Overall Abstract

There is increasing pressure on industries to increase their productivity while simultaneously reducing their environmental impact. In order to meet these new challenges, energy and raw materials need to be put to the best use they can be.

Typically the features of a process are fixed at an early stage in a design. While doing so allows a design to be conveniently arranged into discrete stages, it also results in the loss of many opportunities for innovation. In order to preserve both the chance for innovation and ease of management, new and systematic methods are needed to design processes. The purpose of this research is to demonstrate the use of a novel method of synthesizing process flowsheets, using a graphical tool which we called the GH-space, with the overall goal of minimizing carbon emissions while making the best use of raw materials and for a given production.

Typically mass, energy and work balances are done on flowsheets as a means of analysis. In other words, the flowsheet determines the balances. Unfortunately, once the flowsheet and chemistry of the process has been decided, most of the opportunities for improvement and innovation have been lost.

The GH-space technique uses fundamental thermodynamic principles to allow the mass, energy and work balances to define targets for the performance of a process. Furthermore processes and unit operations can be defined as vectors in the GH-space. Using the targets, one can combine the vector processes in such a way as to approach the target. These vector processes, and the way they are combined, can then be interpreted in terms of flowsheets. This is opposite to what is normally done and allows the process balances to determine what the best flowsheet might look like, allowing for great innovation from the very start of a design. In addition to this, probably the greatest advantage of the GH-space technique is that processes of great complexity can all be analyzed on a set of two-dimensional axes.

Every process that converts some feed material to a product material has a heat and a work associated with it in order to perform that conversion. Using the relationship that exists between heat and work allows the target of a process to be determined and for flowsheets to be formulated that allow these targets to be met. In this research the flows of heat and work are illustrated with the analogy of a heat engine. This is not the only way for heat and work to flow between process units but it allows for convenient illustration of the heat and work interaction between individual process units.

Three case studies were chosen for their reputations as high carbon dioxide emitters: Coal Gasification, Methane Steam Reforming and Fischer-Tropsch synthesis. The GH-space method was then applied to these three examples to determine if these emissions were just a price that had to be paid or if there was any room for improvement.

The case studies shown herein were ideal cases to show the power and flexibility of the technique as well as illustrate a method of using the technique, there is a great deal of additional

details that would still need to be considered for a practical, functioning, plant to be built, such as catalysis and materials of construction, to name only two. While the GH-space provides insight into what the theoretical maximum efficiency might look like it does not necessarily show what the absolute maximum efficiency might be. Another advantage of the GH-space is that it can handle as little or as much detail as is desired.

It was shown in this work that with clear understanding of the flows of mass, energy and work within a process it is possible to design process flowsheets that are potentially carbon negative, produce the intended product and also produce power as a co-product.