EXERGY-BASED METHODS FOR IMPROVING THE THERMODYNAMIC, ECONOMIC, AND ENVIRONMENTAL PERFORMANCES OF ENERGY CONVERSION SYSTEMS

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Exergy-based methods are powerful tools for developing, evaluating and improving an energy conversion system. This presentation deals with integrated conventional and advanced exergetic, exergoeconomic and exergoenvironmental analyses.

An exergetic analysis identifies the sources, the magnitude and the causes of thermodynamic inefficiencies within each process and each system component and assists in improving the overall efficiency of the system. An exergoeconomic analysis combines an exergetic with an economic analysis, to identify the location, magnitude and causes of costs and to pinpoint directions for improving the overall cost effectiveness of the system being considered. Finally, an exergoenvironmental analysis, which is conducted in analogy to an exergoeconomic one, considers with the aid of a Life-Cycle Analysis (LCA) the environmental impact associated with each component and the exergy destruction (thermodynamic inefficiencies) within each component in an attempt to reduce the environmental impact from the overall system.

Exergoeconomic and exergoenvironmental analyses are exergy-aided cost reduction and environmental-impact reduction methods that use the exergy-costing and the exergoenvironmental-costing principles. These principles state that exergy is the only rational basis for assigning monetary values and values of environmental impact to the transport of energy and to the thermodynamic inefficiencies within the components. In the design of a new energy conversion system, exergy destruction represents not only a thermodynamic inefficiency but also an opportunity to reduce the investment cost and the environmental impact associated with the system. Central elements to all these analyses are the general concepts of “fuel” and “product” introduced by the presenter over 25 years ago.

Balances and auxiliary equations for cost and environmental impact are formulated for each system component. The evaluation of components is conducted with the aid of appropriate exergetic, exergoeconomic and exergoenvironmental variables using a formalized approach.

The conventional exergetic, exergoeconomic, and exergoenvironmental analyses have limitations, some of which are removed by the advanced exergetic, exergoeconomic, and exergoenvironmental analyses. These analyses evaluate: (a) the interactions among components of the overall system, and (b) the real potential for improving the most important system components. The main role of an advanced exergy analysis is to provide energy conversion system designers and operators with unique and useful information for improving the design and operation of such systems.

Splitting the exergy destruction, the capital investment cost, and the component-related environmental impact associated with each single component of an energy conversion system into endogenous/exogenous and avoidable/unavoidable parts and a further splitting of the exogenous exergy destruction improve (a) our understanding of the processes that take place and their mutual interdependencies, and (b) the quality of the conclusions obtained from the analyses.

With the methods that will be presented, an energy conversion system can be analyzed in a consistent way from the viewpoints of thermodynamics, economics, and environmental impact, and the interactions among system components as well as the potential for improving them are identified. Thus, the knowledge, experience, creativity, and confidence during the decision–making process of engineers and scientists are significantly enhanced. The information obtained through the exergoeconomic and exergoenvironmental analyses cannot be supplied by energetic, exergetic, economic and life-cycle analyses conducted separately.

An application of the advanced exergy analyses to a simple open gas turbine system will be presented.

Keywords: exergy analysis, exergoeconomics, exergoenvironmental analysis, avoidable exergy destruction and costs, endogenous exergy destruction and costs, gas turbine systems.