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Simulation and Optimization of Gas Sweetening Plant of Iraq Majnoon Refinery

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ABSTRACT

In this research, gas sweetening process of the Iraq Majnoon refinery plant and its optimization scenarios were investigated using ASPEN HYSYS 8.4 and genetic algorithm optimization. First, values of optimization parameters such as the values of the population, generations and crossover for single and multi-objective optimizations were obtained. The effect of temperature and molar flow of feed gas and make-up water on concentration of CO_2 and H_2S in the sweet gas were studied. The result showed that with increasing the temperature and molar flow of feed gas, the concentration of CO_2 and H_2S in the sweet gas was increased. The single and multi-objectives' optimizations of process were carried out with minimizing the concentration of CO_2 and H_2S, minimizing the consumed energy of stripper and overall consumed energy of plant including energy of stripper and cooler. It was observed that for optimization of concentration of CO_2 and H_2S, mole fraction of CO_2 and H_2S decreased to minimum amounts of 5.52 e-4 and 6.84 e-9 between optimization data sets. Also, it was found that with increasing the number of objective functions of the optimization, the ability of the algorithm to reduce the amount of the objective functions decreases, because genetic algorithm should consider more constraints with increasing the number of objective functions. The novelty of this research was a comprehensive study of gas sweetening process optimization with single to four objectives.

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INTRODUCTION

In comparison with other fossil fuels, natural gas has environmental benefits and it is considered as clean fuel. Thus, natural gas has better environmental advantages over coal or crude oil because its emissions of sulphur dioxide are negligible and the amounts of nitrous oxide and carbon dioxide emissions are lower than other fuels [1]. One of the important stages in the natural gas chain is the removal of CO_2 and H_2S, so called gas sweetening, to prepare the natural gas available for the market. CO_2 must be removed for two main reasons: first it is a not-flammable component and will reduce the temperature of the flame, second it can condensate in the cryogenic units. On the other hand, H_2S is removed due to its corrosion effect in presence of water that can lead the formation of sulphuric acid as well as its highly toxicity. For these reasons, the concentration of CO_2 in the sweet gas should be around 2-3 mol% whereas H_2S must be below 4ppmv. The processes of gas sweetening are chemical absorption, physical absorption, adsorption, membrane [2].

Many works have been done in the simulation and optimization of the gas sweetening processes. Zare and Mirzaei [3] compared the simulation results of the simultaneous absorption of CO_2 and H_2S into aqueous solutions of MDEA and DEA with two different simulators. In this study, they used the Aspen HYSYS and Aspen Plus simulators and also, they applied the electrolyte NRTL and the Amine Package for thermodynamic models. Gudmundsson et al. [4] investigated the effect of reducing pressure of the gas sweetening process with MEA, DEA and MDEA as solvents. They found that reducing pressure of gas from the reservoir has direct effect on the amine solution flow rate and also as the gas pressure goes down, the amine flow rate needs to be increased in order to meet the sweet gas specifications. Pellegrini et al. [5] designed a large purification natural gas plant in the Emirates with MDEA solvent. They used three different simulators such as Aspen HYSYS, ProMax and Aspen Plus and compared the results with each other. Abdulrahman and Sebastine [6] simulated the plant of the gas sweetening in the

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Khurmala field in Iraqi Kurdistan region using Aspen HYSYS. The sour gas of this field had high concentrations of acidic gases. Their results showed that using the appropriate facilities will lead to a reduction in the amount of acidic gases. With respect to the inlet stream, they proposed using 20 trays in the adsorption tower. Also, with optimizing the concentration of the solvent with different amines, they found out that using the mixtures of amines had a high performance in separation. Berrouk and Ochieng [7] discussed about the major optimization techniques in gas sweetening plants. They proposed that in gas sweetening unit, first the acid gas gets contact with a 30 wt. % solution of K_2CO_3 that is prompted with 3 wt. % DEA and then it gets contact with a 20 wt.% solution of DEA. Qeshta et al. [8] studied the LPG sweetening process using MDEA as solvent. They used Aspen HYSYS with Amine Package for simulations. Also, they investigated the effect of design parameters including amine flowrate, concentration and temperature in optimization of the process. Kazemi et al. [9] studied several processes for gas sweetening. They proposed that the LO CAT process has a better economical function and also, it has better separation characteristics for acidic gases. Fouad and Berrouk [10] used a mixture of MDEA and DEA for gas sweetening. Their sour gas had a high concentration of hydrogen sulfide and low concentration of carbon dioxide. Al-Lagtah et al. [11] simulated and optimized the Lekhwair natural gas sweetening plant using Aspen HYSYS. Their objective function was the reduction of energy consumption in the process. Their results showed that with the correction of the conventional gas sweetening process, the cost of the energy should be decreased up to 50%. Muhammad and GadelHak [12] investigated several theoretical methods for improvement of the gas sweetening process. They found that by increasing the solvent and the reduction of the stripper energy, performance of the process can be improved. Gutierrez et al. [13] employed Aspen HYSYS and Aspen Plus simulators to investigate the gas sweetening process. They found that the temperature of the regenerated amine and the conversion depending on the pressure of the reboiler. Also, they stated that by increasing the flow rate of the lean amine, the value of the carbon dioxide in the gas flow slightly increases. Akinola et al. [14] investigated the removal of carbon dioxide from natural gas using a mixture of ionic liquid and MEA. They found that using the mixture of ionic liquid and amine will lead to 15% reduction of energy consumption in the reboiler. Jagannath and Almansoori [15] simulated and analyzed four configurations for the regeneration of amine, applying the concept of heat pump. They simulated these configurations in Aspen HYSYS. They found that their configurations lead to savings in the overall energy consumption, cooling energy and operational costs. Alnili et al [16] simulated a gas sweetening process using low temperature distillation with Aspen HYSYS. They found that with using the low temperature distillation, the amounts of the hydrogen sulphide and carbon dioxide in the sweet gas were in the specification of the liquefied natural gas. Also, their proposed process for production of natural gas at a pressure of 35 bar and a temperature of -90°C, making it ready for liquefaction.

This study investigated the optimization of the gas sweetening process at the Iraq Majnoon refinery plant using ASPEN HYSYS and genetic algorithm optimization. Single and multi-objective optimizations were carried out with the aim of minimizing the concentration of CO_2 and H_2S, as well as the consumed energy of stripper and overall consumed energy of the plant. This research provides a comprehensive study of gas sweetening process optimization with single up to four objectives.

SIMULATION AND OPTIMIZATION FRAMEWORK

Simulation

Simulations were performed using Aspen HYSYS 8.4, which is a powerful simulator for gas processes [17]. The main reason for this choice is the existence of wide thermodynamic models in this simulator and its ability to link with MATLAB software to carry out optimizations.

Process flow diagram (PFD) of the gas sweetening process at Majnoon oil field is presented in Figure 1. Sour gas at a temperature of 62.36 °C and pressure of 4000 kPa enters to a gas-liquid separator to separate associated liquids with sour gas. Then, sour gas enters to the absorption tower having 20 trays to be in contact with lean amine solution (DEA). After absorption of CO_2 and H_2S by amine solution, sweet gas and the rich amine with absorbed CO_2 and H_2S exit from the tower. Sweet gas can be used in other processes, but rich amine flow passes from a valve to reduce its pressure to 200 kPa. Then this flow enters the lean-rich amine heat exchanger, in the heat exchanger, temperature of the rich amine flow with receiving heat from lean amine flow reaches to 100^{o}C and after that enters the regenerator (stripper) column having 20 trays. In the stripper column, the solution in the reboiler is heated up to produce steam to reverse the chemical reactions, therefore stripping out the absorbed acid gases. Lean amine from the stripper is sent to circulation pump and its pressure increases to 4000 kPa and then enters rich-lean amine heat exchanger which in this stage lose its heat to the rich amine and its temperature reduces to 74.93 °C. Then it passes from a cooler and its temperature goes down to 42 °C. After this stage, it mixes with water make-up flow and then the amine solution enters the absorption tower.

Properties of the feed sour gas, sweet gas, lean amine flow entry to the absorber and rich amine flow are listed in Table 1.

The operational conditions of the streams are presented in Table 2. For simulations Amine Pkg fluid package with Kent-Eisenberg thermodynamic model for aqueous amine solutions is used.

Optimization

The genetic algorithm (GA) was used for optimization the process [18]. Optimization were done with linking of Aspen HYSYS 8.4 and MATLAB. Genetic algorithms are used for probabilistic optimization methods, which indicate simulations of evolution, and there are some stages. Algorithm builds a sequence of events for a new population in that each individual in a present generation creates a new population [19]. Before, starting the optimization of the gas sweetening process, the optimization objectives, optimization variables and values of the optimization parameters need to be determined.

The objective function is reduction of the amount of hydrogen sulphide and carbon dioxide in sweet gas and the consumed energy of the process. In the next section the different scenarios of objective functions which are used in this work will be discussed. The temperature and flow rate of the feed gas, the temperature and flow rate of the make-up water are the optimization variables in this study. The flow rate of the feed gas is changed in between 900-1000 kmol/h, the temperature of the feed gas is varied between 50-60°C. Furthermore, flow rate of the make-up water is altered between 40-55 kmol/h and the temperature of the make-up water is varies in the range of 40-50°C.

Values of optimization parameters

Before initiation of optimization, the values of the population, generations and crossover should be determined. The type of crossover operator used can have a significant effect on the duration of the optimization process. By changing the crossover operator, required generations for reaching to the optimized values is changing. Therefore, performing a sensitivity analysis is required for every optimization. For this, three optimizations were performed on the Aspen HYSYS simulation of the gas sweetening process. In first optimization process, only the amount of the CO_2 in the sweet gas flow, in second optimization only the amount of H_2S in the sweet gas flow and in the third optimization, multi objective optimization of the amount of the CO_2 and H_2S in the sweet gas were used. The results of the sensitivity analysis showed that for optimizations, the generation number of 60 is adequate for simulations. In this study, the proper number of the population (100) was chosen.

RESULTS AND DISCUSSION

The effect of optimization parameters on the concentration of CO_2 and H_2S in sweet gas

Before performing the optimization, sensitivity analysis of the optimization parameters should be done. In this research, temperature and molar flow of feed gas, temperature and molar flow of make-up water were the

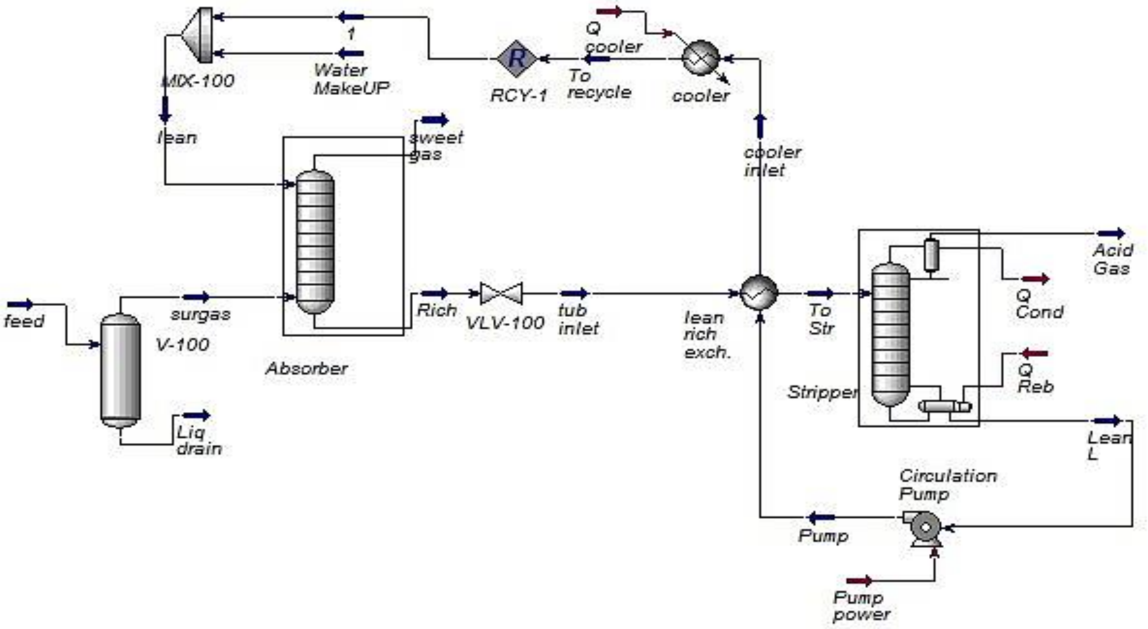

Figure 1. Process flow diagram of gas sweetening process of Majnoon oil field

Table 1. Properties of the feed sour gas, sweet gas, lean amine flow entry to the absorber and rich amine flow

Parameters	Feed sour gas	Sweet gas	Lean amine	Rich amine
Flow (kmol/h)	927.7	799.2	3003	3132
Temperature (˚C)	62.36	42.07	42	73.09
Pressure (kPa)	4000	3900	3900	4000
Components (mol%)				
CH_4	0.82	0.9499	0	0.0005
C_2H_6	0.032	0.0371	0	0
C_3H_8	0.008	0.0093	0	0
N_2	0.0005	0.0006	0	0
H_2S	0.0545	4.248e-8	0	0.0161
CO_2	0.085	7.266e-4	0	0.025
DEA	0	2.82e-8	0.0725	0.0719
H_2O	0	0.0024	0.925	0.8864

Table 2. Operational conditions of the streams

	Temperature (˚C)	Pressure (kPa)	Flow (kmol/h)
Feed	62.36	4000	927.7
Liq drain	62.36	4000	0
Sur gas	62.36	4000	927.7
Rich	73.09	4000	3132
Sweet gas	42.07	3900	799.2
Tub inlet	70.9	200	3132
To Str	100	198	3132
Acid Gas	49.15	50	170.6
Lean L	122.3	200	2958
Pump	123.6	4000	2958
Inlet cooler	74.93	3950	2958
To recycle	42	3900	2958
1	42	3900	2958
Water Makeup	42	3900	45.47
Lean	42	3900	3003

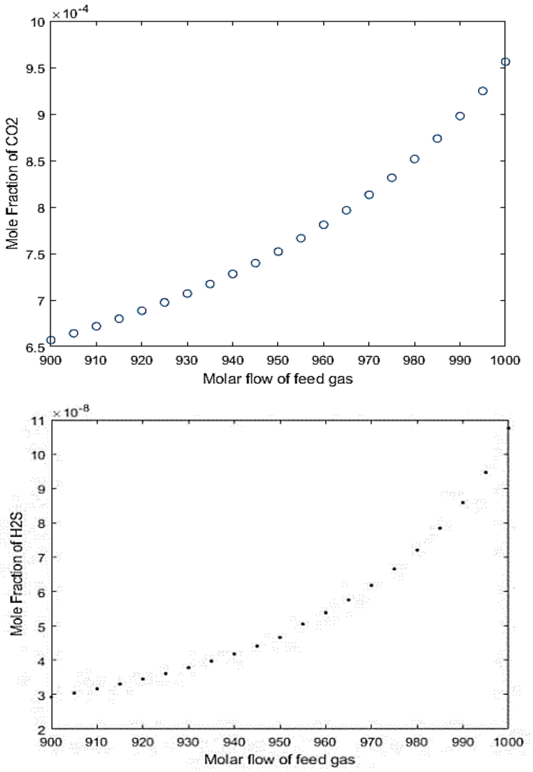

Figure 2. Variations of mole fraction of CO_2 and H_2S against molar flow of feed gas

optimization parameters. The effect of these parameters on the concentration of CO_2 and H_2S in sweet gas were examined.

Effect of molar flow of feed gas

Effect of molar flow of feed gas on the mole fraction of CO_2 and H_2S in sweet gas was studied. Figure 2 shows the effect of molar flow of feed gas on the mole fraction of CO_2 and H_2S. It should be mentioned that molar flow of feed gas was selected to be from 900 to 1000 kmol/h. It can be found that an increase in molar flow of feed gas, concentration of CO_2 and H_2S in sweet gas increased. This can be attributed to this fact that with an increase in molar flow of feed gas the amount of the acid gases in inlet gas feed to the plant increases.

Effect of temperature of feed gas

It is obvious that the temperature of feed gas was changed from 50 to 60ºC. Figure 3 presents the variations of mole fraction of CO_2 and H_2S in the sweet gas with feed gas temperature. It can be understood that concentration of CO_2 and H_2S increased with an increase in the feed gas temperature.

Effect of molar flow of make-up water

Effect of molar flow of make-up water on the mole fraction of CO_2 and H_2S in sweet gas was investigated. Figure 4 illustrates the effect of molar flow of make-up water on the concentration of CO_2 and H_2S in sweet gas. The make-up water molar flow was considered between 40 to 55 kmol/h. It is obvious from these figures that with an increase in the make-up water molar flow until 46 kmol/h, the concentration of CO_2 and H_2S did not change, but with further increasing of make-up water molar flow the concentration of CO_2 and H_2S in the sweet gas decreased. This issue can be

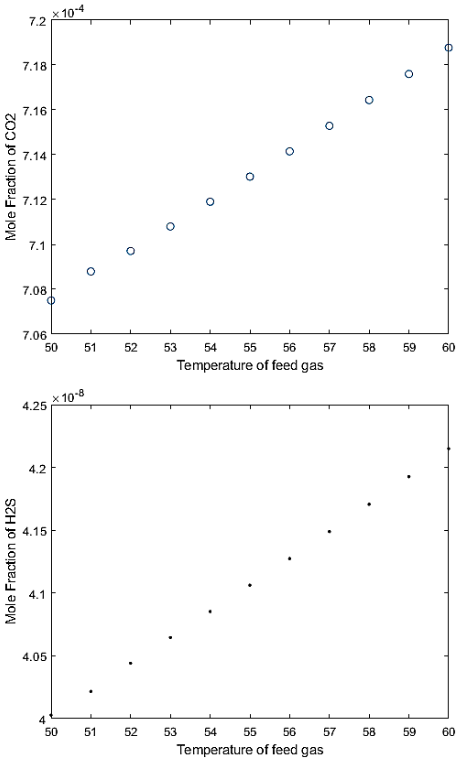

Figure 3. Variations of mole fraction of CO_2 and H_2S with temperature of feed gas

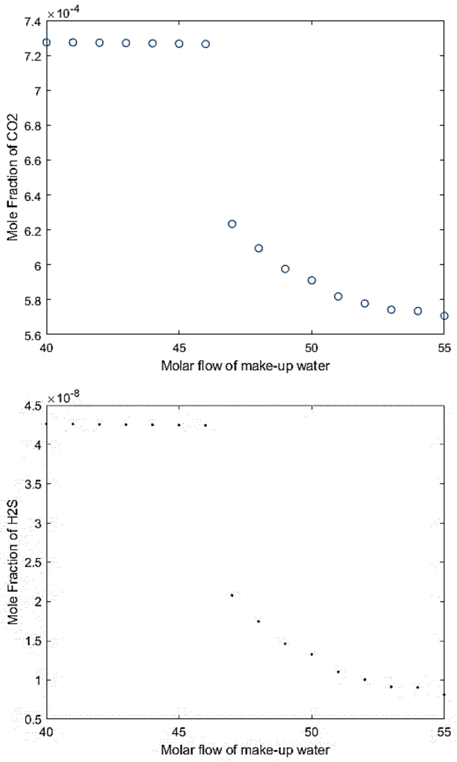

Figure 4. Variations of mole fraction of CO_2 and H_2S with molar flow of make-up water

related to the dissolution of CO_2 and H_2S in water which until 46 kmol/h their solubility remained unchanged but after increasing of water molar flow their solubility increased.

Effect of temperature of make-up water

Figure 5 represents the effect of make-up water temperature on concentration of CO_2 and H_2S in the sweet gas. The temperature of make-up water was varied between 40 to 50ºC. It can be observed form these figures that with an increase in make-up water temperature, concentration of CO_2 and H_2S in the sweet gas decreased and increased, respectively. This phenomenon is related to the solubility of CO_2 and H_2S in the water.

Single objective optimization of gas sweetening process

Since the reduction of concentration of CO_2 and H_2S in the sweet gas is necessary in gas sweetening plant, the optimization objectives were minimizing concentration of CO_2 or H_2S. First, an optimization was performed with single objective of minimizing concentration of CO_2 and then another optimization was carried out with single objective of minimizing concentration of H_2S. Table 3 shows the single objective optimization results. It can be found that mole fraction of CO_2 changed from 7.266e-4 to 5.632e-4 and mole fraction of H_2S varied from 4.248e-

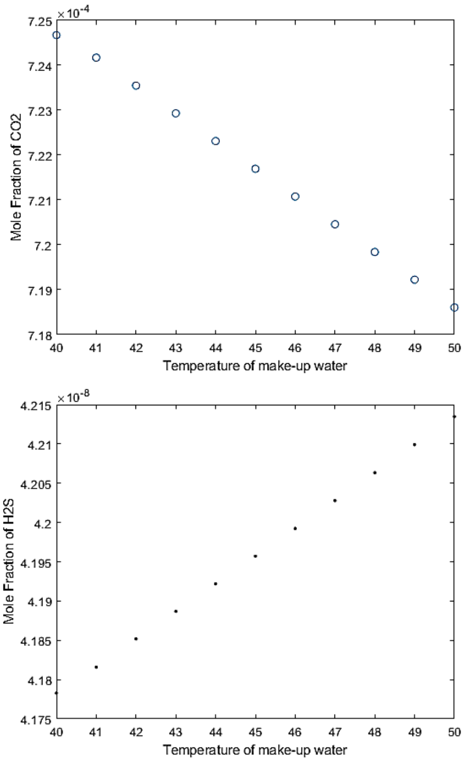

Figure 5. Variations of mole fraction of CO_2 and H_2S with temperature of make-up water

Table 3. Single objective optimization results

Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
CO_2	7.266e-4	5.632e-4	901.9059	50.0494	45.8223	49.9429
H_2S	4.248e-8	7.3453e-9	900	50.0156	40.0937	55

8 to 7.3453e-9. With respect to sensitivity analysis results, it can be observed that the optimized values of molar flow of feed are at its low, the optimized values of temperature of feed are at its low value. The reason for this issue is the fact that sensitivity analysis results showed that concentration of CO_2 and H_2S in sweet gas were at its lower value at low temperature and molar flow of feed gas. Also, the optimized value of molar flow of make-up water are in its higher values, since the sensitivity analysis revealed that at higher values of molar flow of make-up water, concentration of CO_2 and H_2S in sweet gas were low. As well as, the optimized value of temperature of make-up water for CO_2 is at its higher value and optimized value of temperature of make-up water for H_2S is at its higher values. This is because their sensitivity analysis showed that with an increase in the temperature of make-up water, the concentration of CO_2 in sweet gas decreased, while the concentration of H_2S increased.

Two objectives optimization of gas sweetening process

In this section, two objectives optimization of gas sweetening plant was carried out. The minimizing of concentration of CO_2 and H_2S, minimizing of consumed energy of stripper and overall consumed energy of plant including energy of stripper, cooler were the objectives of optimization. In this section, the optimization of process was performed with a dual series of these objectives.

Optimization of process using concentration of CO_2 and H_2S

Optimization of process was performed using two objectives including minimizing concentration of CO_2 and H_2S. The results of the optimization and the optimized values of temperature and molar flow of feed gas and temperature and molar flow of make-up water are summarized in Table 4. It can be concluded from the table that concentration of CO_2 and H_2S was reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water. Also, it can be seen that temperature and molar flow of feed gas values are at the lowest values. However, values of molar flow and temperature of make-up water are at the highest values. With respect to this table, one can find out for a specific value of concentration of CO_2 and H_2S in sweet gas, what optimized values of temperature and molar flow of feed gas and temperature and molar flow of make-up water are needed.

Optimization of process using concentration of CO_2 and energy of stripper

In this section the optimization of process was performed using two objectives including minimizing of concentration of CO_2 and consumed energy of stripper. Table 5 presents the optimization results. It can be seen form the table that concentration of CO_2 and consumed energy of stripper were reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water. With respect to this table, the minimum values of concentration of CO_2 and consumed energy of stripper can be obtained in the optimized values of optimization variables.

Optimization of process using concentration of H_2S and energy of stripper

Optimization of process was carried out using two objectives including minimizing of concentration of H_2S and consumed energy of stripper in this part. Table 6 presents the optimization results. It can be seen form the table that concentration of H_2S and consumed energy of stripper were reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water. With respect to this table, the minimum values of concentration of H_2S and consumed energy of stripper can be obtained in the optimized values of optimization variables.

Optimization of process using concentration of CO_2 and overall consumed energy of plant

Optimization of process was done using two objectives including minimizing of concentration of CO_2 and consumed overall energy of plant. Table 7 shows the optimization results. It can be seen form the table that concentration of CO_2 and consumed overall energy of were reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water. With respect to this table, the minimum values of concentration of CO_2 and consumed energy of stripper can be obtained in the optimized values of optimization variables.

Optimization of process using concentration of H_2S and overall consumed energy of plant

Optimization of process was carried out using two objectives including minimizing of concentration of H_2S and consumed overall energy of plant. Table 8 presents the optimization results. It can be seen form the table that

Table 4. Data sets of optimized values of two objectives optimization of process using concentration of CO_2 and H_2S

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	CO_2	7.266e-4	5.5378e-4	900.0837	50.0374	48.60885	54.8928
	H_2S	4.248e-008	6.8419e-9				
2	CO_2	7.266e-4	5.5296e-4	900.0837	50.06865	49.65279	54.8928
	H_2S	4.248e-008	6.8457e-9				
3	CO_2	7.266e-4	5.527e-4	900.3034	50.02178	49.78659	53.35471
	H_2S	4.248e-008	6.8561e-9				
4	CO_2	7.266e-4	5.5355e-4	900.0837	50.06865	49.15573	54.8928
	H_2S	4.248e-008	6.8422e-9				
5	CO_2	7.266e-4	5.5245e-4	900.0837	50.06865	49.63717	51.37717
	H_2S	4.248e-008	6.8565e-9				
6	CO_2	7.266e-4	5.5318e-4	900.0837	50.06084	49.12448	54.8928
	H_2S	4.248e-008	6.8448e-9				
7	CO_2	7.266e-4	5.532e-4	900.0837	50.01397	49.77487	54.8928
	H_2S	4.248e-008	6.8442e-9				
8	CO_2	7.266e-4	5.5311e-4	900.0837	50.05303	49.81198	54.8928
	H_2S	4.248e-008	6.8454e-9				
9	CO_2	7.266e-4	5.5308e-4	900.0837	50.00615	48.62448	54.8928
	H_2S	4.248e-008	6.8454e-9				
10	CO_2	7.266e-4	5.5399e-4	900.0837	50.0374	48.13742	54.8928
	H_2S	4.248e-008	6.8419e-9				
11	CO_2	7.266e-4	5.5494e-4	900.0837	50.08258	45.97928	54.8928
	H_2S	4.248e-008	6.8417e-9				
12	CO_2	7.266e-4	5.5319e-4	900.0837	50.05303	49.15573	54.8928
	H_2S	4.248e-008	6.8448e-9				
13	CO_2	7.266e-4	5.5292e-4	900.3034	50.0374	49.13034	54.8928
	H_2S	4.248e-008	6.8523e-9				
14	CO_2	7.266e-4	5.5327e-4	900.0837	50.05303	49.81198	54.8928
	H_2S	4.248e-008	6.8427e-9				
15	CO_2	7.266e-4	5.5354e-4	900.0837	50.05303	49.16257	54.8928
	H_2S	4.248e-008	6.8422e-9				

concentration of H_2S and consumed overall energy of plant were reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water. With respect to this table, the minimum values of concentration of H_2S and consumed energy of stripper can be obtained in the optimized values of optimization variables.

Three objectives optimization of gas sweetening process

In this section, three objectives optimization of gas sweetening plant was performed. The minimizing of concentration of CO_2 and H_2S, minimizing of consumed overall energy of plant and minimizing of consumed energy of stripper were the objectives of optimization. In

Table 5. Data sets of optimized values of two objectives optimization of process using concentration of CO_2 and energy of stripper

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	Mole frac. CO_2	7.266e-4	5.5812e-4	903.3612	59.98193	49.52880804	51.60922
	St. Energy [KW]	552837.7	5.5128e5				
2	Mole frac. CO_2	7.266e-4	5.5603e-4	900.4028	51.17762	49.73721921	53.25071
	St. Energy [KW]	552837.7	5.5129e5				
3	Mole frac. CO_2	7.266e-4	5.5593e-4	900.4028	50.80262	49.98721921	53.25071
	St. Energy [KW]	552837.7	5.5129e5				
4	Mole frac. CO_2	7.266e-4	5.5589e-4	900.4028	51.17762	49.98721921	53.25071
	St. Energy [KW]	552837.7	5.5129e5				
5	Mole frac. CO_2	7.266e-4	5.5575e-4	900.1831	50.80262	49.98721921	53.30564
	St. Energy [KW]	552837.7	5.513e5				
6	Mole frac. CO_2	7.266e-4	5.5579e-4	900.4028	51.17762	49.98721921	53.30564
	St. Energy [KW]	552837.7	5.513e5				
7	Mole frac. CO_2	7.266e-4	5.5489e-4	900.4028	50.99013	49.99591672	53.25071
	St. Energy [KW]	552837.7	5.5132e5				
8	Mole frac. CO_2	7.266e-4	5.5524e-4	900.1831	50.80299	49.98770749	53.31937
	St. Energy [KW]	552837.7	5.5132e5				
9	Mole frac. CO_2	7.266e-4	5.5567e-4	900.1831	50.67714	49.97940671	54.56998
	St. Energy [KW]	552837.7	5.5131e5				
10	Mole frac. CO_2	7.266e-4	5.5557e-4	900.1968	50.67773	49.97891843	54.15021
	St. Energy [KW]	552837.7	5.5131e5				

Table 6. Data sets of optimized values of two objectives optimization of process using concentration of H_2S and energy of stripper

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	Mole frac. H_2S	4.248e-008	7.0362e-9	900.1786	51.08435	47.2237797	50.78428
	St. Energy [KW]	552837.7	5.5131e5				
2	Mole frac. H_2S	4.248e-008	7.0264e-9	900.0784	51.12101	45.14097654	54.23957
	St. Energy [KW]	552837.7	5.5131e5				
3	Mole frac. H_2S	4.248e-008	7.0298e-9	900.2926	51.22013	45.85531721	54.34971
	St. Energy [KW]	552837.7	5.5131e5				
4	Mole frac. H_2S	4.248e-008	7.0247e-9	900.1578	51.13466	45.89865133	54.87262
	St. Energy [KW]	552837.7	5.5132e5				
5	Mole frac. H_2S	4.248e-008	7.0264e-9	900.0929	51.16926	45.1988952	54.37873

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
	St. Energy [KW]	552837.7	5.5131e5				
6	Mole frac. H_2S	4.248e-008	7.024e-9	900.142	50.87283	45.37818814	54.88582
	St. Energy [KW]	552837.7	5.5133e5				
7	Mole frac. H_2S	4.248e-008	7.0255e-9	900.0784	51.16788	45.11753904	54.76485
	St. Energy [KW]	552837.7	5.5131e5				
8	Mole frac. H_2S	4.248e-008	7.0238e-9	900.1249	50.86892	45.37818814	54.88582
	St. Energy [KW]	552837.7	5.5133e5				
9	Mole frac. H_2S	4.248e-008	7.0256e-9	900.0784	51.16788	45.12144529	54.74769
	St. Energy [KW]	552837.7	5.5131e5				
10	Mole frac. H_2S	4.248e-008	7.024e-9	900.1283	50.87283	45.38600064	54.89955
	St. Energy [KW]	552837.7	5.5133e5				

Table 7. Data sets of optimized values of two objectives optimization of process using concentration of CO_2 and overall consumed energy of plant

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	Mole frac. CO_2	7.266e-4	0.00062	985.93	50.06	40.06	55
	O. Energy [KW]	555461.1	555221.7				
2	Mole frac. CO_2	7.266e-4	0.000564	906.071	50.12	40.23	54.04
	O. Energy [KW]	555461.1	555266.8				
3	Mole frac. CO_2	7.266e-4	0.000562	902.55	50.12	40.29	54.26
	O. Energy [KW]	555461.1	555271.2				
4	Mole frac. CO_2	7.266e-4	0.000595	953.41	50.03	40.03	55
	O. Energy [KW]	555461.1	555241.4				
5	Mole frac. CO_2	7.266e-4	0.000562	902.55	50.12	40.29	54.06
	O. Energy [KW]	555461.1	555275.3				
6	Mole frac. CO_2	7.266e-4	0.000558	902.58	50.23	49.12	50.74
	O. Energy [KW]	555461.1	555282.7				
7	Mole frac. CO_2	7.266e-4	0.000562	902.55	50.12	40.29	54.32
	O. Energy [KW]	555461.1	555267.8				
8	Mole frac. CO_2	7.266e-4	0.000561	908.01	50.76	49.79	54.68
	O. Energy [KW]	555461.1	555282.1				
9	Mole frac. CO_2	7.266e-4	0.000558	902.13	50.75	49.791	54.74
	O. Energy [KW]	555461.1	555283.5				

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
10	Mole frac. CO_2	7.266e-4	0.00062	985.93	50.05	40.06	55
	O. Energy [KW]	555461.1	555224.2				

Table 8. Data sets of optimized values of two objectives optimization of process using concentration of CO_2 and overall consumed energy of plant

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	Mole frac. H_2S	4.248e-008	7.23e-09	900	50	43	55
	O. Energy [KW]	555461.1	555262.8				
2	Mole frac. H_2S	4.248e-008	7.23e-09	900	50	40.25	55
	O. Energy [KW]	555461.1	555277.6				
3	Mole frac. H_2S	4.248e-008	8.21e-09	945.86	50.18	41.57	53.89
	O. Energy [KW]	555461.1	555256.1				
4	Mole frac. H_2S	4.248e-008	7.23e-09	900	50	41.01	55
	O. Energy [KW]	555461.1	555271.6				
5	Mole frac. H_2S	4.248e-008	8.57e-09	959.92	50.18	41.57	53.89
	O. Energy [KW]	555461.1	555252.2				
6	Mole frac. H_2S	4.248e-008	9.24e-09	984.37	50.02	40.03	55
	O. Energy [KW]	555461.1	555232.8				
7	Mole frac. H_2S	4.248e-008	7.80e-09	928.12	50	41.01	55
	O. Energy [KW]	555461.1	555260.5				
8	Mole frac. H_2S	4.248e-008	8.65e-09	963.44	50.18	41.08	54.77
	O. Energy [KW]	555461.1	555249.5				
9	Mole frac. H_2S	4.248e-008	9.24e-09	984.37	50.03	40.01	55
	O. Energy [KW]	555461.1	555234.8				
10	Mole frac. H_2S	4.248e-008	7.23e-09	900	50	42.99	55
	O. Energy [KW]	555461.1	555266.9				

this section, the optimization of process was performed to simultaneously optimize these four parameters. The optimization of process was performed with a triple series of these objectives.

Optimization of process using concentration of CO_2 and H_2S and energy of stripper

Optimization of process was performed using three objectives including minimizing of concentration of CO_2 and H_2S and minimizing of consumed energy of stripper. The results of the optimization and the optimized values of temperature and molar flow of feed gas and temperature and molar flow of make-up water are presented in Table 9. It can be concluded form the table that concentration of CO_2 and H_2S and the consumed energy of stripper were reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water. Also, reduction of consumed energy of stripper was slightly lower for three objectives optimization in comparison to two objectives optimization.

Optimization of process using concentration of CO_2 and H_2S and consumed overall energy of plant

Optimization of process was carried out using three objectives including minimizing of concentration of CO_2 and H_2S and minimizing of consumed overall energy of plant. The results of the optimization and the optimized values of temperature and molar flow of feed gas and temperature and molar flow of make-up water are shown in Table 10. It can be concluded form the table that concentration of CO_2 and H_2S and the consumed overall energy of plant were reduced with optimizing the values of temperature and molar flow of feed gas and temperature and molar flow of make-up water.

Four objectives optimization of gas sweetening process

Four objectives optimization of gas sweetening plant was carried out. The minimizing of concentration of CO_2 and H_2S, minimizing of consumed energy of stripper energy of cooler were the objectives of optimization. In this section, the optimization of process was performed to simultaneously optimize these four parameters. Table 11 presents the optimization results. It can be seen form the table that concentration of H_2S and CO_2 a little decreased in comparison of two objectives and three objectives' optimizations and consumed energy of stripper reduced by small amount in comparison to two objectives and three objectives' optimizations. Also, it is obvious that four objectives optimization has a lot of constraints to be controlled. In addition, the consumed energy of cooler did not reduce and it increased, instead. This shows that four objectives optimization does not valid for this process and this kind of optimization for this kind of process should be avoided.

Table 9. Data sets of optimized values of three objectives optimization of process using concentration of CO_2 and H_2S and energy of stripper

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	St. Energy [KW]	552837.7	551377.8	900.41	50.24	46.87	54.83
	Mole fraction H_2S	4.248e-008	7.34e-09				
	Mole fraction CO_2	7.266e-4	0.000558				
2	St. Energy [KW]	552837.7	551383	900.41	50.93	48.21	54.39
	Mole fraction H_2S	4.248e-008	7.34e-09				
	Mole fraction CO_2	7.266e-4	0.000557				
3	St. Energy [KW]	552837.7	551384.4	900.41	50.15	47.62	53.51
	Mole fraction H_2S	4.248e-008	7.34e-09				
	Mole fraction CO_2	7.266e-4	0.000558				
4	St. Energy [KW]	552837.7	551379.6	900.41	50.24	46.85	54.83

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
	Mole fraction H_2S	4.248e-008	7.34e-09				
	Mole fraction CO_2	7.266e-4	0.000558				
5	St. Energy [KW]	552837.7	551386.2	900.63	50.4	49.79	52.44
	Mole fraction H_2S	4.248e-008	7.35e-09				
	Mole fraction CO_2	7.266e-4	0.000557				
6	St. Energy [KW]	552837.7	551387.8	900.63	50.4	49.79	53.1
	Mole fraction H_2S	4.248e-008	7.35e-09				
	Mole fraction CO_2	7.266e-4	0.000557				
7	St. Energy [KW]	552837.7	551369	900.63	50.24	46.85	54.17
	Mole fraction H_2S	4.248e-008	7.36e-09				
	Mole fraction CO_2	7.266e-4	0.000559				
8	St. Energy [KW]	552837.7	551370.2	901.29	50.24	46.87	54.39
	Mole fraction H_2S	4.248e-008	7.36e-09				
	Mole fraction CO_2	7.266e-4	0.000559				
9	St. Energy [KW]	552837.7	551389.1	901.29	50.5	49.93	54.17
	Mole fraction H_2S	4.248e-008	7.34e-09				
	Mole fraction CO_2	7.266e-4	0.000557				
10	St. Energy [KW]	552837.7	551372.4	900.41	52.03	49.86	53.08
	Mole fraction H_2S	4.248e-008	7.35e-09				
	Mole fraction CO_2	7.266e-4	0.000557				

Table 10. Data sets of optimized values of three objectives optimization of process using concentration of CO_2 and H_2S and overall consumed energy of process

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	O. Energy [KW]	555461.1	555220.5	900	50	40	55
	Mole fraction H_2S	4.248e-008	1.21e-08				

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
	Mole fraction CO_2	7.266e-4	0.000584				
2	O. Energy [KW]	555461.1	555231	966.81	50.11	42.58	53.76
	Mole fraction H_2S	4.248e-008	1.12e-08				
	Mole fraction CO_2	7.266e-4	0.000619				
3	O. Energy [KW]	555461.1	555224.9	997.72	50.44	49.56	52.33
	Mole fraction H_2S	4.248e-008	1.12e-08				
	Mole fraction CO_2	7.266e-4	0.000639				
4	O. Energy [KW]	555461.1	555252.3	900	50.07	40.26	55
	Mole fraction H_2S	4.248e-008	7.33e-09				
	Mole fraction CO_2	7.266e-4	0.000566				
5	O. Energy [KW]	555461.1	555236.7	900	50	40.01	55
	Mole fraction H_2S	4.248e-008	7.33e-09				
	Mole fraction CO_2	7.266e-4	0.000567				
6	O. Energy [KW]	555461.1	555240.3	900.63	50	40	55
	Mole fraction H_2S	4.248e-008	7.33e-09				
	Mole fraction CO_2	7.266e-4	0.000567				
7	O. Energy [KW]	555461.1	555261.9	900.63	50	41.75	55
	Mole fraction H_2S	4.248e-008	7.33e-09				
	Mole fraction CO_2	7.266e-4	0.000566				
8	O. Energy [KW]	555461.1	555242.4	901.29	50	40.01	55
	Mole fraction H_2S	4.248e-008	7.33e-09				
	Mole fraction CO_2	7.266e-4	0.000567				
9	O. Energy [KW]	555461.1	555270	901.29	50.01	43.48	55
	Mole fraction H_2S	4.248e-008	7.33e-09				
	Mole fraction CO_2	7.266e-4	0.000565				

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
10	O. Energy [KW]	555461.1	555334.9	900.41	52.66	48.76	54.84
	Mole fraction H_2S	4.248e-008	7.35e-09				
	Mole fraction CO_2	7.266e-4	0.000562				

Table 11. Data sets of optimized values of four objectives optimization of process

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
1	St. Energy [KW]	552837.7	552200	933.52	51.45	42.31	46.38
	Mole fraction H_2S	4.248e-008	1.60e-08				
	Mole fraction CO_2	7.266e-4	0.000609				
	Cooler energy	2518	3045.02				
2	St. Energy [KW]	552837.7	552198	922.36	58.88	40.78	45.71
	Mole fraction H_2S	4.248e-008	1.54e-08				
	Mole fraction CO_2	7.266e-4	0.000602				
	Cooler energy	2518	3136.917				
3	St. Energy [KW]	552837.7	552246.7	967.12	50.51	49.34	47.94
	Mole fraction H_2S	4.248e-008	1.86e-08				
	Mole fraction CO_2	7.266e-4	0.000635				
	Cooler energy	2518	2991.784				
4	St. Energy [KW]	552837.7	551788.2	925.24	50.82	40.64	53.01
	Mole fraction H_2S	4.248e-008	1.08e-08				
	Mole fraction CO_2	7.266e-4	0.000586				
	Cooler energy	2518	3439.51				
5	St. Energy [KW]	552837.7	551902.2	990.13	53.51	48.11	41.78
	Mole fraction H_2S	4.248e-008	1.37e-08				
	Mole fraction CO_2	7.266e-4	0.000637				

Data set	Component	Value before optimization	Value after optimization	Molar flow of feed gas [kmol/h]	Temperature of feed gas[ºC]	Temperature of make-up water [ºC]	Molar flow of make-up water [kmol/h]
	Cooler energy	2518	3370.974				
6	St. Energy [KW]	552837.7	551871.8	971.32	51.37	45.84	48.99
	Mole fraction H_2S	4.248e-008	1.27e-08				
	Mole fraction CO_2	7.266e-4	0.000619				
	Cooler energy	2518	3378.247				
7	St. Energy [KW]	552837.7	551648.6	923.01	54.57	48.08	52.96
	Mole fraction H_2S	4.248e-008	9.65e-09				
	Mole fraction CO_2	7.266e-4	0.000577				
	Cooler energy	2518	3622.923				
8	St. Energy [KW]	552837.7	551712	905.68	50.64	42.09	44.56
	Mole fraction H_2S	4.248e-008	9.16e-09				
	Mole fraction CO_2	7.266e-4	0.000569				
	Cooler energy	2518	3596.686				
9	St. Energy [KW]	552837.7	551704.8	977.189	51.25	41.91	49.42
	Mole fraction H_2S	4.248e-008	1.15e-08				
	Mole fraction CO_2	7.266e-4	0.000621				
	Cooler energy	2518	3498.819				
10	St. Energy [KW]	552837.7	551765.9	990.09	53.09	41.74	45.72
	Mole fraction H_2S	4.248e-008	1.21e-08				
	Mole fraction CO_2	7.266e-4	0.000633				
	Cooler energy	2518	3497.862				

CONCLUSIONS

The research investigated the gas sweetening process of Majnoon refinery and its optimization scenarios using simulations and optimizations with ASPEN HYSYS 8.4 and MATLAB programs, including the application of the genetic algorithm to optimize the process. This research used ASPEN HYSYS 8.4 and MATLAB programs, including the application of a genetic algorithm, to investigate the gas sweetening process of Majnoon refinery and its optimization scenarios through simulations. It was observed that the concentration of H_2S and CO_2 a little decreased in comparison of two objectives and three objectives' optimizations and consumed energy of stripper reduced by small amount. It was observed that the concentration of H_2S and CO_2 decreased slightly when comparing the two-objective and three-objective optimizations, and the energy consumed by the stripper was also reduced by a small amount. However, the energy consumed by the cooler did not decrease; it actually increased. This suggests that performing four-objective optimization on this plant has little influence on minimizing objective functions and is not suitable for this type of optimization.

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Persian Abstract

چکیده

در این تحقیق فرآیند شیرین‌سازی گاز پالایشگاه مجنون عراق و سناریوهای بهینه‌سازی آن با استفاده از ASPEN HYSYS 8.4 و بهینه‌سازی الگوریتم ژنتیک مورد بررسی قرار گرفت. ابتدا مقادیر پارامترهای بهینه سازی مانند مقادیر جمعیت، نسل ها و متقاطع برای بهینه سازی های تک و چند هدفه به دست آمد. اثر دما و جریان مولی گاز خوراک و آب تشکیل دهنده بر غلظت CO_2 و H_2S در گاز شیرین مورد بررسی قرار گرفت. نتایج نشان داد که با افزایش دما و دبی مولی گاز خوراک، غلظت CO_2 و H_2S در گاز شیرین افزایش یافت. بهینه‌سازی فرآیند تک و چند هدفه با به حداقل رساندن غلظت CO_2 و H_2S، به حداقل رساندن انرژی مصرفی استریپر و انرژی مصرفی کلی گیاه از جمله انرژی استریپر و کولر انجام شد. مشاهده شد که برای بهینه سازی غلظت CO_2 و H_2S، کسر مولی CO_2 و H_2S بین مجموعه داده های بهینه سازی به حداقل مقادیر ۵/۵۲×e-۴ و ۶/۸۴×e-۹ کاهش یافت. همچنین مشخص شد که با افزایش تعداد توابع هدف بهینه‌سازی، توانایی الگوریتم در کاهش مقدار توابع هدف کاهش می‌یابد، زیرا الگوریتم ژنتیک باید با افزایش تعداد توابع هدف، محدودیت‌های بیشتری را در نظر بگیرد. تازگی این تحقیق مطالعه جامع بهینه سازی فرآیند شیرین سازی گاز با تک تا چهار هدف بود.