ENERGY VERSUS ENVIRONMENT

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We propose here to see how it's possible to extend the usual criteria for efficiency in the world of physics (especially thermodynamics) to the technical (and technological), then the economical and environmental (Ecology) sectors: from the efficiency notion to that of the quality factor.

We can draw consequences in technical terms, but also economical and societal: the need to pass from the Sustainable Development to the Finite Development.

Some usual applications from the Energy sector will be given as examples, to illustrate this idea: combined heat and power plants, thermofrigo pumps, combined systems.

Keywords: Exergy, energy, thermodynamics.

1. Introduction

The stakes for the optimizing energy are they included in the paradigm Energy vs. Environment?

The objective of this paper is to examine the new paradigm that has become crucial for the humanity at the beginning of the new century, where the Economy (and especially the Finance sector) prevails.

Even though attempts have been made in order to understand the necessity to include the humanity in his natural and immediate environment and generally its evolution in the Universe, it seems that the need for a Sustainable Development doesn't represent a priority for the moment, maybe because of the lack of adapted criteria to measure this Development (Evolution for the thermodynamicist). At the same time, there is another very important factor that generates this situation, the current global economic crisis, which leads to cutting subsidies for developing clean technologies and therefore efficient technologies.

We propose to analyze it here in an historical manner according to the science and technology.

The industrial revolution which dates from two centuries has "released" the man by offering him the power of machines, based initially on the use of a

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solid fuel, the coal. And then, the more recent development of transport (especially the automobiles, aircraft, etc.) has allowed, by an increased mobility, the commercial and human trade as we have known since approximately 1 century: the oil, liquid fuel, is the main vector.

Finally, the gas (gaseous fuel) comes reinforce the two precedents effects, especially in the industrial and domestic world. But in the rush and carelessness, only the quantitative aspects related to the energy were accounted for (Extensity, how would say the thermodynamicists), without take care that it was from sources stored, therefore finite and exhaustible, and passing almost entirely by the heat and combustion.

The brutal awareness of this reality with the occasion, especially, of the oil shocks, at the end of the 20th century, obliges us to reconsider the way we use energy, not only of the quantitative point of view (Extensity), but also from the qualitative point of view (intensity): the ubiquitous use of the electricity (electric-power) is a proof.

But also, and especially the relations and consequences for the Environment. The latter are emerged first in the form of acid rain, and it/has led us to deal with the presence of sulfur in fuels; the event the most noticed was the London fog. And then there was the hole in the ozone layer, which has led in the 1980s to a reconsideration, mainly because of the use of CFCS, then HCFCs and finally HFCs.

This has not been without drastic consequences on the refrigeration industry (freezing, under-freezing, air conditioning, air treatment) that concerned our societies in their daily lives.

Finally after a few tens of years, the global warming has become a major concern, with the evolution of the rate of CO2 in the atmosphere. The result is an index well known to all, in the form of the GWP (Global Warming Potential). It should be noted on this occasion that this index represents in fact a Global Warming Potential equivalent in terms of CO2 (the reference), but that it integrates other compounds (including methane, the refrigerants, …).

Knowing that energy and the environment are interdependent, what relevant criterion, the science (THERMODYNAMICS) can propose to allow the engineers to control the energy technologies necessary for the fulfillment of human needs and our societies, without endangering our environment? The preservation of our needs and our environment can pass through the exergy concept which dates from 1889.

This conference proposes the answer elements to this question. Paragraph 2 is dedicated to a brief history of the concept of energy/Exergy and its implementation in perspective until this day. Paragraph 3 shows the complementarity and the differences as compared to other methods more or less similar existing already. The paragraph 4 attempted to justify the choice of the energy/exergetic analysis to deal with the problems of energy-environment.

Paragraph 5 shows the current status of the applications of this analysis. Paragraph 6 discusses the current deficiencies in the view of the results, and allows for placing in perspective by proposals for extensions considered desirable.

2. Put into perspective the concept of Exergy

According to our bibliographic sources and after recent exchange with Gaggioli (2011), it appears that the concept of exergy was invented by Gouy (1889) in the form o "usable energy" in 1889. At the same time Stodola (1898) ran an article on same vocation. But it will have to wait until 1956 for that RANT (1956) introduced the word "Exergy" for " technical disponible work ".

Since things have evolved slowly, with a starting acceleration since the years of 2000 under the impulse of the physicists and engineers. To illustrate this fact, we will give here a succinct vision and selective resulting from the choice of the author (it is hoped that this choice is relevant but it remains open to the discussion).

And with the years 2000 has emerged a tribune dedicated to the exergy in the form of the international journal called ’’Exergy, (2004)’’. An article by Rosen (2002), shows the importance of education in thermodynamics through the concept of exergy which is not yet unanimously transferred and accepted as a basic tool.

There have been books specifically devoted to this method that is the EXERGETIC Analysis, built on the concept of exergy. Among these books, one of the most recent is due to Szargut (2005) and includes as captioning: Technical and ecological applications.

It is therefore at the heart of the subject and the author is one of the inescapable references in this area at the international level. The French community is not without action, both in the past (Marchal, 1956; Le Goff, 1979) to the present (Queiros-Conde et al., 2011).

To show and confirm this rise in power of the concept of exergy, the reader is referred to a recent article of Sciubba and Wall (2007) who wants to be a brief and commented history on the exergy since his birth in 2004.

Even if you may not share the entire document, the latter is very comprehensive and it is done state on the date of issuance of more than 2600 references, which are accessible by a link on the site of the journal (http://www.icatweb.org/vol10/10.1/sciubba-wall.pdf). We can only be convinced, given the amount of work on the concept of exergy and its applications, the relevance and usefulness of the latter.

3. The exergetic analysis

3.1. The definition of the exergy

The most recent definition of the exergy can be put in the following form: theoretical maximum of noble energy usable for a system (or process) S evolving (or carried) to its thermodynamic equilibrium with its immediate environment according to a process in which S interacts only with its immediate environment (Benelmir et al.2002).

Note: the designation “Exergy concept" is used in Europe, whereas it is rather "Available Energy" in the United States (Usable Energy).

3.2. The forms of the exergy and the state of reference

In each form of energy (Cf Feidt, 2006, chapter 3) correspond a form of the exergy (Sciubba-Wall, 2007, p. 3). In summary, the noble energies correspond to Exergies associated (often reduced to the unit of mass when it is possible: specific mass energy).

It should be noted simply that the chemical energy is not fully convertible into another form of energy (for example mechanical or electric); for a pure substance the difference in concentration between the system S(c) and the environment (c0) occurs, along with the potential for chemical reference μ0. It sees here reveal the importance of the state of reference.

For more in the case of the radiative electromagnetic energy, unanimity is not gained and the discussions are continuing (Pons, 2011).

Finally we note that the reference mass has no meaning for the radiative energy, as for the electrical energy.

Contrary to all the noble previous energies (coherent), thermal energy (non-coherent) is an energy which workable part is dependent of a factor of Carnot θ, which is worth:

$$\theta = 1 - \frac{T_0}{T_Q} \qquad (1)$$

T0 is the reference temperature, that of the environment generally assume isothermal

TQ is the temperature representative of the system S, and this must be precised.

For the configuration very common of an open Thermo mechanical system, it comes classically per unit of mass for a pure body:

$$e_x = h - h_0 - T_0(s - s_0) + \frac{v^2 - v_0^2}{2} + g(z - z_0) + \mu - \mu_0 + RT_0 \ln\left(\frac{c}{c_0}\right) \qquad (2)$$

The first 3 terms represent the physical Exergy.

The 2 following terms, the mechanical kinetic and potential exergy.

The last 2 terms, the chemical exergy of the pure body.

The Exergy concept is a function of state (as compared to the baseline status of the chosen environment). It is remembered that the Exergy, E is retained in accordance with the following relationship:

$$E_x = E - An \tag{3}$$

An- represents the ANERGY associated with a processing whatsoever. It corresponds to the destruction of exergy in any real transformation (therefore irreversible) such as:

$$\Delta An = T_0 \Delta S_i \tag{4}$$

ΔSi is the entropy created in the thermodynamic transformation.

Note: The environment may be subject to of developments (for example the atmosphere can vary in temperature, pressure, humidity, according to various time scales seasonal, daily, instantaneous (meteorology) and the exergy varies in consequences. This may be considered and has been long recognized (Gögus).

The relationship (4) is very important because it indicates the fundamental link existing between the exergetic analysis and the entropy analysis, introduced and developed under the impetus of A. Bejan (1982) for the coupled transfers from heat and matter. It is to be noted that the exergetic analysis applied to the energy systems date from the same period (Ahern, 1980).

The entropy analysis is independent of any environmental reference; it therefore appears as a method more absolute, a method of physicist. The exergetic analysis located the system (or process) in its environment; due to this fact it is a method of engineers, and as we are concerned more today.

3.3. Efficiency and optimization

All of the existing studies since the birth of thermodynamics (Brodiansky, 2006) show the concept of efficiency as a key concept, linking the consumption D to a useful effect U. The simplest case, introduced by Carnot, led to the concept of energy efficiency ηe, of a Thermomechanical engine:

$$\eta_E = \frac{EU}{ED} \tag{5}$$

This relationship illustrates well the fact that this efficiency involves only the quantities of energy, regardless of their quality. A discussion therefore exists as to the extension of this concept of efficiency, which then allows him to integrate the extensive and intensive aspect (Feidt, 2009).

To this day, according to Sciubba and Wall (2007), three definitions of the Effectiveness emerge from this discussion:

- an exergetic efficiency also called efficiency within the meaning of the second law:

$$\eta_{Ex} = \frac{E_x U}{E_x D} \tag{6}$$

With Exu, the useful exergy and ExD, the expended exergy

The reversibility coefficient:

$$\Psi = \frac{\text{Exergie cédée}}{\sum \text{Exergied}} \quad (7)$$

$$\Psi = \frac{\text{Product}}{\sum \text{Entry}} \quad (7)$$

The exergy destruction coefficient:

$$\xi = \frac{\text{Exergie détruite}}{\sum \text{Exergie d'entrée}} = \frac{T_{0i}}{\sum \text{Exergie}} \quad (8)$$

The definition (6) that characterizes for us exclusively the exergetic efficiency (to the exclusion of the efficiency within the meaning of the second law, Cf Feidt, 2009) is very useful. On the contrary the relationship (7) which is an efficiency within the meaning of GRASSMANN (Feidt et al, 2002) do not seem to have a lot of usefulness

The ratio of destruction of exergy (8) appears more interesting because it connects to the exergy of constant entry, the exergetic optimization to the entropy optimization. It is here the minimization of dissipation. This minimization has been particularly studied by A. Bejan (1982) for the coupled transfer of material and heat, in the form of a method known as EGM (entropy Generation minimization). It appears to the author that this vision is reductive as it is explained in the paragraph that follows.

3.4. Stakes of the exergetic optimization

Sciubba and Wall (2007) emit the idea that except in Thermo-economy, "from 1970 to 2000, all of the work is relative to the procedures of optimization: the challenge is to define the objective function the most appropriate to maximize the exergetic efficiency of a system (or process) for an entry of resources imposed". These authors summarize the work made in this direction, under a number of topics:

- theoretical developments
- applications to the conservation of energy
- Improvement of the Efficiency
- progress in chemical processes
- development of design tools
- study of the properties of raw materials and of standard states of reference.
- work to educational and informative vocation

3.4.1. Energy efficiency

It is proposed here to pose the problem more precisely in terms of optimization in targeting on energy efficiency in a first time (Feidt, 2009).

It is certain that the concept of efficiency is a difficult concept and that it must be used with caution. We have shown that the efficiency within the meaning of the second law (η_{II}) that we will call rather Fq (quality factor) is not independent of the system environment, and the constraints associated with it. For example in the case of Carnot engine (well known), it comes:

In energy expenditure imposed, Q_0

$$F_q(Q_0) = 1 - \frac{}{(T_{SH}} \quad (9)$$

T_{sh} and T_{sc}, temperatures respectively of the hot thermostat and the cold thermostat

To useful effect imposed, W0

$$F_q(W_0) = 1/\left[1 + \frac{T_{SC} \cdot \Delta S_i}{W_0}\right] \quad (10)$$

The relations (9) and (10) clearly show that under certain very specific conditions (constraints), the optimization of the quality factor corresponds to the minimization of the entropy created by the dissipation. But this optimization rest energy, although in relationship with the environment of the system (here source and sinks).

3.4.2. Exergetic Efficiency

The system is here deliberately considered in its reference environment. The application to a Carnot machine for reverse cycle (Feidt, 2009) led to the following results:

- for the machine, the exergetic efficiency is:

$$\eta_{Ex}(\text{machine}) = \frac{C}{CO} \quad (11)$$

This efficiency depends on the temperature T_C of the cold fluid cycle, and T_0, the temperature of the ambient thermostat.

- for the system (machine, hot and cold thermostats, environment to T_0), the exergetic efficiency becomes:

$$\eta_{Ex}(\text{système}) = \frac{C}{COP} \quad (12)$$

This efficiency then depends on T_0 and Tsc, the temperature of the cold thermostat. The immediate consequence is the difference between the relative exergetic efficiencies and the quality factor: they are identically in the particular case $T_0 = T_{SH}$, therefore the need to situate the machine or the system (process) in its environment.

The expansion to other references that thermal (T_0) appears as a challenge for the environmental studies and the criteria to associate (Feidt, 2009).

3.4.3. Optimization energetic and constraints

Energy optimization in which we limit ourselves now, shows the main objectives functions following:

with $$\mathrm{Max(Eff.)} = \mathrm{Max}\left|\frac{UE}{EC}\right| \qquad (13)$$

We see from (13) that Max (Eff.) differs from Max (EU) and Min (EC). A differentiated optimization is therefore needed with any constraints to identify. The minimization of rejects R is clearly an environmental optimization.

It is concluded that in general there is a matrix of optimization for objectives constraints functions or non-constraints. Table 1 gives a statement of these from an energy approach. The transposition to an exergetic approach is immediate. It should be noted that the extension to the economy is well covered, while that on the environment still deserves a careful review.

The application to engines was recently illustrated (Feidt, 2009). The same approach has been applied for machines to reversed cycles (cold machines, heat pumps).

Table 1

Matrix of optimization of a system (or process) forced or non-forced

O.F. \ **Constraints**		E.U.	D.E.	Efficiency	S_T	Finite Dimensions	Costs	Others
E.U.	MAX	[redacted]	MAX	MAX	MAX	MAX	MAX	MAX
D.E.	Min		[redacted]	Min	Min	Min	Min	Min
Efficiency	MAX	MAX	MAX	[redacted]	MAX	MAX	MAX	MAX
S_T	Min	Min	Min	Min	[redacted]	Min	Min	Min
Finite Dimensions	Min	Min	Min	Min	Min	[redacted]	Min	Min
Costs	Min	Min	Min	Min	Min	Min	[redacted]	Min
Others (Environment)								[redacted]

4. Conclusions - Prospects

The EXERGETIC optimization appears as a natural crucial extension; therefore, the use of energy becomes intimately linked to the environment. The most common practice presupposes an environment represented by its reference temperature T0 (constant). This is happy because the intensive variable temperature is connected to the variable s extensive entropy, so that the entropy analysis or the exergetic analysis joins together.

Still a variable reference temperature complicates the problem. A reference in multiple variables (pressure, concentrations, chemical potential …)

must also be developed, if to take into account environmental concern becomes more important. Results exist in this direction, but are to develop.

Finally, the THERMODYNAMICS optimization shows that the potential objective functions are numerous, as well as the constraints. Also the development of a search is often multi-criteria (the example of the efficiency criterion is a very good illustration).

It appears to us that the development of an Optimal THERMODYNAMICS in Finite Dimensions is a subject that is very current, in whose development we work (FDOT, Finite Dimensions Optimal THERMODYNAMICS).

R E F E R E N C E S

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