EXERGY ANALYSIS. ADDING INSIGHT AND PRECISION TO EXPERIENCE AND INTUITION.

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Abstract

Exergy analysis is one of the most impressive applications of thermodynamics, although it seems rarely be applied. The analysis can provide a revealing picture of the in- and output of energy and its devaluation in a process, if process conditions and the thermodynamic properties of the process flows are known. As such it can be part of the thermo economic process analysis in which the cost of fuel and capital are the main parameters. Pinch technology may be a substantial part of the analysis as it mainly concentrates on the optimal integration of heat flows.

In a series of examples exergy and exergy analysis will be discussed and illustrated. It is then speculated that the process industry may often be responsible for considerable exergy destruction of chemical origin without necessarily being aware of it or assuming too quickly that these losses are inevitable. Therefore a plea is made to stimulate the designer to make exergy losses, i.e. "lost work", visible in the design and to conserve exergy as much as reasonable. It is also suggested that for excessive losses alternative process routes are considered and evaluated to find a thermo-economic optimum route.

Introduction

Thermodynamics is one of the basic disciplines in process technology. This is no surprise if one considers its potential to establish heat and work requirements, the position of phase and chemical equilibria and the thermodynamic efficiency of processes (Fig. 1). Thermodynamics is an intricate network of relations between equilibrium properties of the system under consideration and is solidly based on its fundamental laws. In many applications these laws have been lost out of sight, for example in the calculation of phase equilibria, but in the case of thermodynamic process analysis the laws predominate. This will be illustrated by the calculation of lost work or exergy losses for steady state flow processes. Under these conditions, for the simplest situation of a single stream of matter, entering and leaving a control volume, with an overall massflow rate \( \dot{m} \), the first and second law of thermodynamics are given by:
\[ \dot{Q}_{in} = \dot{m}(\Delta H + g \Delta z + \frac{\Delta u^2}{2}) + \dot{W}_{out} \]  

(1)

\[ S_{pr} = \dot{m} \Delta S + S_0 \geq 0 \]  

(2)

It is remarkable that the subject of thermodynamic efficiency receives relatively little attention compared to the other applications of thermodynamics. For those who have ever made an exergy analysis which, as we shall show, is equivalent to the calculation of a process' efficiency in terms of energy and its quality or usefulness, it is difficult to understand why, as the results seem so useful. One reason may be that little attention is given to this subject in most textbooks. A pleasant exception is the excellent book by Smith and Van Ness (1987) on chemical engineering thermodynamics, in which the last chapter gives a very clear treatment on the thermodynamic efficiency. And another reason may be that promoters of the concept of exergy analysis have raised too many and high expectations or have suggested solutions instead of indicating the possibility of comparing alternatives.

**Applications**

**Heat and work requirements**

**Phase equilibria**

**Chemical equilibria**

**Thermodynamic efficiency**

Figure 1  Applications of thermodynamics in the process industry.