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Optimization of Energy Consumption and Energy Analysis in KHDS and GHDS units of Tehran Oil Refinery

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ABSTRACT: Currently, the importance of efficiency to increase national production has been accepted. When efficiency increases, gross national product (GDP) will increase faster than production factors and the production average also increases per unit of every production factors. Heat pump is a means which has the ability to absorb heat in a low temperature and return it in a higher temperature, so that amount of retrieved heat is more than required energy to set up the machine. The applied energy to the machine is the same mechanic work needed to transfer heat from lower temperature to higher temperature. In the present research study and analysis of energy and optimization of energy consumption has been conducted by exact examination of a series data of KHDS and GHDS units' production line in oil refinery of Shahid Tongooyan Oil Refinery, Tehran. In fact, in this method KHDS and GHDS units have been studied and evaluated to examine the amount of work that has been converted into useful work, calculating and comparing the irreversibility and the second law efficiency for both units. Energy waste calculation shows that in design discharge, irreversibility rate of KHDS unit is 29.66 MW and in GHDS unit is 24.60 MW. Also calculations show that in design discharge of second law efficiency KHDS unit is 71.36% and in GHDS is 71.15%. Also a diagram of irreversibility values changes and second law efficiency in different discharges into unites have been illustrated. Finally, by examining different factors involved in irreversibles, opportunities to improve and suggestions and solutions have been provided.

Keywords: Optimization, energy, KHDS, GHDS, Tehran Oil Refinery

I. INTRODUCTION

Increasingly rise of energy consumption from one hand, and energy carriers cost increase, in the other hand, has doubled the importance of energy consumption optimization and identification of energy waste places in different industries particularly oil and gas. In this regard and to examine energy waste places and analyze wastes and the kind of analysis methods, different procedures have been applied from a long time. One of the appropriate and efficient methods to analyze wastes and, in the other words, the role of irreversible in different industries is energy analysis method. Energy analysis method is a very efficient procedure to analyze different industrial units' energy. In the other hand, catalytic processes are considered one of the most important and key operations of oil, gas, petrochemical and chemical industries in developed or developing countries and considering that catalysts have a vital role in production of types of fuels and a wide range of intermediate and final products necessary for society, their significance increasingly is rising. The heat pumps operation principles are based on knowledge related to cooler equipments and its initial goal is taking heat and cooling a low temperature space.

A special knowledge is required to identify appropriate potentials to install and employing heat pump in process systems. In this regard the pinch technology is used as a thermodynamic tool along valuable experiences with exploitation and process operations. In a research performed by Goodarzvand *et al.* (2014) energy consumption operational optimization was examined in separation process using integration of heat pump. In this study by providing a fast examination algorithm, the technical and economic possibility of heat pump installation have been evaluated and analyzed during separation process in an industrial unit using pinch analysis and applying valuable practical experiences. Results show that by employing heat pump in separation process of liquid gas treatment in Tehran Oil Refinery, $144000 energy save is obtained annually which its investment return period is about 4 years.

In another study Ameli (2013) examined the Subsidy reform impact on energy carrier consumption in Iran: case study, gasoline, oil, and diesel fuel. This article addressed to impact of change in energy career such as oil, gasoline and diesel fuel price on their consumption during 2011-2016 in Iran using self-regression method.

Results obtained from interaction functions indicate that consumption of oil, gasoline, diesel because of price change at first has been decreasing and in a short period will increase. The research findings show that changes of energy carriers' price hasn't significant impact on these products consumption level. Considering the issues it is suggested that in order to reduce these carriers consumption in our country, the price policies (rising price of oil, gasoline and diesel) as only policy tool is avoided seriously. Also results of Granger causality test suggest that there is a unidirectional causality from energy carriers' consumption side to their price. Also Granger causality test show that to reduce oil, gasoline and diesel consumption level it couldn't be just relied on price solutions and to lower energy carriers' consumption the non-price solutions must be performed including modifying households consumption pattern. Aim of this study is Exergy analysis of KHDS and GHDS units in Tehran Oil Refinery and examining the participation of irreversibles in the different sections of these units or, in the other words, analyzing these units from thermodynamic second law viewpoint. In this research the level of irreversibles in different parts of the units have been examined in different work conditions and by revealing that irreversibility level of boiler is more than the other parts, the boiler was examined more accurate. In general, aim of this study is examination of second law and the participation of irreversibles.

II. METHODOLOGY

The conventional method to evaluate a physical or chemical process in terms of energy is writing energy balance based on thermodynamic first law that can be used to reduce heat waste or increase of heat retrieval. Though it provide no insight on energy quality occurring during a process. Exergy method overcomes on these limitations of thermodynamic first law. In this method thermodynamic wastes are estimated according both first and second thermodynamic laws. Exergy analysis method determines energy waste location during a process and result in improvement of units' operations conditions or technical equipments of process.

Exergy (useful work capability). To determine Exergy of a system or control volume, in addition to processes that occur within a system or control volume, drop level of Exergy of a system or control volume due to energy connection and transfer between system and its outside environment also in considered. In this case real Exergy of a system is evaluated. Thermodynamic first law states amount of different energies. While second law discusses about the issue that two kinds of energy with same amount can have different Exergy. During the process because of existing wastes in different processes, Exergy of a certain amount of energy is reduced and it is stated that energy has found rank1 degradation. Prevention of Exergy reduction during its use is very important. If we would like to have to determine the Exergy of a system in a certain condition or to determine change of Exergy of a system in a certain condition or obtain change of its Exergy during a process, must apply both laws concurrently on the system. This method differs from typical method in which each law is applied separately on system.

In order to obtain a relation that related work directly to irreversibles , we combine first and second laws together. It must be noticed that in these relations work and heat transfer input and output of a system have been assumed positive and negative, respectively. In terms of temperature and heat transfer of outside recourses we can write:

$$\frac{d}{dt}(E + P_o V - T_o S)_{cv} = \sum_{j=1}^{n} \dot{Q}_j \left(1 - \frac{T_o}{T_j}\right) + \sum_{in} \dot{m}\left(h + \frac{v^2}{2} + gz - T_o s\right) - \sum_{out} \dot{m}\left(h + \frac{v^2}{2} + gz - T_o s\right)$$
$$+ W_{act} - T_o(\dot{S}_{gen})_{tot}$$

Irreversibility. We aim in this study to write a Exergy balance process for operations units and compute the wasted 2 Exergy amount that is in fact the same wasted central work for each one. Difference between real work and reversible work of control volume when have been occurred by irreversibly, is called irreversibility and denoted by I.

$$\dot{I}_{CV} = \dot{W}_{act} - \dot{W}_{rev} = T_o(\dot{S}_{gen})_{CV}$$

GHDS unit of Tehran Oil Refinery. A unit in which hydrogen purification or dehydrogenation of diesel is performed. In this way, light gas oil, heavy gas oil and fusion naphtha obtained from distillation units of this unit pass and its sulfur and nitrogen derivatives is purified under pressure and high temperature in vicinity of catalyst, and pure gas oil in terms of sulfur is produced. To the end, thermodynamic equipments and processes are used in this unit that this research seek to examine them.

Flows characteristics. Kerosene flow and entrance fusion naphtha (flow 1): to unit KHDS in design conditions with discharge of 213800 kg/h and temperature of 38°C and pressure of 1043 psi and chemical analysis is entered in the KHDS unit. **Consumption electric power (stream 2):** Consumption power in dehumidification unit includes electric power that is revived by gas fans and is compressed that its information is presented in tables of Appendix 1.

Fig. 1. Model of total control volume of unit GHDS.

This amount for design capacity is equal to 342 KW. Exergy of consumption power equals its amount.

Gas of fuel consumption in rehabilitation oil furnace (stream 3 and 9): in furnace in order to increase kerosene temperature, gas fuel revival is used that increases revival oil temperature from 38 to 302°C. Because the discharge of consumption gas fuel isn't measured, so its Exergy is computed based on transferred heat to revival oil. In more simple words, we use Exergy substitute of heat transfer:

$$EX_Q = \Phi_Q = Q_i(\text{۱} - \frac{T_o}{T_i})$$

Input cooling cool water flow (stream 4): Cooling water with temperature of 29°C and pressure of 65 psi and discharge of 26.61 M3/h is entered into heat converter.

Air flow instrumentation (stream 5): Air needed for instrumentation is considered an input flow that its amount is insignificant.

Output light gas oil (stream 6): natural gas output from dehumidification unit in design conditions with discharge of 212090 kg/h and temperature of 38°C and pressure of 1023 psi2. Molecular weight of natural gas according calculations of tables of Appendix 1 is obtained 16.38 kg/km and its compressibility is 0.99, so using complete gas relations is possible.

Flow of output sulfur derivatives (stream 7): Hydrocarbons separated in drying tower in heating condition 3 with discharge of 1.2 m3/h and temperature of 38°C and pressure of 1000 psi2 is removed from revival gas separator and is transferred toward hydrocarbon liquids fixation unit.

Flow of output warm cooling water (flow 10): Warm cooling water with 41°C temperature and pressure of 65 psi2 and discharge of 26.61 m3/h is discharged from heat converter.

Output waste stream (stream 11): Because discharged stream from valves in normal condition isn't generally in stable state and have insignificant impact on calculations, so they aren't' entered in calculations.

Exergy analysis with a general approach: given the input and output streams passing from control volumes, its Exergy balance equation is:

$$\frac{d}{dt}(EX)Cv = \sum_{in-out}(EX_Q) + \sum_{stream}(EX)_{in} - \sum_{stream}(EX)_{out} + \sum_{in-out} W_{act} - T_o(\dot{S}_{gen})_{tot}$$

$$\text{۰} = (EX_Q)_{\text{۳,۹}} + EX_{\text{۱}} + (EX_w)_{\text{۲}} + EX_{\text{۴}} - EX_{\text{۴}} - EX_{\text{۶}} - EX_{\text{۷}} - EX_{\text{۸}} - EX_{\text{۱۰}} - T_{\text{۰}}(\dot{S}_{gen})_{tot}$$

The unit's total Exergy wastes and total Exergy output can be computed:

$$I_{tot} = T_{\text{۰}}(\dot{S}_{gen})_{tot} = \text{۰.۷۱۵}MW$$

$$(\varepsilon)_{DEW} = \text{۹۷.۶}\%$$

Exergies of temporary streams hasn't been considered in this relation.

KHDS unit of Tehran Oil Refinery. Main feed of this unit is kerosene and fusion naphtha obtained from distillation unit and its product is kerosene with little sulfur. To analyze main parts within sweetening process and a more accurate description of internal operations of the process, we examine the diagram of stream process from sweetening process in Oil Refinery.

Fig. 2. Model of total control volume of unit KHDS.

Streams characteristics. Input naphtha flow (stream 1): naphtha in design conditions with discharge 346000 m3 standard 4 /h and temperature of 21°C and pressure of 1063 psi2 and following chemical analysis is entered in unit KHDS. Molecular weight of naphtha has been obtained according calculation tables of Appendix 1 as 18.74 kg/km and its compressibility coefficient is .89.

Consumption electric power and central power (stream 2 and 4): consumption power in unit KHDS include two parts: a part of it is electric energy that is used by booster pumps, reflux pumps, Amine fans and Acidic fans that its data is presented in Appendix 1 tables. Another part includes central power of circulation high pressure pumps that is used by steam turbine driver and turbine. This amount is for design capacity equal to 3.116 MW. Exergy of consumption power equals with amount of energy by its time unit.

Low-pressure steam flow (stream 3): Low-pressure stream in order to heat revival towers with discharge 0f 67767 kg/h and temperature of 147°C and pressure of 62 psi2 (in design conditions) is entered in reboilres. Unit KHDS has four reboilers.

Air flow instrumentation (stream 5): Air needed for instrumentation equipment is considered as an input stream, but its amount is very insignificant.

Output light naphtha stream (stream 6): Output naphtha from unit KHDS in design conditions with discharge of 213800 kg/h and temperature of 38°C and pressure of 1043 psi2 and following chemical analysis is entered into dehumidification unit. Light naphtha molecular weight according Appendix 1 tables is 16.30 kg/km and its compressibility coefficient is 0.99.

Stream of output sulfur derivatives. Output sulfur derivatives from unit KHDS in design conditions with discharge 39100 m3 standard /h and temperature of 52°C and pressure of 22 psi2 and following chemical analysis is entered into sulfur recovery unit. Derivatives molecular weight is 38.05 kg/km according calculations of Appendix 1 tables and its compressibility coefficient is .99, so using complete gas relations is possible.

Nitrogen output stream: nitrogen output derivatives from unit KHDS in design conditions with discharge of 3010 m3 standard/h and temperature of 56°C and pressure of 88.9 psi2 and following chemical analysis is transferred toward torches to burn. Derivatives molecular weight is 16.37 kg/km according calculations of Appendix 1 tables and its compressibility coefficient is .99, so using complete gas relations is possible.

Output condense water flow (stream 9): low-pressure water steam after heat transfer to solution in the form of condense water with discharge of 67767 kg/h and temperature of 100°C and pressure of 14.5 psi2 is removed from the unit and is sent toward water and steam unit.

Output waste flow (stream 10): because discharged from valves in normal condition isn't in stable state, so has a very insignificant impact on calculations and isn't entered in calculations.

Exergy analysis with total approach. Given the input and output flows passing from the total control volume boundaries, Exergy balance will be written. Finally considering the Exergy balance relation, for these unit relevant streams can be substituted and its total Exergy wastes obtained. In general, unit KHDS has been considered as a control volume. Given the input and output streams passing from control volume, its Exergy balance equation is:

$$\frac{d}{dt}(EX)_{cv} = \sum_{in-out}(EX_Q) + \sum_{Steam}(EX)_{in} - \sum_{steam}(EX)_{out} + \sum_{in-out} w_{act} - T_{\text{٠}}(S_{gen})_{tot}$$

$$\text{٠} = \text{٠} + EX_{\text{١}} + EX_{\text{٢}} + EX_{\text{٣}} + EX_{\text{۴}} - EX_{\text{۶}} - EX_{\text{٧}} - EX_{\text{٨}} - EX_{\text{٩}} - T_{\text{٠}}(S_{gen})_{tot}$$

Given the relations (3-3) to (8-3), the unit's total Exergy wastes and total Exergy return can be obtained as following:

$$I_{tot} = T_{\text{٠}}(\dot{S}_{gen})_{tot} = \text{۲۹.۶۶MW}$$

$$(\varepsilon)_{GTU} = \text{۷۴.۶\%}$$

Temporary streams Exergy because of very insignificant impact isn't considered in the calculations.

III. DISCUSSION AND CONCLUSION

Considering the amounts of affectability it can be understood that improvement opportunities for sulfur recovery unit and KHDS is much more than unit GHDS.

Amount of irreversibility and affectability of GHDS Refinery units (in design conditions with discharge 346000 m3 standard)

Existing waste flows and a lot number of machineries in processes KHDS and sulfur recovery compared with GHDS process are among main reasons for difference of Affectability and irreversibility.

Results analysis of unit KHDS (according different discharges). Exergy waste in unit KHDS as a result of work done to separate sulfide hydrogen and dioxide-carbon increases by raising naphtha discharge irreversibility level. Amount of irreversibility in discharge of 180000 m3standard /h fall a little that is because of servicing Amine circulation pump with hydraulic turbine driver and also increases somewhat in discharge of 310000 m3standard/h that these changes is as result of servicing fourth Amine circulation pump with steam turbine driver.

Irreversibility changes on unit KHDS. Examination of pumps number impact while designing unit is such that given the considered discharge, that pump has the best efficiency. So, any change that result in movement from determined work point while designing, result in movement of pump work point and its return drop. It is clear that movement of pump work point can be due to reducing unit capacity (in circulation Amine reduction) or increase of the set parallel pumps number. To examine effects of pump discharge change on its efficiency, it is necessary that according pump characteristic curve, the pump return function is extracted in terms of passing fluid discharge.

Results analysis of unit GHDS. Exergy waste in unit GHDS due to work done in order to oil's sulfur derivatives. The unit affectability increases with oil discharge that its reason can be searched in design procedure of unit GHDS. According the sent naphtha from distillation unit in beginning of unit GHDS is divided into two parts that main part is transferred to two in service drying towers in order to separate nitrogen derivatives and sulfur derivatives with them and another part as revival gas goes toward another two drying towers for cooling and reviving catalysts. There is no consumer of power in the main stream path but revival air fans, compressor and furnace have been located in the path of revival gas that are according compressor constant design and furnace with a certain service discharge.

Existing naphtha discharge - changes of unit GHDS affectability. Amount of consumption power according different discharges of input oil have been shown. It is worthwhile to mention that changes of consumption power are related to consumption electric energy of revival second fan.

Amount of irreversibility has been shown according different discharges of input oil. Considering the definition of irreversibility with increase of oil discharge, Exergy amount resulted from consumption power and Exergy resulted from Exergy constituted for heat transfer is constant but the wish that is output light naphtha and sulfur derivative increases.

Irreversibility changes of unit GHDS. Consumption power amount according different input oil discharges have been shown. It should be mentioned that changes of consumption power is related to consumption electric energy of revival second fan.

In the end it is stated that conducting Exergy analysis studies in the other natural refineries result in identifying weakness and strengths of processes, systems and refinery units and will be very effective in designing new refineries and substitution of new technologies and also in evaluating in service refineries performance in terms of energy efficiency.

REFERENCES

[1]. Amirhoseyn Tarigh AlEslami, Mohammad Reza Amidkhaah, Investigate the ways to reduce energy consumption in Tabriz refinery atmospheric distillation tower by using Exergy Analysis, specialized in monthly new process, Issue, 1386, **9** Ss64-57.

[2]. Sajjad Khashe, Energy efficiency of Abadan refinery catalytic conversion unit by using combined pinch-exergy, chemical engineering master's thesis, University of Sistan and Baluchestan, 0.1392.

[3]. Kotas T.J., The Exergy Method of Thermal Plant Analysis, Exergon Publishing Company, 2012.

Dincer I. and Rosen M.A., Exergy, Energy, Environment and Sustainable Development, Elsevier Publication, 2013.

[4]. Szargut J., Morris D.R. and Steward F.R., Exergy Analysis of Thermal, Chemical and Metallurgical Processes, Hemisphere Publishing Corporation, 1988.

[5]. Ataei A. and Yoo C.K., Combined Pinch and Exergy Analysis for Energy Efficiency Optimization in a Steam Power Plant, *International Journal of the Physical Sciences,* Vol. **5**, No. 7, 2010, pp. 1110-1123.

[6]. Rooh Allah Azarnoosh, Pinch-combination exergy analysis to optimize energy consumption in Isfahan oil refinery distillation tower, chemical engineering master's thesis, University of Sistan and Baluchestan, 0.1387, spring, check the exergy in integrated cycle electricity and steam, engineering graduate thesis.

[7]. M.A. Rosen, "Clarifying Thermodynamic Efficiencies and Losses via Exergy", *Exergy, An international jounal*, PP3-5, 2002.

[8]. K. Wark, "Advanced Thermodynamics For Engineers", Mc Graw- Hill Inc, 1995.

[9]. Mehdi, Sinai, gas treatment and sulfur recovery units of Razi Petrochemical process analysis and improvement by using Exergy, a master's thesis, Tehran University, Faculty of Engineering, Chemical Engineering, Persian date Dey 1378.

[10]. T.J. Kotas, "The Exergy Method of Thermal Plant Analysis", Anchor Berndon Ltd, Tiptric, Essex, 1985.

[11]. Gas refinery projects of Hasheminejad in comprehensive energy audit (Khangiran), Power engineering and Consulting Engineers, Persian date Ordibehesht 1382.