FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 2, N^o 2, 2002, pp. 123 - 133

MATERIAL-ENERGETIC INFLUENCE TECHNOLOGICAL SYSTEMS ON ENVIRONMENT

UDC 504.064

Ivan Krstić, Branislav Anđelković

Faculty of Occupational Safety, University of Nis, Yugoslavia

Abstract. *Enormous significance of rational use material and energy in all range human activity require evolution of methods to estimate efficiency technological systems. Because of that the goal of working is to show element equation to balance material, energetically and exegetical course more exactly the level of useful, i.e. loses. Sensually are interest places biggest looses how will later in that part technological system place balance surface and determinate center of losses. Minimizing mass, energetically and exegetical losses, in the same time is lover the risk of the pollute of environment and give starting base to optimal technological system with characteristics 3E (ecology-economy-energetic). With complete analyze material and energetically course we can speak about their quality like index quality of matter and energy.*

Key words: *technological systems, equation balance, environment.*

1. Introductory Remarks

Conduct of system presents changing condition of system in current time. In system perform to observe material, energetically and information course. In to the system is entering matter, energy and information in some form what can be looking like as starting form. In system threw finally row changes conditioning form in new shape of matter, energy and information with some other new condition, witch like a output from the system watched like finally condition.

If we wont to show connection of elements in system using a law of keeping mass and energy we must know how to use balance sheet, and with them we can consolidate a estimate risk of polluted environment. These sheets may be described in shape: mass, energetic and exegetical balance.

Received May 15, 2002

2. MASS BALANCE

Mass (material) balance is assembled on basis detail analysis technologic process and changes in technological operations and processes. Shows importance means of partial analysis technological system. The bases for analysis partial balance are scheme technological system with definite entrance, technical process and way out. At production material balance starts at consolidate quantity material at entry in technological process and comparing that quantity with quantity received on way out of technological process, threw are comparing the losses of material in that technological process. First are consolidating material balance technological system, and then to determine the biggest places of losses material, because of uncover and determinate the sample that phenomenon, performs analysis material balance for: some stages technological process, some technical operations, some machines and devices or one material in technological process.

How mass carry with herself energy that with balance mowing mass threw some of the process we can get indirect answer of energetic consumption in that process. For any kind of the technical process its strongly important and interesting balance of consumption water, like steam and balance current compressed air. With mass balance we are start from basic law of keeping mass inside of process. He describes one of the basic laws physics, and on that theory the mass cannot be created or destroyed, however mass closed-system keep being constant during a process. This law is correct when the system is moving neglect speed in ratio of speed of light (supposition are bring into because of Einstein's relation $\Delta E = \Delta mc^2$) and it can be used in solving all technical problems, independence of measured mistake.

$$m_d - m_0 = 0 \tag{1}$$

where is: $m_d = \Sigma m_{di,}$ mass what entering at the process; $m_{o,}$ mass what exiting from the process.

Next what is the more important to know is do mass go out from the process on wished place (she is needed at that place for using in other process or operation) or no. We can recognize "useful mass" $m_k = \Sigma m_{ki}$ what stand out from process on wanted place and $m_g = \Sigma m_{gi}$ what stand out from process on unwanted place, mass who is potential polluter of environment. And then equality is in effect.

$$m_d = m_0 = m_k + m_s \tag{2}$$

Directing mass to wanted ways usually thrive complete, however, when that completing particularly, to appraise for exploit the mass is necessary to have a parameter. This parameter is coefficient used by mass.

$$\eta_{km} = m_k / m_d = (m_d - m_g) / m_d \tag{3}$$

Degree of unused mass (lose) is:

$$\eta_{gm} = m_g / m_d \tag{4}$$

Results of all balance must frequently show as model. Usually it's give as i.e. detail model of mass flow in some process, an integrated model on the whole process and model with an energetic levels. All models is giving by product unit. If is a mass flow, at the same time the energy flow is continual, the models can be given by time unit. When is process uncontinual, then the model is giving by process product unit, for example, one time cooking malt in the bear factory [4,5].

On the next picture schematically is shown mass balance mixing of malt and water (figure 1a) and exchanger of heat (figure 1b).

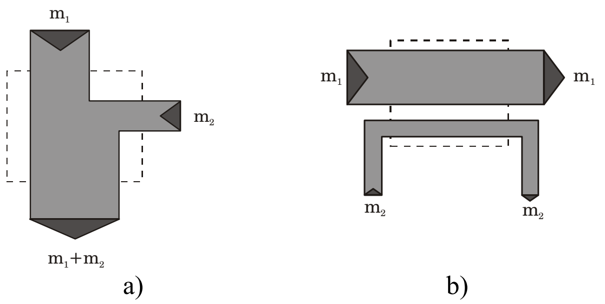

Fig. 1. Diagram of material flow

3. ENERGETIC BALANCE

An energy showing a feature of matter and like that energy can not be maked or destroy. On energy consumption analysis or just the heat, balance of warm i.e. energy is very important. When put an energy balance we starting from basically law of energy maintaining.

$$E_d - E_0 = 0 \tag{5}$$

where is: $E_d = \sum E_{di}$, energy which input to the process; $E_0 = \sum E_{0i}$, energy which output from the process.

And here, such as mass balance, it is needed to know if the energy flow out on the right place (to be useful in the next process or operation when she is needed) or not. An energy witch flow out from the process on the right places is calling useful energy. $E_k = \sum E_{kr}$

However, that energy which is throughout from the process on right place it's calling lost energy. $E_g = \sum E_{gr}$, potentially polluter of environment. Because of that, follow:

$$E_d = E_0 = E_k + E_g \tag{6}$$

Certainly, on the low of saving the energy, energy can not be lost, but the energy that flowing out from process differently of our wish it's called the lost energy. For example, on the cooking process, burning out fuel producing some quantity of heat and in that process some part of heat moving to cooking court (useful energy) but the part of heat going to working or environment (the lost energy). It's almost impossible to direct all the energy to the court for cooking. When directing energy to the wanted direction is succeeded only particularly we will define an energetic level of using.

$$\eta_{ke} = E_k / E_d = (E_d - E_g) / E_d \tag{7}$$

If this level is closer to 1, more energy is directed to wanted ways.

The level of unuseful energy defining like as:

$$\eta_{ge} = E_g / E_d \tag{8}$$

Warmth, like as an energetic balances, in dependence of system purpose and complexity can be shown tabular and graphic. With them we frequently defining the heating loss *Qg*, they are separately testify. The energetic balance is showing like i.e. **Sankey diagram** (figure 2). These diagrams can be detail or integral. Using this diagram, we can almost immediately have an impression about relatively value of energy which using in analyzing processes. That model is usually related on product unit.

If process is continual energy at that moment should be equal with time unit, and if it is discontinues then it is same as process unit.

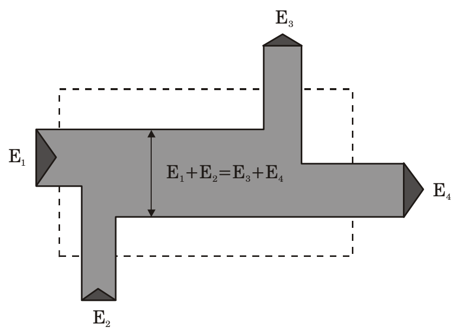

Fig. 2. Sandkey's diagram

4. EXERGETIC BALANCES

In accordance with Kotas and Shargut, an exergy is defining like maximal useful work of no returning process in relation with selected environmental condition, i.e. they represent certain part of the energy which can be completely transformed without limit into the any other shape of the energy and certainly, into mechanical work. In regard that system exergy is defining with relation to her environment, it is important to choose appropriate referent conditions of environment. It is believed that the environment is the thermal abyss large capacity with constant pressure and temperature parameters. He can be defined with referent temperature $T_0 = 298.15$ K and referent pressure $p_0 = 1$ Bar, except if her defined on other way. Realization of useful effect from another system is possible only if that status is not in equilibrium with suite's status [6].

If we are for criteria of energy division adopt level of transformation one form of energy to another, exist three group of energy:

The Energy who can be unlimited transformed to other forms of energy, we call **The Exergy.** In this group mechanical end electrical energy belongs.

The Energy who can be limited transformed to other form of energy, for example the intrinsic energy and the heat.

The Energy who can be transformed into some other form of energy we call **The Anergy.** The example for this type of energy is surrounding energy and the energy of the sea.

Introducing notion of the exergy and the anergy we can defining a first law of Thermodynamics on following way: "In all energetic processes sum of exergy and anergy is constant". The most general expression for any type of energy is:

$$Energy = Exergy + Anergy$$

next to note that is one of members on the right side of expression can have zero value.

For an energetic transformation is effect:

In all no return process, the exergy is transforming into the anergy.

Only in a reversal processes the exergy is still constant.

It is impossible to transform the anergy into the exergy. A realistic energetic processes are more or less irretrievable, so that thorough some transforming one form of energy to another, a exergy stock decreasing, because one part of exergy is transforming to the anergy. On this explanation base, the name of second principle of thermodynamics, so-called the principle of reducting exergy, is excused.

It means that for an energetic process is not enough any other kind of energy, but the exergy i.e. the energy who can be transformed to another form of the energy. It means that the energetic sources are really exergetic sources. Usual terms "energy consumption" or "loosing energy" is in opposition with the energy keeping law, and in this case the energy can't be spend or lose. A terms "spending exergy" or "loosing exergy" have a full meaning because the exergy is spening and loosing and finally irreversible transforming to the anergy.

Irreversible processes are which their system and surroundings can't back in starting state without supplementary consumption of energy (for example, a process in which one part of mechanical energy transforming into the thermal energy).

Measure of processes irreversibility, in other words, energy degradation, can be defined like as the entropy. In irreversible processes come into increasing whole entropy in relation to quantity degradating energy. It means that is whole change of entropy by the second principle of thermodynamics always positive ($S^{uk} \geq 0$).

The entropy increasing multiplied with surrounding temperature showing by the Govy-Stodola equation and represent loosing the exergy (degradated exergy), i.e. showing irreversibility of process in sign I.

$$Ex_{gub} = W_{gub} = I = T_0\left(\sum_{out} S_{out} - \sum_{in} S_{in}\right) = T_0 \Delta S = T_0 \Delta S^{tot} \qquad (9)$$

It means, for a one irreversible process, useful work loosing is equal to exergy loosing. Irreversibility of process can be calculated by the exergy balance, i.e. determining distinctions between the exergy on input and output, with equation:

$$Ex_{gub} = I = \sum_{in} Ex_{in} - \sum_{out} Ex_{out} \qquad (10)$$

An exergetic analysis of process is based on second principle of thermodynamics, on the basis of which we can say: "Sum of exergy in some stationary process can only to slant or in border condition for reversible process to stay constant, but she never can to increase".

Should be one more accent that is in calculation an exergy is separate a three influence which defining the exergy:

The influence of mechanical work on an exergy, i.e. the exergy is defining like as maximal useful work of irreversible process in relation to chosen referent state of surroundings (W_{max}):

$$Ex = W_{max} \tag{11}$$

Influence of the heat on exergy with value exergy (Ex) depends on values quantity of the heat (a) and can be recall by this formula:

$$Ex = \int_A \left(\frac{T - T_0}{T}\right)\dot{Q}_i \, dA \tag{12}$$

where is: A - surface transfer of the heat;
T_0 - temperature of surroundings;
T - an authoritative temperature transfer of the heat.

With permanent temperature we can get:

$$\int \dot{Q}_i \, dA = \dot{Q}_A \Rightarrow Ex = \dot{Q}_A \left(1 - \frac{T_0}{T}\right) \tag{13}$$

The influence of circulate flow of substance with which will be describe the basic component exergy for circulate flow that mean that it will describe physical and chemical exergy.

Phisical exergy is the part of exergy which appears in consequence of difference in temperature and pressure of considering substance with temperature and pressure of surroundings (T_0, p_0).

Physical exergy can be calculated with equation for maximal useful labor which is function of beginning and ending state and condition of surrounding:

$$Ex_{fiz} = h - h_0 - T_0(S - S_0) = Ex^{\Delta T} + Ex^{\Delta p} \tag{14}$$

where are, with h or h_0 marked entropy of the beginning state and state of surrounding.

Physical exergy is contemning warmth ($Ex^{\Delta T}$), and pressure ($Ex^{\Delta p}$) exergy.

Physical exergy of gases expressed with specific heat capacity (cp) like:

$$Ex_{fiz} = Ex^{\Delta T} + Ex^{\Delta p} = c_p \left[(T - T_0) - T_0 \ln \frac{T}{T_0}\right] + RT_0 \ln \frac{p}{p_0} \tag{15}$$

Where T or T_0 marks the temperature of the given gas or temperature of surrounding, and with P or P_0 pressure of the given gas or the pressure of the surroundings, and R is gas constant.

Physical exergy of firm body and liquid expressed with appropriate heat capacity like:

$$Ex_{fiz} = c\left[(T - T_0) - T_o \ln\left(\frac{T}{T_0}\right)\right] - v_m(p - p_0) \tag{16}$$

Where is with v_m marked specific volume which is definite with temperature T_0.

Exergy which is appeared because of differences in it's concern considering substance and it's surrounding is chemical exergy. Differences in count position mean different component of system and different concentration of component.

Chemical exergy describe maximal value useful work for observe substance which is gain bringing up substance in state surrounding which is defining with parameter (p_0,T_0). Because of that process of the transfer of the heat and exergy of the substance is done but only with surrounding.

Chemical exergy gases and their relation with observing surrounding and partial pressure appropriate component of gas in this formula:

$$Ex_{chem} = RT_0 \ln(p_0 / p_\infty) \tag{17}$$

Where is p_∞ marked partial pressure components of the given gas.

For observing single component chemical exergy can be express in this formula:

$$Ex_{chem} = -\Delta G_o - \sum_i x_i Ex_{chem,i}^{in} + \sum_i x_i Ex_{chem,i}^{iz} \text{ .(18)}$$

where is with p_∞ marked formula Gibbs, equation which is expressing from common relation:

$$\Delta G_o = \sum_{product} v_k \Delta g_k - \sum_{reac\tan t} v_j \Delta g_j \tag{19}$$

where is with v_k, v_j i Δg_k, Δg_j marked stechiometric coefficients.

So the all Gibbs's formula given for *j*'s beginning reactant and *k*'s product of chemical process.

Chemical process can be consider as crossing chemical energy with beginning reactant on ending products.

Equation chemical exergy of mixing is:

$$Ex_{chem,mix} = \sum_i x_i Ex_{chem,i} + RT_0 \sum_i x_i \ln \gamma_i x \tag{20}$$

where is: x_i - minor's share *i*-'s component;
R - minor's gas's constant;
γ_i - active coefficients (which is ideal value 1).

With combustion chemical exergy is defining with size of full combustion (VPS) and chemical content of the fuel (Φ) in this formula:

$$Ex_{chem.burn.} = \Phi \cdot \text{VPS} \tag{21}$$

where is Φ defining using formulas for chemical contain of the fuel (for different variety liquid fuel and petrol it motions in the limit of 1.04 to 1.08).

Exergetic diagrams are different from Senkie's because exergetic diagrams represents and so-called exergetic loss (figure 3).

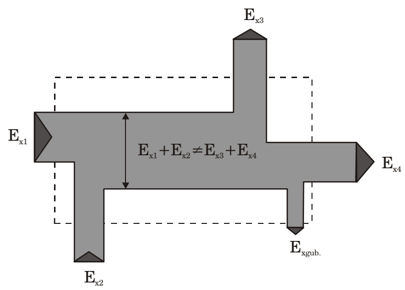

Fig. 3. Exergetic diagram

Exergetic efficiency are using for compare a level of thermodynamics faultless from different processes and certain factory. For correct defining exergetic system efficiency we must defining a border i.e. system surface control which to envelope all irreversibleness of thermodynamic processes on the frame of considering system.

The simplest shape of exergetic efficiency is simple exergetic efficiency. There are defining like a relation of all output and input exergy and she is calculating by formula:

$$\eta = \frac{\sum_{out} \dot{E}x_{out}}{\sum_{in} \dot{E}x_{in}} \tag{22}$$

Defining in this way, exergetic efficiency apply for all considered stationary processes. Unfortunately, she giving a surface impression about thermodynamically faultless of system in case where is all input component of exergetic trend transforming into other component.

Rationally exergetic efficiency is defining like relation between wanted (outputted) exergy and useful (used) exergy by formula:

$$\psi = \frac{\dot{E}x_{wanted\ out}}{\dot{E}x_{used}} \tag{23}$$

Where are wanted (outputted) exergy (Ex_{wanted}) sum of their components (thermal, pressure, chemical) of all outputted exergy which we want to increasing on the exit of considered system, while is useful energy (Ex_{useful}) sum of all inputted system exergy.

For irreversible processes is valid that are irreversibleness (I) equal:

$$\dot{I} = \dot{E}x_{used} - \dot{E}x_{used\ out} \tag{24}$$

Bringing irreversibleness into formula for Ψ, we obtain following form:

$$\psi = 1 - \frac{\dot{I}}{\dot{E}x_{used}} \tag{25}$$

Rational exergetic efficiency is form of exergetic efficiency which is easy to calculate and it give better results for processes then simple exergetic efficiency.

Passing exergetic efficiency is improving for a simple exergetic efficiency and from inputted and outputted exergy we subtracting appropriate untransformed component of exergy.

Passing exergetic efficiency defining is through the following formula:

$$\eta_e = \frac{\sum_{out} (\dot{E}\,x_{out} - \dot{E}\,x_p)}{\sum_{in} (\dot{E}\,x_{in} - \dot{E}\,x_p)} \tag{26}$$

where are Ex_p – passing exergy.

Sorin is 1994. y. defined a passing exergy like as part of exergy which passing through the system without take part in mechanical, thermal and chemical changes which is play in system. Value of passing exergy do not have influence on thermodynamically efficiency of process and he is subtracting from inputted and outputted exergy before is calculated this form of exergetic efficiency [1].

5. Quality of the Matter and the Energy

For all energetic processes the energy is needed, but it is not enough any kind of energy but exergy, in other words, energy which can be transformed into other forms of energy. Because of that quality of energy can be mark by index which giving approximate contents of exergy by insight percent of energetic content. This "quality index" is in range from 100% for the energy which is pure exergy and can be completely transformed into other forms of energy, to 0% for the energy which no have exergy (table 1).

Table 1. Quality of diferent energy form

Energy form	Quality index (% of exergy)
Potential energy	100
Cinetic energy	100
Electric energy	100
Nuclear energy	approximately 100
Sun's lightness	95
Chemical energy	95
Overheated steam	60
Thermal energy	30
Waste heat	5
Thermal radiation of earth	0

Analogous to quality of energy and quality of some certain material can be expressed like as exergy quantity of this material. The most pure form of matter is consisted of only completely known elements which entropy is almost equal to zero. A soothe matter and a matter inside the mixture have higher entropy value and because of that a lower quality.

Matter quality forms can be also expressed by index which give an approximately contents of exergy, more exactly, quantity of "elements in a settled form" like a percent of matter quantity.

Being that the exergy of the system define like ratio of surroundings, it's strongly recommended to choose the right condition referral surround. Because of that in there are growing all real processes it's strongly recommended to turn on she's influence to analysis of energy transformation.

Surrounding is making by atmosphere, water surfaces and the earth. She is like the battery of the energy largest sizes what parameters condition don't changing without considerate the energy. Neighbourhood to the processes influence she's heat, pressure and structure. In the moment of side by side appears balance.

Starting from she's specific needs for the useful energy in technical processes must be chosen the best elements of industrial energetic what are connecting in one smaller or bigger energetic system [2]. Assignment of energetic system is to provide the needed energy. For security executing the assignment in making it's need to organise controlling energetic and do the continuously paying and control energetic course. Because of that, except the energetic section must exiting and the unit of collecting and adoption of information from the unit, and to creating energetic balances and analysis energetically units.

Because of size energetic system, may be used mathematical models and computers for the analysis of information and getting wright answers.

To control with energetically system have like first order to give wright direction every operations in technological process, threw conversation, transformation and the transporting of energy. Basic meted to coordinate and direct inside of energetic system and in the same time between energetic system and producing in what they are perform.

6. CONCLUSION

In the work is shown methods of balances what means one of the basic and elements for the correct mark of worked unit, like energetically, economic and ecological parameters. How the outgoing heat one of the basic elements of the destroying the human environment, because of that the aspiration for reduce of flow out this elements and heir's returning to the process of production enable energetically effect of the process like a effect of protection human surroundings. This attitude is pointing us on theory that the energetic effect in tight connection with environment.

REFERENCES

1. Cornelissen R.L., Thermodynamics and Sustainable Development, The Use of Exergy Analysis and the Reduction of Irreversibility, Phd Thesis, University of Twente, Enschede, The Netherlands, 1997.
2. Jovanović Lj., Gereke Z., Gazdovanje energijom u radnoj organizaciji, Savez energetičara Srbije, Beograd, 1985.
3. Končar-Đurđević S., Mićić J., Simonović D., Hemojsko inženjerstvo, Izdavačka radna organizacija "Rad", Beograd, 1987.
4. Laković S., Rašković Pl, D. Živković, Ivica Stevanović, Heat recovery of batch processes case study brewing process in D.D. "Pivara" Niš, Energz formu, Varna, 2000.
5. Živković D., Laković S., Rašković Pl, Laković M., Mass, energy and extergy balance of the brewing process, Energy forum, Varna, 2000.
6. Wall G., Exergy flows in industrial process, Extergy, ecology, democracy, Molndal, 1999.

MATERIJALNO-ENERGETSKI UTICAJ TEHNOLOŠKIH SISTEMA NA ŽIVOTNU SREDINU

Ivan Krstić, Branislav Anđelković

U radu su prikazane metode bilansiranja koje predstavljaju jednu od polaznih osnova za pravilnu ocenu rada postrojenja, kako energetskih, ekonomskih, tako i ekoloških parametara. Definisani su stepeni korisnosti, odnosno gubitaka, karakteristični za sve bilansne jednačine. Minimiziranjem masenih, energetskih i eksergijskih gubitaka smanjuje se rizik zagađenja životne sredine i daje polazna osnova optimizaciji tehnološkog sistema, sa karakteristikama 3E (EKOLOGIJA-EKONOMIJA-ENERGETIKA).

Kako je otpadna toplota (dimni gasovi, isparenja i dr.) jedan od glavnih elemenata zagađivanja životne sredine, to je težnja da se smanjenjem ispuštanja ovih elemenata i njihovim vraćanjem u proces proizvodnje omogući energetska efikasnost procesa kao i efikasnost zaštite životne sredine. Ovaj stav nas upućuje na činjenicu da je energetska efikasnost u uskoj vezi sa zaštitom životne sredine.

Ključne reči: *tehnološki sistemi, bilansne jednačine, životna sredina.*