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Energy Management

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Abstract: A new revised energy concept is proposed from relativistic approach using different kinds of spaces. It is not always feasible to implement a project for saving energy. It is not merely heating a stream and cooling another stream. The study includes other considerations. A total feasibility study should be performed. The cost and the income should be calculated. In this study it is shown how to perform such a feasibility study from scratch up to detailed implementation. It is an investment approach. There are two energy balances: one thermal and the other mechanical. They are not separated but they complete each other. The decision is upon rigorous energy balance. First the question where the energy will go shall be answered from 2nd law of thermodynamics.

Key words: Entropy, energy, feasibility, study.

Nomenclature

A	cross sectional area
c	Speed of light
D	Pipe diameter
F	Darcy friction factor
g	Acceleration of gravity
H	Enthalpy
h	Hour
J	Joule
k	1,000
L	Equivalent pipe length for pressure drop
P	Pressure
Q	Heat
s	Second
S	Entropy
u	velocity
V	Flow velocity
Z or, h	level
ρ	fluid density
ΔP	Pressure drop
W_s	Shaft work
$\dot{m}$	Rate of mass flow rate.
Ψ	Wave function.

1. Introduction

Thermodynamics is defined as the study of energy, its forms (kinetic, potential and internal) and transformations (work and heat), and the interactions of energy with matter [1]. In thermodynamic sense, heat and work refer to energy in transit across boundary between the system and its surroundings. These kinds of energy can never be stored. To speak of heat or work as being contained in a body or system is wrong; energy is stored in its potential, kinetic and internal forms. These forms reside with material objects and exist because of the position, configuration and motion of matter. The transformation of energy from one form to another and the transfer of energy from place to place often occur through the mechanisms of heat and work [2]. Entropy is a property of a system. This means that irrespective of the path between two states the total change in entropy is the same, hence the lost work, which is the amount of energy which becomes unavailable for work. The available energy ready to be converted into work is different from the efficiency of the process, the available energy [3] is calculated as function of some properties of the system while the efficiency is not a property dependent but most of the time a process hardware dependent. It is needed to add work to the system to affect the flow within the system. This work energy needs to be managed. There is a difference between the efficiencies of conversion of heat energy

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into work and the conversion of work energy into heat. Neither work energy, nor heat energy could be totally converted to other forms of energy except in reversible processes. The 2nd law of thermodynamics can predict the direction of heat flow but not the rate of heat flow, rather, heat transfer can tell the rate of energy flow.

The first law of thermodynamics deals with all kinds of energy and their transformations while the second law of thermodynamics deals with the quality of energy that is being transformed from a kind of energy to another kind of energy taking into consideration that work and heat are energy in transfer.

Hatsopoulos and Keenan proposed the following second-law statement in 1965: A system having specified allowed states and an upper bound in volume can reach from any given state a stable sate and leave no net effect on the environment.

In petroleum refineries the crude oil is brought to the refinery at room temperature, its temperature is raised to make separations and reactions to upgrade the product, then its temperature is brought back to room temperature without any conversion to any useful form of energy (work). What happens is only upgrading the selling value of crude oil.

Heat is a threat which means it is a hazard. All process safety in refineries is about containment of flammable liquids and gases. There are no stable equilibrium states and no adiabatic processes. There is a great effort to stop losing energy but at the end it should be lost, by cooling. Process efficiency studies the effect of entropy change on the energy conversion (Heat and Work) of fluids inside the processes.

When energy as heat transforms in an engine into useful work as in steam turbines the efficiency of the system is a comparison between actual work and isentropic work (irreversible). This happens in some applications in refineries. The original form of heat transformed into useful kind of energy is usually fuel oil and fuel gas.

Energy leak is considered loss of containment and hence a process safety concern. As more entropy is generated as more the process is unsafe. How much process heat is transformed into useful energy in separation and reaction?

The economy of entropy is minimizing waste of energy. It is concerned with energy and material management which find a concern in energy and material balances as a mathematical and physical procedure for them. But in common sense reversible processes in refineries are not feasible.

Waste heat recovery systems are a vital component in energy economy in refinery and chemical processes.

The user controls irreversibility of a process (losses) or efficiency and the irreversibility of a process controls energy conversion (heat and work).

2. New Energy Concept

$$m = m_0/\sqrt{1 - v^2/c^2}$$

Rearranging and substituting [4]: $p = -i\hbar\nabla/c = mv$.

Then: $\hat{m} = \pm\hbar\nabla/c = \pm 3.5178 \times 10^{-43}\nabla$ with m_0 negligible compared to m, this operator operates on the wave function, the meaning of this operator taking into consideration the extremely small scaling factor and that it is a vector (refer to Fig. 1 for simplicity):

(1) $\nabla\Psi$: Directional derivative; direction of mass change. Euclidian space.

(2) $\nabla \cdot \Psi$: Divergence; inhalation or creation, speed change. Hilbert space.

(3) $\nabla \times \Psi$: Curl; rotation characteristics. Fock space.

The Hilbert space as a state space gives information about the position, configuration and motion of constituents within it. The meaning of the operator depends on the type of physical state within the system of consideration. These equations help in defining the direction of deferential change in mass or energy.

The mass operator is like the gradient operator, it is a multiplying operator and as mass is equivalent to energy this is also an energy operator. For this quantity calculated for mass or energy to be significant the gradient operator multiplied by wave function must yield a very large value, because the scaling value is extremely small.

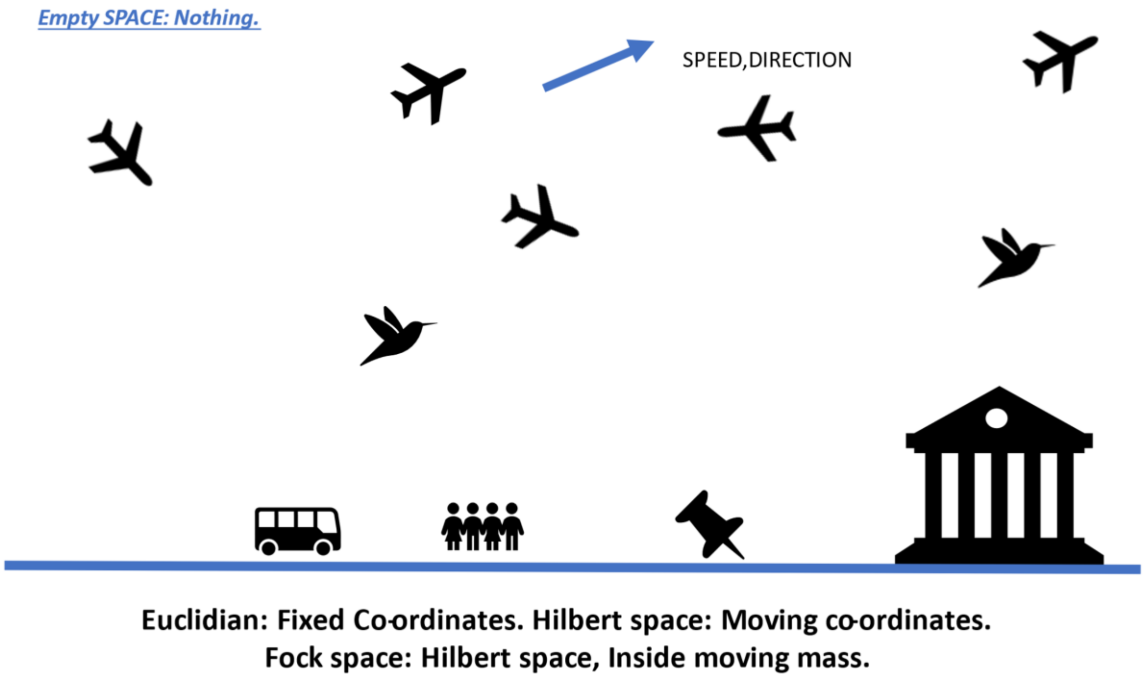

Fig. 1 Euclidian (three or less co-ordinates), Hilbert (infinite co-ordinates) and Fock spaces. A moving body in Hilbert space is a point.

Over macroscale the mass or energy is very small due to the scaling factor. Energy stored is related to velocity and change of wave function is related with corresponding position. It is worth to note that the mass or energy operator is a differential operator not an integral operator which means that there is no constant of integration which means that there is no bias line i.e. no reference value.

Energy is an exchange between two different concentrations, the concentration of time in space outside what we call matter and the concentration of time in matter space which is the matter itself. The concept of motion for energy is replaced by time space interactions with time taken as solid matter. Motion enhances the exchange between the mass and its surrounding time in space, annihilation and creation are special forms of this exchange. During the motion of a mass, it increases as a result of this dissolution [5].

The challenge is to proof that the wave function which is the probability of finding some matter somewhere, has a direction, this is achieved by considering that the wave function is a tensor.

3. Thermal Energy Balance versus Mechanical Energy Balance

There is no apparatus to completely transform heat into work and there is no process to transfer heat from a lower temperature to higher temperature. Whilst friction concerns sometimes the process of transforming work into other forms of energy, the system loses its ability to generate entropy.

Bernoulli’s equation (mechanical energy conservation) [6]:

$$\frac{p}{\rho g}+\frac{u^2}{2g}+h=\text{constant}$$

Another similar equation but from thermodynamics for one stream control volume:

$$\Delta H+\frac{\Delta u^2}{2}+g\Delta z=Q-W_s$$

$$Q=T\Delta S$$

It is usually possible to measure the head or pressure but not the velocity of a liquid in a medium. The unit acceptable for measuring energy which could be diverted instantaneously into financial value is: kW ħ which is:

$$10^3 \times \frac{J}{s} \times 3600\ \ s = 3.6 \times 10^6\ \ J$$

To determine the effectiveness of energy transfer between two streams a feasibility study should be done. A comparison between the physical cost of the project and the income of the project is performed and a break even point is located to know were the project ends returning its cost and were it begins to profit (break even point) and on the other hand, is the project is feasible or it is just heating and cooling without any return value. This should be clear and straight forward. First it should be decided that one of the streams is waste heat. The decision is taken by how much equivalent cost of fuel oil or fuel gas is saved by this change. The costs are heat exchangers' cost and extra pump head cost which require more spending in the process if not providing an extra pump.

The energy of the head h is:

$$Energy = \ \ gh$$

where the energy is for unit mass, for total energy multiply by total mass depending on the time basis taken.

Energy per unit volume is simply pressure drop:

$$Energy = P$$

Total energy equal PV were V is total volume passing depending on time basis.

Usually the units of energy related directly to its cost is: kW h. The cost of buying or generating power is usually known. However, when using turbines with pumps the situation is slightly different, the cost is not for electrical energy but for steam which comes basically from fuel oil and fuel gas consumed in the boiler, where the efficiency of the boiler is included in the calculations.

The steam enters the pump turbine as high pressure steam and leaves it as low pressure steam.

Low pressure steam 8.5 bar, 180-185 ℃, enthalpy ≈ 2,781.2 kJ/kg.

High pressure steam 16 bar, 290-300 ℃, enthalpy ≈ 3,009.9 kJ/kg.

The real consumed energy is the difference between the above enthalpies.

Energy consumed in the turbine ≈ 228.7 kJ/kg steam.

The total energy is taken depending on the time basis taken.

The above calculations were for the cost part of the feasibility study. There is the gain part of the feasibility study which is the amount of heat recovered in the process:

$$Energy = \dot{m} C_p \Delta T$$

Either for cold side or hot side which theoretically means the energy exchanged must be the same. The heat capacities are given in Table 1.

The continuity equation:

$$\dot{m} = \rho u A$$

The mass flow rate and velocity is calculated using other quantities or sometimes using specially prepared models. This equation is not easy to apply within the frame work of any practical project despite its simplicity.

There are mechanical energy losses due to friction (directly as heat), fittings and bends (head losses depending on bends) and all of this is added to the cost of the new change.

The above calculation is made for any project concerning energy management which means optimum use of energy. It is not always feasible to implement a change without proper calculations of the income and cost. Usually pumps are factory tested on water to decide their head, however the petroleum products' viscosity is different and thus attention should be drawn to that.

The pressure drop through segments of pipes and fittings is proportional to the velocity when the flow is laminar while when the flow is turbulent the pressure drop is proportional to the square of the velocity which means it is proportional to the kinetic energy. This means that there is a constant of proportionality. The head loss due to friction is negligible compared with fittings and accessories. The equations which should be solved for resistance in a fitting are: momentum, continuity and Bernoulli's equations. The pressure drop is calculated using equivalent length in place of the fitting itself.

The pressure drop equation (Darcy Weisbach formula) is given by:

$$\Delta P = \frac{fL(V)^2\rho}{2D}$$

Table 1 Heat capacity and density of selected materials.

Material	Heat capacity (kJ/kg ·℃)	Density (kg/m^3)
Crude oil	2.13	800-900
Gasoline	2.22	715-780
Naphtha	2.19	750-785
Kerosine	2.01	775-840
Diesel	1.75	830-900
Liquid Asphalt	2.09	1,050
Fuel Oil	1.67-2.09	800-1,010
Water	4.18	1,000

The Darcy friction factor is primarily determined by the flow type (laminar or turbulent) and the roughness of the pipe's internal surface (smooth). It can be obtained using lookup tables, correlations, or software from experimental data.

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