CHAPTER II
LITERATURE SURVEY

2.1 Definition of Exergy

Exergy is the shaft work or electrical energy required to produce the materials in its specified state from materials in their natural state in the environment by a reversible process, heat being exchanged with the environment at a temperature, T_0 only.

Normally excluding nuclear, magnetic, electrical, potential and kinetic interfacial effects the exergy can be defined as

$$B = B_{ph} + B_{ch} \quad (2.1)$$

where B_{ph}= The physical exergy which is the work obtainable by taking the substance through reversible physical processes from its initial state temperature T, pressure P, to the state determined by the temperature T_o and pressure P_0, of the environment.

B_{ch}= The chemical exergy which is the work that can be obtained by taking a substance having the parameters T_0, P_0 to the state of thermodynamic equilibrium with the datum level components of the environment.

In order to compute the exergy a reference environment has been defined. The reference environment is the state of maximum chaos, which every system will tend to approach ultimately. It is a model of the situation on the earth at sea level and is determined by the temperature 25°C, the pressure 1 ATM and the concentrations of gases in the air, minerals and other components in the sea or the Earth's crust.

The physical exergy (B_{ph}) is composed of two parts, one depends on temperature(B_{pht}),the other depends on pressure(B_{php}). It can be written as

$$B_{ph} = B_{pht} + B_{php} \qquad (2.2)$$

where

$$B_{pht} = (H-H_0) - T_0(S-S_0)$$

$$= \int_{T0}^{T} (dH - T_0 dS)$$

$$= \int_{T0}^{T} n(CpdT - T_0 Cp \frac{dT}{T})$$

$$= nCp\left[(T - T_0) - T_0 \ln \frac{T}{T_0}\right]$$

$$B_{php} = \sum_i n_i RT_0 \ln \frac{P_i}{P_0}$$

$$\therefore B_{ph} = nCp\left[(T - T_0) - T_0 \ln \frac{T}{T_0}\right] + \sum_i n_i RT_0 \ln \frac{P_i}{P_0}$$

And $B_{chi} = \Sigma n_i \mu_i$

$$\therefore B = \Delta H - T_0 \Delta S + \Sigma n_i \mu_i \qquad (2.3)$$

2.2 Research Related to Exergy Analysis

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 offshore platforms using a Hysim version C to obtain thermodynamic properties. 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.