ON EXERGETICS, ECONOMICS AND DESALINATION

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Summary

Exergy is a useful concept since it is a link between the physical and engineering world and the surrounding environment. Exergy expresses the true efficiency of engineering systems, which makes it a useful concept to find possible improvements. In systems where energy appears in many different forms, e.g. thermal, chemical and mechanical, this is particularly important. Therefore, exergy is a very useful concept in the design of engineering systems, especially desalination processes.

Exergy is *the* "fuel" for systems that are sustained by converting energy and materials, i.e. metabolic or dissipative processes, e.g. a living cell, an organism, an ecosystem, the earth's surface with its material cycles, or a society. If only renewable resources sustain these systems, then we may also regard them as sustainable, and exergy is a suitable concept to describe such systems scientifically. The solar powered desalination processes that occur in green plants are sustainable.

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The exergy concept has mostly been used within heat and power technology, where one works with thermal energy of varying qualities. However, the field of application is gradually increasing to the totality of energy, material and information conversions in the society, e.g. life cycle assessment or life cycle analysis (LCA) and environmental economics. This yields a uniform description of the use of physical resources and the environmental impacts in connection with this use.

Methodologies based on exergetics and economics are developing, and will soon gain global acceptance as useful tools for optimizing the design, operation and maintenance of energy systems, including desalination plants. By adopting the methods of exergy flow diagrams and LCEA new technology of a sustainable society could be further developed.

Reverse osmosis processes offer the highest exergy efficiency of present desalination techniques. However, MSF and MEB processes can be combined with a power production process, where the waste heat is used for the desalination process.

1. Introduction

Designing efficient and cost effective systems, which also meet environmental conditions, is one of the foremost challenges that engineers face. In the world with finite natural resources and large energy demands, it becomes increasingly important to understand the mechanisms which degrade energy and resources and to develop systematic approaches for improving systems and thus also reduce the impact on the environment. Exergetics combined with economics, both macro- and microeconomics, represents powerful tools for the systematic study and optimization of systems, e.g. desalination processes. Exergetics and microeconomics forms the basis of thermoeconomics, which is also named exergoeconomics and exergonomics. The concept of utility is a central concept in macroeconomics. Utility is also closely related to exergy, and an exergy tax is an example of how exergy could be introduced into macroeconomics.

Optimization pervades the fields of science, engineering, and business, which is concerned with finding the best system among the entire set by efficient quantitative methods. Computing makes the selection feasible and cost efficient. But to employ them requires, firstly critical analysis of the process or design, secondly insight as to what the appropriate performance objectives are, i.e. what is to be accomplished, and thirdly use of past experience, sometimes called "engineering judgment". This is sometimes also expressed accordingly: It is much more important to be able to survey the set of possible systems *approximately* than to examine the wrong system *exactly*. It is better to be *approximately* right than *precisely* wrong.

However, design is much more than using proper tools and performing a correct optimization. In a real system design consideration for environmental, social and ethical consequences must also be taken. Good design methods should also make maximum use of the designer's skills, knowledge, and experience. In addition, a designer should also be alive to ecological and social consequences, as well as ethics and morals.

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This article introduces the concept of exergy, different ways to define exergy efficiency, and distinguishes between exergy destruction, i.e. irreversibility and exergy loss or waste due to unused exergy. Net-exergy analysis or Life Cycle Exergy Analysis (LCEA) as methods of calculating the total resource use for a specific product or service is presented, as well as the application of exergetics in micro- and macroeconomics. Exergy is a useful concept in the analysis of systems involving both thermal and mechanical energies, as most desalination processes, e.g. in Multi-Stage Flashing (MSF) and Multiple Effect Boiling (MEB). Reverse Osmosis (RO) uses only electrical or mechanical energy.

Fresh water is a scarce resource in most parts of the world. Thus, it is very important to develop efficient and sustainable methods of desalination. Physically, desalination is a matter of separation, i.e. to separate salt from water by different means. Imagine that we have 100 molecules, i.e. particles, of seawater of which two are salt and the rest pure water molecules. If they are completely mixed, than the probability that we pick a water molecule is directly proportional to its fraction in the mixture, i.e. 0.98 or 98 per cent. However, if we have picked one water molecule, the probability to pick another one is slightly reduced, or 97.98 per cent. Thus, the saltier the water becomes, the harder it is to desalinate.

2. Exergetics

In 1824 N. L. Sadi Carnot claimed that the available work from a given amount of heat is related to the temperature difference of the heat transfer. This was a first step towards the second law of thermodynamics, which was stated later when Clausius introduced the concept of entropy (1865). The notion of available work, including the diffusion term, was first introduced by Willard Gibbs in 1873.

Exergy is a thermodynamic potential, it is a general measure of "difference" or contrast. It has been interpreted as "available" energy, "the capacity to do work", and the "transformable or convertible component of energy". In 1953 the term *exergy* was suggested by Z. Rant, it denotes "technical working capacity" (Rant 1956). At an international conference in Rome, 1987, it was agreed among the participants to encourage strongly the use of *exergy* for the general concept of the potential to cause change, in lieu of terms such as availability, available energy, essergy, utilizable energy, work potential, available work, convertible energy, etc. "The term exergy will be preferred for use in all future conferences, symposia, and workshops involving the participants" (Moran and Sciubba 1987). Recently, the concept of exergy has been widely used.

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