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Conceptof Exenergy for Temperature Systems

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Abstract- Exenergy is the concept that explicitly indicates 'what is consumed'. All systems, not only engineering systems but also biological systems including the human body, work feeding on exenergy, consuming its portion and thereby generating the corresponding entropy and disposing of the generated entropy into their environment. The exenergy balance on an open steady state system, which is much more relevant to thermodynamic analysis of energy systems, is also described, as well as the different exergetic efficiency factors introduced in the thermodynamic analysis of energy systems. exenergy calculation for space heating systems

Index Terms- Exenergy; Entropy; Space; Heating; Cooling; Air-conditioning; Radiant; Environment

1. INTRODUCTION

Over the last two decades various so-called "energy saving" measures have been conceived, developed, and implemented in building envelope systems and also their associated environmental control systems such as lighting, heating, and cooling systems. Those measures can be categorized into two groups: those for "passive" systems and those for "active" systems. "Passive" systems are defined as building envelope systems to make use of various potentials to be found in the immediate environment such as the sun, wind, and others to illuminate, heat, ventilate, and cool the built environment. The history of passive systems is very long; we may say that it emerged with the evolution of human being.

The recent development of material science has brought about various building materials such as low-emissivity coated glass and others; this enables us to design advanced passive systems.

"Active" systems are the systems consisting of various mechanical and electric components such as fans, pumps, heat pumps, and others, all of which work by the use of fossil fuels. Most of the active systems available these days have been developed with an assumption of the abundant use of fossil fuels so that they do not necessarily work in harmony with passive systems.

2. IMPORTANCE OF EXENERGY FOR TEMPERATURE SYSTEM

Energy, exenergy, and entropy flow in and out a building envelope system. The amounts of energy flowing in and out are the same under thermally steady-state condition according to the law of energy conservation; on the other hand, the amount of entropy flowing out is larger than flowing in according to the law of entropy increase. The amount of exenergy flowing out is smaller than flowing in, since exenergy is consumed within the system to produce entropy.

Four Steps of Exenergy-Entropy Process

Feed on exenergy
Consume Exenergy
Generate Entropy
Dispose of Entropy

3. WARM EXENERGY AND COOL EXENERGY

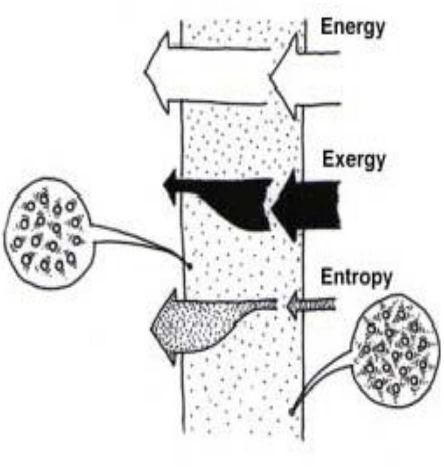
The exenergy contained by air at a temperature higher than its environment is an ability of thermal energy contained by the air to disperse into the environment. On the other hand, the exenergy contained at a temperature lower than its environment is an ability of the air, in which there is a lack of thermal energy compared to the environment, to let the thermal energy in the environment flow into it. We call the former "warm" exenergy and the latter "cool" exenergy (Shukuya, 1996).
Either "warm" exenergy or "cool" exenergy described

above is a quantity of state contained by a substance. We have room temperature higher than the outdoor environment when the space is heated. In such a case room air has "warm" exenergy as a quantity of state. On the other hand, when we have a room temperature lower than the outdoor environment, room air has "cool" exenergy as a quantity of state.

4. RADIANT EXENERGY

Radiant exenergy transfer plays more important role in low-temperature-heating or high- temperature-cooling systems than in conventional air heating or cooling systems, because they require heat sources with a rather large surface area whose temperature is only slightly higher than room air temperature.

This suggests that low exenergy systems for heating and cooling of buildings are realized provided that heating and cooling exenergy requirements for room space is decreased by the installation of rational building envelope systems, thus the heating and cooling is provided at a temperature close to room temperature.



5. EXENERGY BALANCE EQUATION

Let us introduce a general expression of exenergy balance using the case of the above- mentioned simple building envelope system. The purpose here is to outline the structure of the exenergy balance equation and we do not discuss the detailed mathematical expression. Those who are interested in the detailed mathematical expressions should refer to Bejan (1988), Shukuya (1994)

Energy is the concept to be conserved so that the energy flowing in must be equal to the sum of the energy stored within the system and the energy flowing out from the system. This energy balance can be expressed as follows.

(Energy input) = (Energy stored) + (Energy output) (1.1)

Since the steady-state condition is being assumed here, there is no energy storage and hence the above equation turns out to be the following simpler form.

(Energy input) = (Energy output) (1.2)

Secondly, let us set up the entropy equation consistent with the above two equations. Energy flowing into the system as heat is more or less dispersed energy. Heat is a energy transfer due to dispersion, thus entropy necessarily flows into the system as heat flows in and some amount of entropy is generated inevitably within the system in the course of heat transmission. The sum of the entropy input and the entropy generated must be in part stored or in part flows out of the system. Therefore the entropy balance equation can be expressed in the following form.

(Entropy input) + (Entropy generated)
= (Entropy stored) + (Entropy output) (1.3)

Since the steady-state condition is being assumed, there is no entropy storage as well as no energy storage. Therefore, the above entropy balance equation turns out to be

(Entropy input) + (Entropy generated)
= (Entropy output) (1.4)

The fact that the outgoing entropy from the system includes the entropy generated within the system suggests that the system disposes of the generated entropy with the entropy output.

Combining the energy and entropy balance equations brings about the exenergy balance equation. Entropy (or entropy rate) has a dimension of J/K (or W/K) and energy (or energy rate) has a dimension of J (or W). Therefore we need a kind of trick to combine the two equations.

"Energy generated" is such energy that originally had an ability to disperse and that has just dispersed. We can state this in the other way; that is, exenergy is consumed. Energy generation is equivalent to exenergy consumption. Using the term "exenergy", the above equation can be reduced to the following equation.

(Exenergy input) – (Exenergy consumed)
= (Exenergy output) (1.5)

This is the exenergy balance equation for a system under steady-state condition such as the building envelope system Exenergy consumed, which is equivalent to energy generated, is the product of entropy generated and the environmental temperature.

(Exenergy consumed) =
(Environmental temperature)
X (Entropy generated) (1.6)

Exenergy consumed is exactly proportional to the entropy generated with the proportional constant of environmental temperature.

6. GLOBAL ENVIRONMENTAL SYSTEM

Our near-ground atmosphere receives all the entropy that is generated and discarded by all systems involving lighting, heating, and cooling of the built environment. This also applies to any living systems such as bacteria, plants, and animals, since the involved biological phenomena can be reduced to the combination of chemical and physical phenomena, although such reduction alone cannot give us an answer to why the biological phenomena are so complex or how living systems evolve.

Since the entropy contained by a substance is, as described in the previous section, a function of temperature and pressure, the near-ground atmospheric temperature must rises if the near-ground atmosphere continues to receive the entropy discarded from various systems. But, what is actually occurring in the nature is different; the average atmospheric temperature is almost constant from year to year. This is due to the fact that the atmosphere has an exenergy-entropy process that works feeding on and consuming solar exenergy, thereby producing the entropy, and finally disposing of the produced entropy into the Universe. We call this the global environmental system.

7. CONCLUSION

A thermodynamic concept of exenergy which explicitly indicates "what is consumed" was explained from the viewpoint of its application especially to describing building heating and cooling systems, together with an explanation of entropy, which explicitly indicates "what is disposed of".
All working systems work as exenergy-entropy process, in which exenergy is supplied, a portion is consumed and thereby the resultant entropy is generated, and finally the generated entropy is discarded into the environment. The structure and function of the exenergy balance equation were outlined, and the features of "warm" exenergy and "cool" exenergy were presented. The general characteristics of the exenergy-entropy process of passive design were also described together with the global environmental system. What is suggested from the discussion here is that rational passive design is a prerequisite to realize low exenergy systems for the heating and cooling of buildings.

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