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DISIPAREA DE MATERII ȘI ENERGIE – POLUAREA MEDIULUI UN SISTEM BINOMIAL

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MATERIALS AND ENERGY DISSIPATION – ENVIRONMENTAL POLLUTION A BINOMIAL SYSTEM

The goods production and consumption is followed by a huge dissipation of raw materials and noble energies transferred as electrical and mechanical work. The paper analyses electrical energy production using the particular efficiencies for the conversion chain of a thermal power plant, using the fossil fuels. Additionally, the losses in the transport and distribution of electrical energy, with more tension stages are also evocated. We have divided the chain in three stages: the raw fuel extraction and transport, the power plant and the electrical transport and distribution system. For each module the efficiency was shown and the final efficiency to the consumer was related to the heating value of the extracted fuel at the ore. Based on values of the efficiencies, the process and the equipment with high losses were identified. The impact of these losses on the surroundings was mentioned.

Keywords: de-growth, material and energy, dissipation, effective efficiency, crude fuel
Cuvinte cheie: descreșterea, disiparea, materiale și energie, eficienţa globală, combustibil primar

1. Introduction

The dissipation concept was introduced applied sciences by William Thomson (Lord Kelvin) in 1852 in his famous work "On a Universal Tendency in Nature to the Dissipation of Mechanical Energy"

[1]. The connotation of the word dissipation, in energetics, means „loss or diminution, usually undesirable, of power, the loss of power being converted in heat” [2]. In the large sense dissipation, inducing by various kind of loss is due to the natural and anthropic activity and it concerns the physico-chemical processes which occur in the nature and in the various equipment's. In the manufacturing analysis the dissipation is considered as useful loss of energy and materials. Complementary, these losses have a negative impact on the environment and diminish drastically the efficiency of concerned activity. In fact the conservation law is applied to the couple formed by the concerned system and the environment as a whole. It is well known that every power generation/consumption needs heat dissipation system at one of the heat sink (e.g. condenser - cooling tower and the waste gas stack, Joule effect, radiations, etc.). Generally the dissipation of energy and materials occurring in technology processes is called "waste" of fabrication, this waste having its particularity. We may consider the dissipation as degradation? This concept was deeply analysed by Nicholas Georgescu Roegen in its famous work *The Entropy Law and Economic Process* [3], and in other of its papers ([4], [4], [5]). He postulates that „in a closed system, matter continuously and irrevocably degrades” from un available to unavailable state arriving at a state of „maximum entropy”. In other words the complete recovery is impossible. More recently, the papers C. Levallois [6], and C. Kershner [7], follow Georgescu Roegen's way, they sustained that he was the first that twenty years before the sustainable development concept being introduced, which previewed the dangerous effect of the economic growth. The **de-growth concept**, introduced also by Georgescu Roegen, may be sustained by the cooperation between subjects [8].

Based, on the above considerations in this paper using the modular approach, the conservation principle and the second law of thermodynamics was applied at a macroscale size. Therefore, the efficiencies of a production chain must be related to the particular process and re-related to the source origin.

2. Production/consumption and environmental Impact analysis

The production system is always in close interaction with the environment. All material and energy changes occur in this binom. Its extension is variable and the time must be included in the evolution of that. On the fig. 1 these interactions are displayed. The conservation of mass and energy may be written, according with Georgescu-Roegen model, as:

$$\sum_{in} \dot{m}_i = \sum_{out} \dot{m}_{i,positive} + \sum_{out} \dot{m}_{i,negative}$$

and

$$\sum_{in} \dot{E}_i = \sum_{out} \dot{E}_{i,positive} + \sum_{out} \dot{E}_{i,negative}$$

The outlet fluxes of mass and energy may be divided in positive fluxes, used and included in products, and negative fluxes exhausted in the environment. The negative fluxes in fact represent the polluting fluxes which have their characteristic by the reaction with the environmental compounds.

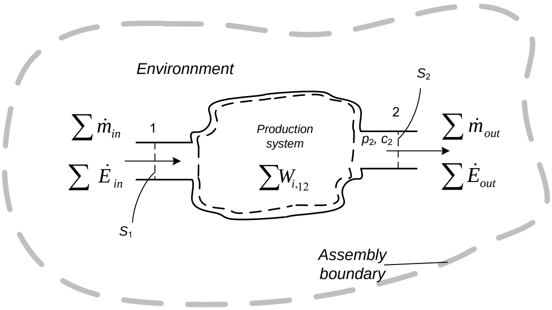

Fig. 1 Production system-environment assembly

The study of the behaviour of the production/consumption-environment couple is based intrinsically on thermodynamics concepts. Therefore the first and second laws of thermodynamics and different kind of efficiencies must be personalized to each analyzed case. For the different forms of energy production the various fluxes consumed in each process must be related to the overall efficiency of the involved system, in function of its primary sources. Therefore the different type form of energy and materials used in the production chain, must refer to the raw material and energy found in the ore before be exploited, which are used in its fabrication process. Also, a complementary analysis concerns the life cycle assessment of the product ([9], [10]).

In aim to enhance the chain overall efficiency it is necessary to increase the energy efficiency conversion of each processes consuming one or other form of energy and auxiliary materials. That implies a detailed approach of the particular phenomena through the laws of thermodynamics, exergetical analysis. Also, the inventory of the material and energy loss on the transport and distribution operations must be made [9], [11]. The high degree of chain fiability during the operation is necessary to be ensured.

3. Case analysis of the electrical energy production chain in a thermal power plant

This analysis is mainly based on the diagram displayed on the fig. 2, which presents a simplified scheme for the electricity production in a thermal power plant [12]. The start point of the below analysis is based at the fuel sink. For the crude fuel exploitation the amount of various form of energy are spent for: extraction operation, transport, ventilation and other specific facilities.

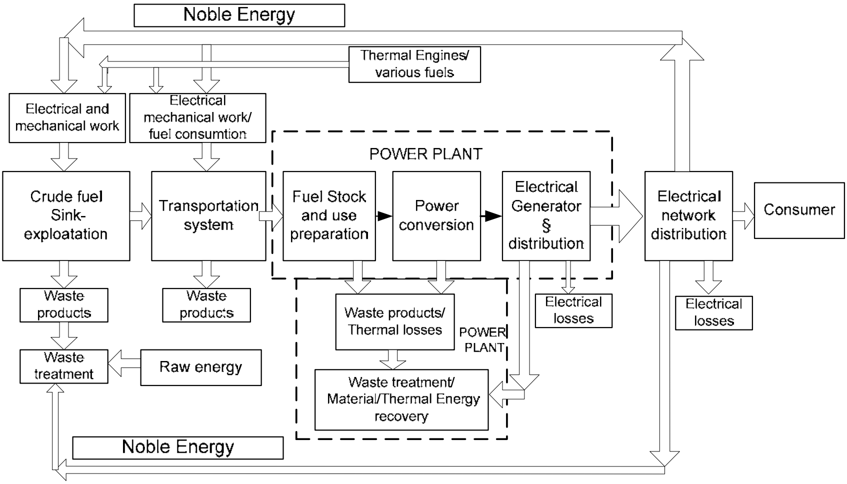

Fig. 2 Electrical energy production/consumption diagram applied to a thermal power plant

The electrical and mechanical work, as noble energy-exergy, is needed to achieve this task. Also, the various forms of additional energy and materials for the waste treatment are spent. During the mass of fuel transport operation and manipulation, the supplementary energy is used and some mass is dissipated in the environment, which involves hazardous pollution with dust and vapour. Unfortunately these effluents deposit in the sol-air route/rail vicinity and their accumulation in time may have the *negative and durable consequence*. At least the fuel reaches its destination arriving to the power plant border. The power plant converse the fuel energy in electrical energy with a particular efficiency, and generates the effluents with a certain pollution degree. We note that the energy consumption for the pollution reduction is taken into consideration in the power plant efficiency. The electrical energy furnished by the power plant is transferred to the electrical network distribution system and delivered to the consumers.

4. Overall Efficiency evaluation related to the fuel sink

Concerning the efficiencies the diagram displayed on the fig. 3 the main sequences are shown. Initially, the first two sequences are referred to the origin ore. The third module, concerning the power distribution, is related to the electrical generator output.

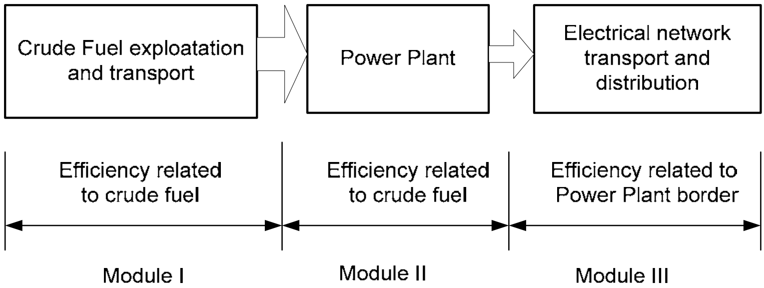

Fig. 3 The efficiencies diagram for the electrical energy chain produced by a power plant

Generally the efficiency of a thermal power plant, module *II*, concerns the energy input at its border by the energy of fuel. So, more or less this efficiency may be defined as:

$$\eta_{PP} = \frac{P_{el}}{C_f \, H_s} \tag{1}$$

where: P_{el} is the net electrical power at the end border of the power plant in kW; C_f is a flux of fuel consumption, in kg/s or m_N^3/s, and H_S represents the higher heating value of the concerned fuel, in kJ/kg and kJ/m_N^3 , respectively.

We have seen that the first module of the chain consumes a lot of energy having different origin. For this module the electrical energy supply is made with the electrical energy provided by the power plant, but after a series of transformation and losses in the electrical network. The efficiency of the electrical network for the first module is defined as the ratio between the quota of power used in the first module $\Delta P_{el,I}$ and the corresponding quota ΔP_{el} to the power plant border:

$$\eta_{el,net\,I} = \frac{\Delta P_{el,I}}{\Delta P_{el}} = \frac{\left(\Delta P_{el,extraction} + \Delta P_{el,transport}\right)_I}{\Delta P_{el}} \qquad (2)$$

The subscripts *extraction* and *distribution* signify that the electrical power is consumed for the mentioned operations. This module also, is supplied in mechanical energy by other thermal engines having a overall thermal efficiency in function of the fuel type defined by the ratio between the mechanical power produced $\Delta P_{m,I}$ and the particular fuel consumption $\Delta C_{f,I}$ and its higher heating values $H_{s,I}$.:

$$\eta_{th,I} = \frac{\Delta P_{m,I}}{\Delta C_{f,I}\, H_{i,I}} = \frac{\left(\Delta P_{m,extraction} + \Delta P_{m,transport}\right)_I}{\left(\sum \Delta C_{f,i}\, H_{s,i}\right)_I} \qquad (3)$$

The denominator of this fraction shows that it may be used a various type of fossil fuels during these operations. The overall efficiency for the module *II* was defined previously. The problem in efficiency evaluation of the entire chain presented above is related to a certain type of energy. In that analysis we consider as the reference the *energy contained in the fossil fuel found in the natural deposit.* We consider the *core* of the analysis the module called *power plant*. The reference is the unit of quantity of crude fuel having its energy that can be delivered, as was mentioned above. This assertion indicates that the analysis has validity only for coal and natural gas, which are mainly used in the thermal power plant. Consequently, for one unit of quantity of fuel must spend the energy for the extraction and transport to arrive to the plant border. In plus, there are some mass quantity losses in the extraction and transport operations, $\Delta c_{f,I}$, in kg or m_N^3 of lost fuel per unit of the crude fuel at the ore boundary. All these losses are converted in thermal energy of crude fuel with the relation:

$$\Delta H_{lost} = \sum_i \frac{\Delta p_{el,i,I}}{\eta_{PP}\,\eta_{el,net,i}} \Delta t_i + \sum_j \frac{\Delta p_{m,j,I}}{\eta_{th,j}} \Delta t_j + \sum_k \Delta c_{f,k,I}\, H_s \qquad [\mathrm{kJ/qu}] \qquad (4)$$

where: $\Delta p_{el,i,I}$ is the electrical power for the operation *i*, in the module *I*, for a quantity of unit of extracted fuel, noted **qu**, in kJ/qu; Δt_i represents the time interval for the operation *i*; $\Delta p_{el,j,I}$ is the mechanical power provided by thermal engines, for the operation *j*, in the module *I*, for a quantity of unit of extracted fuel, kJ/qu; Δt_j represents the time interval for the operation *j;* $\Delta c_{f,k,I}$ is the loss of fuel referred to the one quantity of extracted fuel during the operation *k*, in $qu_{lost}/qu_{extracted}$; H_s represents the higher heating value of the crude fuel, in $kJ/qu_{extracted}$. With these quantities it may be defined the *extraction-transport* efficiency of the unit quantity of fuel as the ratio:

$$\eta_{ex-tr} = \frac{H_s - H_{lost}}{H_s} = \frac{H_{ef}}{H_s} \tag{5}$$

where $H_{ef} = H_s - H_{lost}$ constitutes the *effective heating value of the fuel* at the power plant border. By taking into account this effective heating value of the fuel, the effective power plant efficiency defined by the relation 1 becomes:

$$\eta_{PP,ef} = \eta_{ex-tr}\ \eta_{PP} = \eta_{ex-tr} \frac{P_{el}}{C_f\ H_s} \tag{6}$$

In aim to find a true efficiency, called the *effective efficiency of electrical energy use* $\eta_{el,ef}$ *at the consumer,* for the entire chain must include the *electrical efficiency of the third module,* used only for transport and distribution of the electrical energy $\eta_{el,net,III}$. Therefore:

$$\eta_{el,ef} = \eta_{PP,ef}\ \eta_{el,net,III} = \eta_{ex-tr}\ \ \eta_{PP}\ \eta_{el,net,III} = \eta_{ex-tr} \frac{P_{el}}{C_f\ H_s} \eta_{el,net,III} \tag{7}$$

In aim to put in evidence the effect of losses accounted to the module I and II it is considered a unit of 1 kg of coal having the higher heating value H_s = 20 000 kJ/kg. For the module I it is considered for each kg a consumption of a specific electrical power $\sum \Delta p_{el,i,I}$ = 1 kW/kg and a mechanical power furnished by various thermal engines $\sum \Delta p_{m,j,I}$ = 1,5 kW/kg. The necessary time for the operations with these devices are Δt_i = 10 min and Δt_j =15 min, respectively. Concerning the efficiencies we take $\eta_{el,net,i} \cong 0.8$ and $\eta_{PP} \cong 0{,}32$ and $\eta_{th,j} = 0{,}4$. The specific coal mass lost is around 5 % per kg, $\Delta c_{f,k,I} = 0{,}05$ kg lost/kg. Using these values in the relation (4)

$$\Delta H_{lost} = \frac{1 \cdot 10 \cdot 60}{0{,}8 \cdot 0{,}32} + \frac{1{,}5 \cdot 15 \cdot 60}{0{,}4} + \; 0{,}05 \cdot 20000 \; = 6718 \text{ kJ/kg}$$

This represents the effective heating value of the fuel:

$$H_{ef} = H_s - \Delta H_{lost} = 20\,000 - 6718 = 13\,282 \,\text{kJ/kg}$$

And the extraction-transport fuel efficiency is calculated with the relation (5):

$$\eta_{ex-tr} = \frac{13\,282}{20\,000} = 0{,}664$$

With the relation (6) the effective power plant efficiency becomes:

$$\eta_{PP,ef} = 0{,}664 \cdot 0{,}32 = 0{,}212$$

Taking a mean value of $\eta_{el,net,III} = \eta_{el,STD} = 0{,}6$ [13], [14], the *effective efficiency* $\eta_{el,ef}$ with the relation (7) results:

$$\eta_{el,ef} = 0{,}664 \cdot 0{,}32 \cdot 0{,}6 = 0{,}127 = 12{,}7\%$$

This global analysis shows that the raw energy related to the ore is lost in enormous quantity on the entire chain production/use. The percentage of losses of around 90 % is unbelievable high even with the new technologies in the energy domain. These losses represent a huge source of entropy production for the environment which impacts only with the analysed system.

On the other hand, all these losses must be correlated each of them with its characteristic life time in the environment, in aim to evaluate the accumulation rate in a decided time interval.

This kind of approach allows estimating the trend of each pollutant concentration in environment (solid-liquid-gas). By this method the regularisation of the production of a certain good may be also prepared.

5. Conclusions

The question is how percentage of these energy and material dissipated in the environment may be recovered and reused? We think that the energy effort is not compensated. If at the complex pollution case presented above we add the pollution provided by other production/consumption technologies a dangerous chart of the next future is at the horizon. Is our environment saturated?

The actual natural disasters that have a high frequency and damages increasing from year to year show us that the natural equilibrium is broken. Therefore in aim to de-grow the energy and material dissipation in the environment must reduce the exploitation of the Earth resources and the complementary pollution diminishes. Concerning so called "natural disasters" must say that the anthropic activity is responsible and we may assert that these are in fact the artificial disasters.

A global analysis of the must include the time evolution of the production/consumption technologies that are coupled with the space volume affected by the industrial plants with the scope of environmental parameters rehabilitation. This complex scope of rehabilitation is a very consumptive one which reduces more the estimated global efficiency described.

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DISIPAREA DE MATERII ȘI ENERGIE – POLUAREA MEDIULUI UN SISTEM BINOMIAL

Rezumat. Producerea şi consumul de energie provoacă o imensa risipă de materii prime şi energii nobile (lucrul electric şi mecanic). Lucrarea analizează randamentele de producere a energiei electrice într-o centrală termoelectrică cu combustibili fosili, precum şi pentru sistemul de transport şi distribuție a ei, pe diferite trepte de tensiune. Analiza făcută s-a bazat pe trei module: extracție-transport combustibil, centrala propriu zisă şi rețeaua electrică de transport şi distribuție. Au fost puse în evidenţă randamentele diferitelor module precum şi randamentul efectiv la consumator, raportate la puterea calorifică a combustibilului din zăcământ. Din analiza valorilor eficienţelor înlănţuite pot fi identificate procesele şi echipamentele cu pierderi ridicate, deci cu risipă de energie. Aceste pierderi de energii şi materii în natură au ca efect poluarea mediului.

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