

# EXERGY AND OPTIMIZATION

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## Schedule

- Definition of exergy
- Concept of exergy
- Exergy components
- Criteria of performance
- Thermoeconomic applications of exergy

## Definition of Exergy

- The maximum theoretical useful work (shaft work) obtainable as the system interact to equilibrium, heat transfer occurring with the environment only.
- The minimum theoretical useful work required to form a quantity of matter from substances present in the environment and to bring the matter to a specified state.

A. Bejan, G. Tsatsaronis, M. Moran,  
"Thermal Design and Optimization" John  
Wiley & Sons, 1996, Canada.

## Concept of Exergy

- Universal Standard of energy quality
- The maximum work which can be obtained from a given form of energy using the environmental parameters as the reference state
- Exergy balance and the law of "degradation of energy "
- Exergy balance vs. conservation of energy

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

## Exergy Components

- Kinetic Exergy  $\rightarrow \dot{E}_k = \dot{m} \frac{C_o^2}{2}$
- Potential Exergy  $\rightarrow \dot{E}_p = \dot{m} g_E Z_o$
- Physical Exergy
  - Non-flow  $\Xi = (U - U_o) + P_o(V - V_o) - T_o(S - S_o)$
  - flow  $E = (H - H_o) - T_o(S - S_o)$
- Chemical Exergy
  - Non-flow  $\Xi_{ch} = \sum_{i=1}^n (\mu_i^* - \mu_{o,i}) N_i$
  - flow  $E_{ch} = \Xi_{ch}$

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

## Criteria of Performance

- Rational efficiency  $\rightarrow \psi = \frac{\sum \Delta E_{out}}{\sum \Delta E_{in}}$
- Efficiency defect  $\rightarrow \psi = 1 - \frac{\dot{I}}{\sum \Delta E_{in}}$
- Component efficiency defect  $\rightarrow 1 - \psi = \sum_i \dot{I}_i / \sum \Delta E_{in}$
- Dimensionless exergy balance  $\rightarrow \delta_i = \dot{I}_i / \sum \Delta E_{in}$
- Relative irreversibilities  $\rightarrow 1 = \psi + \sum_i \delta_i$
- Relative irreversibilities  $\rightarrow 1 = \sum_i \dot{I}_i / \dot{I}$

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

## Thermoeconomic Applications of Exergy: The Analysis of Thermal Plants

- Attainment of an optimal system structure, i.e. An optimal arrangement of components of the system.
- Optimisation of the geometrical parameters of the components for maximum component efficiency,
- Assessment of economically justified costs of these components through thermoeconomic optimisation.

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

## Optimal Arrangement of Components

- There are no general formal techniques for utilising the findings of system analysis for determining an optimal system sytructure.
- Given the necessary insight into the nature of irreversibilities, an appreciation of the practical limits to their reduction, and an understanding of the interrelations inherent in system structures, the optimal structure of a plant can be arrived at through an empirical process of successive improvements.

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

## Optimisation of the Geometric Parameters of the Plant Components

### Classification of Categorical Components:

- «Ready made» components selected from a manufacturer's catalogue, eg pumps, compressors, turbines, etc.
- Components specially designed, or «tailor-made» for the plant, eg heat exchangers, pressure vessels, pipe and duct system, etc.

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

### «Ready made» Component selection

- Geometric parameters of «ready made» components may be assumed to have been optimized by the manufacturer; at the thermoeconomic stage of optimisation, the plant designer need only select a component which fits the technical specification and whose capital cost is justified by its thermodynamic efficiency.

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

## «Tailor made» component optimization

- Optimize the particular component geometry for a range of components of different prices

T.J. Kotas, "The Exergy Method of Thermal Plant Analysis," Butterworths, 1985, Great Britain

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The aim of this study is to analyze a sensible heat thermal energy storage system designed for storing and later using of energy from thermodynamic point of view, and also to obtain optimum operation conditions for various operation parameters in order to minimize the irreversibilities in the system taking into account the pressure drop effect. The operation of the investigated sensible heat thermal energy storage system is divided into two parts: storage and removal processes. Considering the first and second law of thermodynamics, each part is studied separately. The results are combined in order to get the final solution for complete system. The detailed analyses were performed from both the first and second law perspective of thermodynamics on the proposed model to store sensible energy at optimum conditions. The parametric studies were focused on the determination of optimum operational values such as dimensionless storage time, dimensionless temperature, Number of Transfer Units, the first law and second law efficiencies, the ratio of mass flow rates.



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### Thermodynamic Analysis: optimization Of A Thermal Energy Storage System

The Second Law Efficiency



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