EXENERGY IN RENEWABLE ENERGY & SOLAR SYSTEMS

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Abstract — The present trend of resource depletion and environmental destruction raise the question of exenergy use in the society. The persistent avoidance of using the exenergy concept in the society has tragic consequences. Exenergy analyses are needed if we are serious in our efforts of a more equitable distribution of resources in the world and of our concern for future generations. Hence, utilization of solar energy in the proper and efficient manner aids in energy saving policy Solar energy is one among the renewable energy available which is clean, cheap, easily available and abundant.

Key words— Exenergy analysis, solar energy, renewable energy solar drying process, solar air conditioning and refrigeration

INTRODUCTION

Development of renewable energy sources as a replacement of fossil fuels had been taken into consideration in past few decades [1,2]. Solar energy as an available, cheap and environ- mental friendly alternative source has been the subject of many theoretical and experimental studies [3]. The integration of solar energy with different kinds of systems plays an important role in energy saving policy. In case of combining the photovoltaic and solar thermal components, both heat and electricity can be produced from the same system. It is widely known that a solar heating device has a significant role in reducing the energy consumption. Applying solar energy in desalination process is a clean option to provide drinking water from saline water.

Exenergy is the tool, which indicates how far the system departs from equilibrium state. The concept of exenergy was put forward by Gibbs in 1878. It was further developed by Rant in 1957. Exenergy analysis evaluates the efficient usage of solar energy. By determining the sources and magnitude of irreversibility's, exenergy analysis can be used to improve the efficiency of a system. Number of studies has been conducted in performance evaluation of different systems in residential [4], commercial [5,6], industrial [7–8] and transportation sectors [9]. Investigators such as [10,11] have performed exenergy analysis of refrigeration cycle. Exenergy analysis is employed in different fields of solar air conditioning and refrigeration systems [11,12], solar drying process [12]

IMPORTANCE OF EXENERGY ANALYSIS

Let us take an example. In case of coal fired power plant, the first law indicates that the condenser greatly effects the power plant efficiency as large amount of heat is transferred to the cooling water without providing any clue on the real usefulness of this relatively low temperature fluid. Also, energy balances do not provide information about the internal losses such as throttling valve and heat exchanger. Second law or exenergy

balance, however indicates that there is hardly 1% exenergy loss in the condenser with more than 60% in the boiler. The contribution in the boiler exenergy loss accounts for irreversibilities associated with combustion and finite temperature differences. Hence, analysis of exenergy plays a deterministic role in identification of processes and rectifying the components.

EXENERGY ANALYSIS OF SOLAR AIR CONDITIONING AND REFRIGERATION

Onan et al. studied the exenergy analysis of a solar assisted absorption cooling system. The calculation was based on two different dead states of standard temperature and environment temperature. Applying the formula generated by Banat and Jwaied, the second law efficiency of solar collector was calculated and found to have a maximum value of 11.98%.

The equation is

$$\Sigma (1 - (T\infty/T)) Q - W + \Sigma (mi\psi i) - \Sigma(mo\psi o) = Ex\ dest \quad \text{Eq.1}$$

Exenergy destruction was mainly found at solar collectors and generator of absorption chillers Pridasawas and Lundqvist considered a refrigeration cycle consisting an ejector, a generator, an evaporator, a condenser, a pump and expansion device and they studied the optimum operating conditions of solar driven ejector refrigeration system. The exenergy balance of the system is given as

$$Es, h + Ee + Wp, el = Ec, out + Itotal$$

The exenergy efficiency of the soalr collector was reported to be 0.66% and the solar collector was found to be the main source of irreversibility. Koroneos et al. investigated the performance of solar air conditioning system by application of exenergy analysis and the exenergy efficiency of the system was computed as

$$\eta = 1 - \frac{\Sigma X_{lost}}{\Sigma X_{in}} \quad \text{Eq.2}$$

Results obtained where compared with that of Sencan et al. and was found to be in good agreement. The found that the exenergy efficiency decreases with increase in components, both electricity and heat can be produced from the same system.

Energy is based on the first law of thermodynamics and gives the quantity of energy whereas exenergy deals with the second law of thermodynamics and gives the quality of the energy. Exenergy analysis identifies the causes, locations and magnitude of the system inefficiencies and provides the true measure how a system approaches to the ideal. Exenergy analysis evaluates the efficient usage of solar energy. By determining the sources and the magnitude of irreversibility, exenergy analysis can be used to improve the efficiency of the system. Performance of most of the renewable energy conversion systems is based on energy analysis accounting only the energy entering and exiting. Numerous studies have been conducted in performance evaluation of different systems in residential, commercial, industrial, and transportation sectors. Some investigators have performed exenergy analysis of refrigeration cycle. Exenergy analysis is employed in different fields of solar power generation, solar water desalination, solar air heating, solar air conditioning and refrigeration systems and solar drying process. This paper deals with an extensive literature survey on exenergy analyses of various renewable energy systems or solar applications and identifies the various sources involved in exenergy destruction. This paper would be of great help for investigators on the field of exenergy analyses in the future.

EXENERGY ANALYSIS OF SOLAR DRYING PROCESS

Celma and Cuadros performed exenergy analysis of olive mill waste water solar drying process. They carried out number of experiments on the designed model. The total exenergy included kinetic, potential, physical and chemical exenergy.

Physical exenergy

Physical exenergy, known also as thermo mechanical exenergy, is the work obtainable by taking the substance through reversible process from its initial state (T, P) to the state of the environment (T_0, P_0).

The specific physical exenergy is written as:

$$e_{ph} = (h - h_0) - T_0 (s - s_0)$$

Chemical exenergy

Chemical exenergy is equal to the maximum amount of work obtainable when the substance under consideration is brought from the environmental state (T_0, P_0) to the dead state (T_0, P_0, μ_{0i}) by processes involving heat transfer and exchange of substances only with the environment. The specific chemical exenergy e_{ch} at P_0 can be calculated by bringing the pure component in chemical equilibrium with the environment.

For pure reference components, which also exist in the environment, the chemical energy consists of the exenergy, which can be obtained by diffusing the components to their reference concentration P_{00}. The specific molar chemical energy of a reference component present in the environment at partial pressure P_{00i} is:

$$e_0 = RT_0 \ln \frac{P_0}{P_{00,i}}$$

The general form of total exenergy equation is given by

$$E = mda\ cp\ [(T - T0) - T0 \ln (T/T0)] \quad \text{Eq.1}$$

The exergetic efficiency was found using the equation

$$\Psi = 1 - (E1/Ei) \quad \text{Eq.2}$$

The experiment was conducted for two days and the maximum input exenergy was found to be 0.345kJ/kg and 0.27kJ/kg for the first day and second day respectively. They also proved that the exergetic efficiency decreases with increase in inlet temperature. The variation of exergetic efficiency with drying time was also investigated.

Midilli and Kucuk conducted exenergy analysis of shelled and unshelled pistachios by utilizing a solar drying cabinet.

Exenergy was calculated using the following equation

$$\text{Exenergy} = cp\ [(T - T\infty) - \{(T\infty \ln T)/T\infty\}] \quad \text{Eq.3}$$

CONCLUSION

From the literature review of exenergy analysis of various renewable energy conversion systems, it may be concluded that

- Exenergy efficiency is highly dependent on incident solar radiation and radiation intensity.
- Thermal efficiency itself is not self sufficient in choosing a desired system. Along with thermal efficiency, exergetic efficiency should also be considered.
- Higher exenergy destruction was found to be seen in the solar collectors in most of the systems.
- Increasing the mass flow rate leads to an increase in the exergetic efficiency of photovoltaic thermal systems.

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