CHAPTER II
LITERATURE SURVEY

2.1 Research Related to Exergy Analysis

Morris *et al.* (1999) introduced the comparative analysis of the consumption of energy of two wood pulping processes. They set equations presented for the cumulative energy analysis of a process with numerous recycle streams and multiple products. The equations enable a quantitative assessment for alternative processes in the production of a particular product. This method was applied to the production of chemical pulp from wood by the Kraft process and a proposed alcohol extraction process. The Kraft process was found to be superior to the alcohol extraction process in terms of specific cumulative energy consumption for the production of chemical pulp (50% consistency) as the only useful product: 14.5 vs. 19.9 MJ/kg. However, if by products of the alcohol extraction process are considered as useful products, the specific cumulative energy consumption of the chemical pulp is reduced to 12.3 MJ/kg, which is below that of the Kraft process. Cogeneration of steam and electricity decreases the specific energy consumption for pulp production significantly for both processes.

Mozes *et al.* (1997) examined the efficiency of the conventional textile washing process done by using the cumulative exergy consumption. Exergy is the quantity of work that can be extracted from material or energy by reversible processes. Cumulative exergy consumption shows the exergy consumption in all production steps from the extraction of natural resources to the final product. The aim of the study was to minimize the cumulative exergy consumption of the washing process. In order to minimize the cumulative exergy consumption, some experiments had been performed to quantify the exergy consumption of the different process steps that occur during the washing process. These experiments showed that the electrical heating process consumes the most exergy. Hence, different alternatives of this process were proposed. Finally, the washing performance was related to the washing temperature and the detergent quantity, by performing a number of experiments. With this relation an optimum combination of washing temperature and detergent quantity could be found for the different heating systems, that results in an acceptable washing performance with a minimum quantity of cumulative exergy consumption. It was shown that replacing the conventional electrical heating system by central heating or district heating would reduce the cumulative by 35 or 57 percent, respectively.

Hinderink *et al.* (1996) analyzed the synthesis gas process from natural gas by the exergy method, showing the exergy analysis as a valuable diagnostic tool. Exergy calculations had been carried out by user-defined subroutines, which were integrated with a flowsheeting simulator. Firstly, in order to systematically perform exergy analysis, the overall exergy loss for each process is determined. Absolute exergy losses based on final product yield, which is chosen to be methanol, are used for process comparison and diagnosis rather than exergetic efficiencies. Compared to the conventional steam reforming process giving an overall exergy loss of approximately 8.5 GJ/ton of methanal, the exergy loss can be reduced to about 4.9 GJ/ton of methanal by application of the convective reforming option in combustion with partial oxidation. Secondly, by considering progressively smaller subsystems within the overall process, locations of major exergy loss are revealed and their potential for improvement can be indicated. Finally, the mains value of the standard Gibbs energy of the overall reaction of each process, denoted as available reaction exergy, is compared to the exergy loss associated with this overall reaction. This comparison demonstrated that available reaction exergies should always be minimized to reduce exergy losses associated with chemical reactions. For the chemical reactions during synthesis gas production, improvements can be attained by reducing the extent of downhill reactions relative to reactions uphill. As a result, the available reaction exergy, playing a crucial role in the extent of the unavoidable exergy loss, was reduced. The practical exergy loss associated with an overall reaction is mainly determined by this unavoidable exergy loss. It is therefore recommended to reduce the available reaction exergy of the overall reaction. Losses are minimized when no net physical exergy is produced, but cannot, however, be eliminated completely when reactions are only thermally coupled. Further improvement will only be possible by direct coupling of reactions by their complete Gibbs energy of reaction. Application of fuel cells with special catalysts, enabling such a complete coupling of reactions, is therefore recommended from an exergetic point of view.

Dincer and Erkan (1986) analyzed the exergy loss in a Turkish refinery. They found that furnaces (3 furnaces) were the most exergy loss equipment (about 60% of the total exergy loss) due to no heat recovery of the flue gas. The second most loss was air and water cooling equipment that was used for reducing the temperature of various streams. An exergy loss for the equipment was about 19%. By using the integrated heat exchangers between hot and cold may reduce this loss. However it will increase the initial capital cost. Other equipment producing exergy loss were heat exchangers (9.25% of total loss) and distillation columns (6.65% of total loss). They found that the overall exergy efficiency of this refinery was 5.9%.

Oliveira and Homeeck (1997) presented an exergy analysis of petroleum separation processes at Brazilian offshore platforms using a Hysim version C to obtain thermodynamic properties and idetified possible ways of increasing the overall performance of the platform. They analyzed the process divided into three modules; separation, compression, and pumping. They found that the separation module which was composed of a heater and a separator had the lowest efficiency (22%) compared with those of the compression (48%) and pumping (62.1%) modules because of the temperature difference between the separation and exhaust gas. The overall exergetic efficiency of the offshore platform was 9.7%.

Zemp *et al.* (1997) presented a new procedure for the analysis of the energy of distillation process based on the analysis of the distribution of the driving force in the column , given by the temperature and composition change across a stage. This method has been used to show the exergy loss profile along the distillation column. The shape of the exergy loss profile was then used to determine the overall loss of the distillation column. The shape of the exergy loss profile could be used to identify beneficial column modifications which could lead to a higher column efficiency.

Graveland and Gisolf (1998) presented an exergy analysis of vinyl chloride plant using Aspen Plus and Exercom software to calculate the exergy content of the streams. The results they showed in an exergy flow diagram provided a clear picture on how the exergy was lost through the process. They found the solutions to reduce primary exergy losses in the process in which they were; optimization of the utility generation process; optimization of the unit itself, co-production, selecting more exergy efficient process routes, reducing the required process steps, and heat integration.

Doldersum (1998) developed a commercially available exergy analysis program. Most recently an exergy analysis of reaction and distillation sections within a refinery has been performed. In the reaction section endothermic reactions take place after which the product stream is cooled in a heat exchanger network afterwhich the reaction products are separated in a distillation section. From the exergy analysis it can be seen that the main part of the loss occurs in the furnace and distillation columns. To reduce the exergy losses in this distillation column, he proposed several modifications. These are 1) decrease operating pressure to achieve lower operating temperatures, 2) use high pressure steam reboiling instead of a furnace reboiler, 3) separate feed streams and 4) recompress the over head. With these methods the total exergy losses may be reduced by 70% that directly result in a primary fuel reduction of 40% for the column. Separating of feed streams could save an addition 10% of the request energy and give a more stable operation of the column.

Cornelissen and Hirs (1998) presented an exergy analysis of cryogenic air separation process, which is the main method of air separation. They showed that more than half of the exergy loss takes place in the liquefaction unit and almost one –third in the air compression unit. Minor exergy losses take place in the distillation unit and heat exchanger. The overall efficiency of the liquefaction unit was 25%, 46% for the distillation unit and 86% for heat exchanger. In the liquefaction unit the major exergy loss occurs from the low efficiency of compressor.

Rivero *et al.* (1999) calculated the physical exergy and the chemical exergy of a mixture of light crude oil (Isthmus) and heavy crude oil (Maya) by using Aspen plus in obtaining the thermodynamic properties. They used a Fortran computer program to calculate the exergy. The first step was to characterized the components of the crude oil mixture by experiment. Then determine the reference conditions and calculate the physical exergy of each component by using Aspen Plus and Fortran programs. The chemical exergy must be identified for each component and pseudo components before the calculation is made by the computer program. Finally, the sum of the chemical exergy and physical exergy is used to give the total exergy of a stream. They found that the variation of the mixture will affect the chemical exergy of crude oil. The physical exergy contribution to the total exergy of the mixture is small compared to the chemical exergy only about 4% of the total exergy.