan 2000 -2010 in % (ADEREE)

In 2010, the energy consumption of industrial processes represented Moroccan 11.6 Mteq (mega tone of oil equivalent) [4], corresponding to 21% of energy consumption Moroccan, furnaces and kilns are processes with a high energy demand. Fossil fuels are the main source of energy consumed by the industry to produce heat.

The importance of energy efficiency has been underlined by many economic actors and international policies. The economies and the depletion of fossil resources are one of the driving forces in the development of processes more effective.

3. Energy analysis of the systems that produce heat

Regardless of the system studied, the objective is to provide the products a quantity of heat determined by:

- Its initial temperature;
- The temperature desired final;
- The mass of the products to heat;
- The specific heat of the products and, if there is place, the heats of transformation during the rise in temperature.

Either Q_u this quantity of useful heat.

The establishment of the thermal balance of a system producing heat has for purpose to determine its performance and its specific consumption, i.e. the consumption reported to the unit produced useful. This implies the most precise knowledge as possible of all inflows and outflows and all the parameters of influence that are related to it.

The performance of a system producing the heat is the report of the useful energy to the energy Q that it must provide the system [3]:

With Q_p the various thermal losses, it comes

$$Q = Q_u + Q_p \quad (1)$$

$$\eta = \frac{Q_u}{Q} = \frac{Q - Q_p}{Q} \quad (2)$$

The term Q_p includes:

- The losses by the fumes Q_f ;
- The losses by the walls Q_w ;
- The energy required to heat the walls and handling systems of the Q_{mv} product;
- The losses by the openings of the oven Q_e .

There is place to determine these losses to calculate the performance of the system.

This representation (Fig.1) gives a general idea on the system as well as the necessary parameters for the calculation of the losses and its performance.

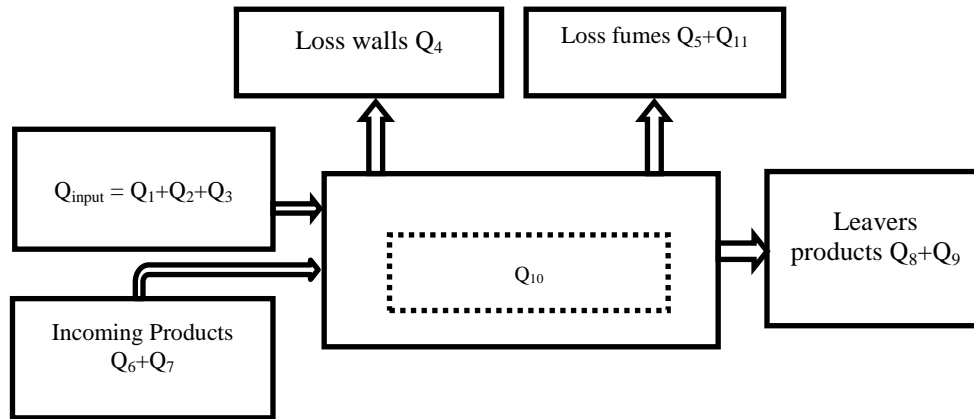


Figure 2. simplified diagram of a system for thermal balance sheet

$$Q_{input} = Q_{useful} + Q_{output} \quad (3)$$

$$Q_{input} = Q_1 + Q_2 + Q_3 + Q_6 + Q_7 \quad (4)$$

$$Q_{lost} = Q_{fumes} + Q_{walls} \quad (5)$$

$$Q_{output} = Q_{lost} + Q_8 + Q_9 \quad (6)$$

NOMENCLATURE

- $Q_1 = m \cdot PCS$: Heat of Combustion provided by the fuel (m =Mass of fuel, PCS (Kwh/kg), its gross calorific value);, sensitive heat provided by the fuel, (CG (Kwh/kg.k): thermal capacity of the mass fuel, TG its temperature);
- $Q_2 = m \cdot C_g \cdot T_g$,sensible heat generated by the fuel (C_g (kwh / kg.K): specific heat capacity of the fuel, T_g its temperature.
- $Q_3 = M_a \cdot C_a \cdot T_a$, Sensitive heat provided by the incoming air (includes the combustion air and gas introduced), (M_a : mass of air and the gas entering, C_a : their thermal capacity average mass and T_a their average temperature). heat is lost by the walls and the openings;
- Q_4 : heat lost through the walls and the apertures;
- $Q_5 = M_f \cdot C_f \cdot T_f$: sensitive heat lost with the fumes, (M_f : mass of fumes, C_f their heat capacity, T_f their temperature);
- $Q_6 = M \cdot C_c \cdot T_1$, heat provided by the load, (M : its mass, C_c its Thermal capacity and mass T_1 : inlet temperature of the load and accessories);
- $Q_7 = M_d \cdot C_d \cdot T_1$: heat provided by the accessories or media handling, or accompanying products the load, (M_d : mass of accessories and C_d their capacity mass thermal);
- $Q_8 = M \cdot C_c \cdot T_2$: heat is lost by the load, (T_2 : The temperature of the outgoing load and accessories);
- $Q_9 = M_d \cdot C_d \cdot T_2$: heat is lost by the accessories;
- $Q_{10} = M \cdot C_r$: heat consumed during the treatment (useful heat), (C_r : enthalpy of KWH treatment /kg).
- Q_{11} =latent heat lost by the fumes = $M_f C_{11}$ (C_{11} : latent enthalpy of smoke increased the power fuel of some constituents rejected if applicable.

These equations allow us to calculate the losses that are related in part to the performance with which heat is produced and on the other hand to the amount of useful heat.

The energy analysis of the processes is based on the principle of conservation of energy, or more commonly designated by the first principle of thermodynamics. It indicates that the energy can neither

be created nor destroyed but retained when a transformation or a transfer (Lechatellier, (1884)). The two forms of energy found are the work W and heat Q .

$$\Delta U + \Delta E_{cin} + \Delta E_{pot} = W_{1 \rightarrow 2} + Q_{1 \rightarrow 2} \quad (3)$$

The energy balance of the processes is based on the first principle of thermodynamics. It allows you to perform a quantitative analysis of the energy flows in a system thermodynamically open, but it is impossible to distinguish the quality of the different forms of energy.

4. Energy simulation of rotary kilns

The study of the thermal transfers occurring in a process can be performed from an energy modeling an open system. The rotary kilns are processes complex to model including the transportation of materials, fluid dynamics, and the heat transfer.

In the literature, a three-dimensional approach of the simulation of a rotary kiln has already been proposed for the heating of granular materials [5]. The study a torque A Modeling Computational Fluid Dynamics (CFD) with a DEM modeling (discrete element method). The method allows CFD modeling of the combustion reaction as well as the phenomena of turbulence is establishing in the gas phase of the oven. One of DEM allows a resolution of the solid phase including the transportation and the dynamic between each grain. The exploitation of the results shows that the average temperatures of the materials and gases are significantly overestimated by the model. The temperature of the gas in output on the process is normally close to 500K, but the temperature estimated by the model is closer to the 2300K. This result was expected because of the complexity of the process to simulate and shows the difficulty of putting in place a three-dimensional simulation of physical phenomena involved in the modeling of rotary kilns industrial.

The use of energy audits one-dimensional for the description of the phenomena of transfer is establishing in rotary furnaces allows you to simplify the modeling of rotary kilns and is already widely proposed in the literature. The models 1-D proposed allow studying the thermal transfers in rotary kilns of cement plant ([6] and [7]) or of the pyrolysis ([8], [9], [10]). Once the 1-D model is validated, it is easily possible to change some parameters to imagine changes in link with the optimization of energy efficiency.

Thus, the employment of energy balances allows one-dimensional considerably reduce the power and the computation time required to the modeling of rotary kilns. However, as any simulation, this methodology for modeling of the heat transfer is limited by the initial conditions, and limitations of the model.

The authors [6], present a model one-dimensional energy to simulate the key process is establishing in the bed of materials of cement kilns. In this model, an energy balance including transfers by conduction, convection and radiation between the different phases gas and solid has been resolved following the progress of the materials in the oven. This modeling 1-D has been validated by a comparison of temperature profiles obtained numerically to the experimental results. Then, the authors have used this model to study the influence of the operational parameters and design on the energy consumption of the oven. In addition to providing an effective tool in the simulation of performance of cement kilns, the model allows to provide a useful basis for the development of a full model in three dimensions.

Today, in the industry, the heat recovery is considered as a value added of the manufacturing process. The recovered heat can be used by the process, or in the production of additional services, such as the electrical energy or heat to a network of heat.

5. Recovery of energy at the level of industrial furnaces

Our study concerns particularly the recovery of energy in the ovens and industrial dryers or any other similar equipment, with a view to produce electrical energy. The solution envisaged remains specific

to each type of installation with the maximum care to respond to the call as long of news of the improvement of energy efficiency and the economy of energy.

The principle diagram of this recovery can be shown in Figure 3.

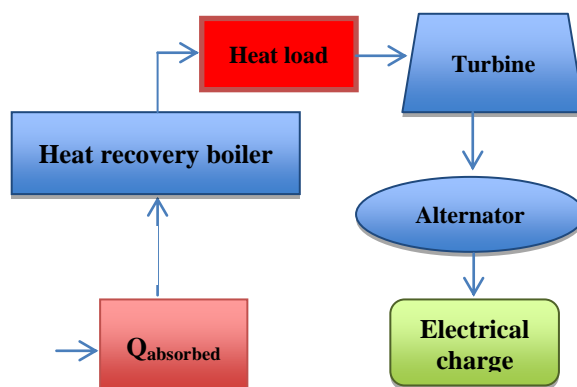


Figure 3. Presentation of the system for recovery of heat lost

The medium used for the recovery of the said energy lost, constitutes an innovative solution is optimal for respond to the problem. This solution was chosen from among several, in the course of the simulation study and the establishment of mathematical correlations linking the parameters of influence of the system and can describe the various systems in which it can be applied as well as the prediction of their thermal behavior.

As an example model, we considered a cement kiln on which a follow-up has been carried out in situ and in which we will have to confront our model.

The fundamental principles of the transfer of material and heat and the principles of thermodynamics applied to the ovens and industrial dryers are used to describe the operation of the system considered and the technical solution adopted as well as the means of conversion of the recovered energy into electricity.

6. Conclusion

The energy used in the industrial sector is considerable. This share can represent up to one quarter of the total energy consumption, the recovery or the upgrading of this energy allows increasing energy efficiency and reducing operating costs.

Energy efficiency is one of the major routes of improvement of the tools of production. By increasing the energy efficiency, we use less energy and we thereby reducing the emissions of greenhouse gases, thereby protecting the environment through the recovery of heat sources lost.

In fact, to recover and exploit the heat sources today lost on industrial processes requires a good knowledge of the industrial processes themselves, but also of technology upgrading to implement and know-how to select and dimension the best solutions, on the basis of technical criteria, economic and environmental. However a large part of these knowledge and know-how are today present in the academic world but broadcast little toward the industry, which, therefore, has a lot of difficulties to engage on the tracks of the heat recovery.

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