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Optimization of Three Phases Horizontal Separator Using the Genetic Algorithm (G.A.) Method to Reduce Manufacturing Costs and Promote the Phase Separation Process in the Petroleum Industry

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Highlights

- Optimization of three phase separator with genetic algorithm.
- Acceptable error of the predicted results.
- The total weight of separator decreases about 24 %.

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Abstract

It is essential to separate two immiscible liquids from gas to produce the light liquid, heavy liquid, and vapor phases. The separation of water from hydrocarbons is a practical example in the oil industry. For such separation in industry, three phase separator is used. In this study, different parameter and the weight of the three-phase separator was optimized with the genetic algorithm (G.A.) and finally, the total cost of manufacturing the separator was decreased. Different types of three-phase separators are vertical, horizontal, and spherical. The separator works in the operating condition of 172 kPa and 445 K, respectively and the real weight of the separator is 8131 kg. For the optimization target, the flow of vapor, light liquid, and heavy liquid was considered constant during the optimization process. The objective function (O.F.) is obtained from the weight of the separator and 3 multiparameter equations. Also, 7 parameters which include: separator aspect ratio (L/D), the height of heavy liquid (H_{HL}), height of light liquid (H_{LL}), hold-up time (T_H), surge time (T_S), low liquid level (H_{LLL}) and vapor level (H_v) are used in G.A. as constraints. The weight of the optimized separator was calculated 6001 kg approximately. So, with this method, the total weight of the separator decreases by about 26.2 % as compared to the real weight of the separator. On the other hand, the maximum difference between the answers was 3.3%, which is acceptable. Also, error analysis of the predicted results is calculated by mean absolute percentage error (MAPE) for 7 design parameters of the three-phase separator and separator weight, which are in an acceptable level of accuracy. The presented approach can have potential application for the development of low-cost manufacturing of three-phase separators in the petroleum industry.

Keywords: Optimization, Three-phase separator, Genetic algorithm, Petroleum, Objective function

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1. Introduction

According to the United States (U.S.) energy information administration, 81 million barrels per day of oil products were produced around the world in 2016 approximately. Therefore, the increasing demand for the product requires new equipment with optimal design to work at maximum efficiency without economic losses (Ahmadi, 2015; Wang et al., 2017; Xu et al., 2016). The separator is one of the necessary equipment in the oil and petrochemical industry. Many of the oil products, which include all liquids and gases, enter the separators to separate gas from liquid for later treatment (Wilkinson et al., 2000; Carios et al., 2013). Converting oil to different products is done by different separators, the basis of which is based on the gravity force (Stewart & Arnold, 2008). Emulsions that were formed from oil and water are readily formed in the production of crude oil, making many problems at downstream stages of production. Large horizontal cylindrical gravity settling vessels have been traditionally used in this separation for the first time by Behinet. al. The three-phase separator has been commonly used when there is a large amount of gas to be separated from two immiscible liquids. The vessel dimensions are determined by the gas and liquid flow. One of the common applications of this kind of separator is the separation of gas, oil (hydrocarbon), and water (Van Veldhuizen & Lamont, 2000). The principle of three-phase separation design is similar to two-phase (liquid and gas) separation. The only differences are liquid–liquid settling rates and free water removal (Van Veldhuizen & Lamont, 2000). Gas in the separator moves through an extractor, which removes entrained liquids remaining, then moves to the top of the separator and exits as shown in Fig. 1.

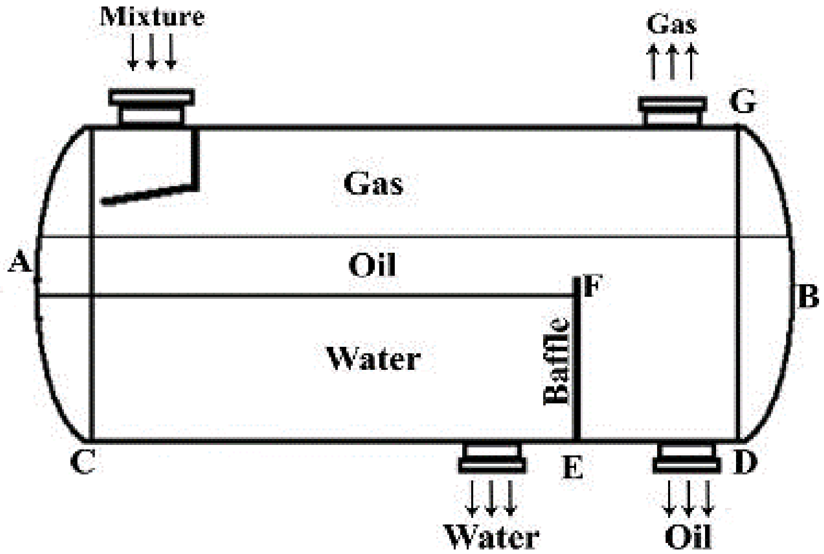

Figure 1

Schematic of three phase horizontal separator

Finally, the gas is inserted into other treatment units for purification and eventually selling. In addition, it can be burned in a flare system. There are a lot of instrumental tools that set interfaces of the liquids at a favorable level and prevent them from exiting through the gas outlet. For example, one of them is a metal protector. Two of the common liquids which are entered in these separators are water and hydrocarbon. Water is separated from oil based on the difference in the specific gravity of oil and water and it makes the water level lower level than oil because the specific gravity of water is higher than oil. A weir plate allows the oil to move into the oil chamber while water is kept in its chamber (Fig. 1). There are some indicators and level controllers (L_c) which indicate and control the level of water and oil in the separators to the operator and also can control the interface level of two liquids in the range of satisfied (Monnery & Svrcek, 1994; Sayda & Taylor, 2007). Fig. 2 shows the principle of separation in the typical horizontal three-phase separator.

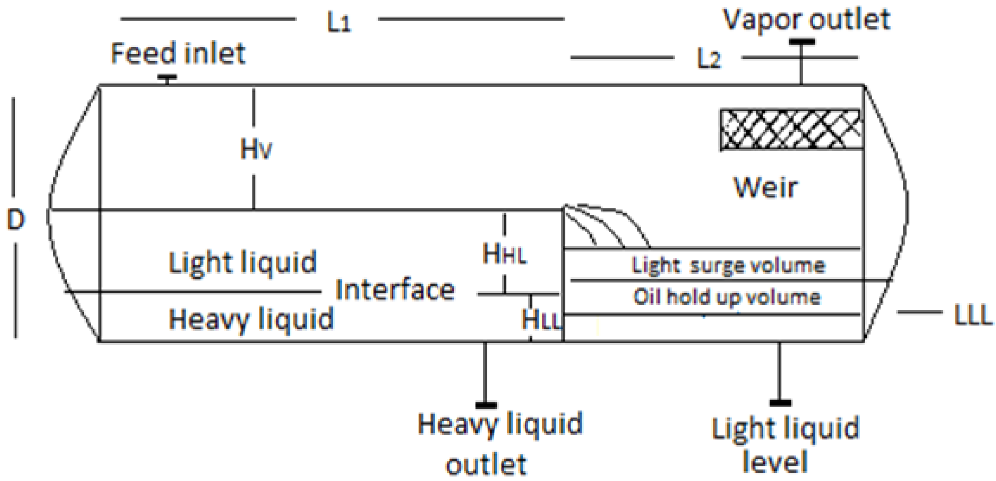

Figure 2

The height of light liquid, heavy liquid, vapor and low level of liquid (Monnery & Svrcek, 1994)

Maximum and optimal separation of the oil phase from gas and water is an important and effective challenge in the petroleum and petrochemical industry in the past. Some of the defects in oil–water separation process, which limited the application of this process in the industry, are low separation efficiencies, and slow separation processes, large capital and operating costs and long residence time of fluid (Li & Gu, 2005).

Therefore, extensive research has been done to resolve existing problems. Qaroot et al. studied the effects of the oil droplet size distribution in a turbulent multiphase on the oil carry-over in a production separator flow by the Discrete Phase Model (DPM). The new internals were designed for the enhancement of droplet coalescence leading to a minimal breakup rate confirmed by the small Weber number (Qaroot et al., 2014). Feng et al. (2008) investigated the impact of different parameters on efficiency of 3 three-phase horizontal separator. The trajectories with the residence of the oil droplets vary significantly with the sizes of the droplet. As the diameter of the oil droplet increases from 1 to 20 μm, the maximum residence time reduces from 4.89 to 0.855 s. On the other hand, the separation efficiency increases with the oil injection flowrates, but an optimal discharge pressure exists for the higher separation efficiency. The discharge pressure of 0.65 Mpa leads to the highest separation efficiency. Separator aspect ratio (L/D) is one of the important parameters in the design of the separators that are determined by an economic analysis which should be in a reasonable range (Feng et al., 2008). Bradley (1987) suggested applying a maximum of about 8.0–9.0 and a minimum of about 1.0–2.0 and to the aspect ratio. The preferred aspect ratio range for horizontal separators is 2.0–6.0, and the value for vertical separators is 2.0–3.0. According to Monnery et al. (1994) separator aspect ratio changes in the range of 3–5.0 based on the operating pressure of the separator in the range of 0 KPa to more than 3400 KPa.

One of the modifications in the separation process is reduced in their size without losing separation efficiency, which would reduce capital cost and lead to higher economic performance (Wilkinson et al., 2000). Various research has been carried out to optimize the dimensions of 3-phase separators using computational fluid dynamics (CFD) (Ghaffarkhah et al., 2017; Ghaffarkhah et al., 2019; Joshy & Nambiar 2022). There are different physical parameters to optimize. In another work, the separation efficiency was calculated using the CFD method, and various parameters such as gas flow rate, droplet size, and pressure differences were optimized (Shoghl et al., 2021). In one of the recent works, the physical parameters of diameter and length were optimized and very acceptable results were obtained (Gong et al., 2023). But there are a few works on the optimization of physical parameters by the G.A. method that affect the size and finally the total cost of the separator. G.A. is a method that works on the base of the evolutionary optimization approach. It makes some problems, possible to study, which may not be modeled as precisely using another method. G.A. is a useful algorithm in all different science for optimization and determination of related parameters; some of these sciences are mechanical, electrical, and biological (Garg 2019; Manasrah & Ba ali, 2018; Azad et al., 2018). One of the differences between other algorithms and G.A. is that G.A. does not require any initial guess, although only needs the upper and lower bounds of the variables.

In this research study, the size and finally the weight of the separator with the genetic algorithm (G.A.) were chosen as O.F. and tried to minimize the weight and finally the cost of manufacturing. On the other hand, the other parameters in the separator as the aspect ratio of a separator (L/D), hold-up time, surge time, the height of the heavy and light liquid, etc are optimized and their values obtained. Constraints and equations are discussed below, which are used to reach the final equation.

2. Experimental

2.1. Genetic algorithm method for optimum weight

The G.A. has four main stages, which are evaluation, selection, crossover, and mutation. Genetic algorithms can find the best solution for nonlinear problems that have an important role in all kinds of science (Wongthatsanekorn & Phruksaphanrat, 2015). The G.A. calculates the fitness of each individual solution in the population. The process in G.A. selects individuals of the chosen population randomly and forms modification of the next solution and the generation that has a higher chance of survival in the future generation. The crossover process takes two individuals elected and after combining them, creates two new individuals (Nazemzadegan et al., 2018; Abdoun & Abouchabaka, 2012). The mutation process modifies the genes of an individual subject randomly to create a small mutation factor and introduce further randomness into the population. This iterative continues until a known optimal or satisfied solution level is attained; or the maximum number of generations that we specified, have been performed. Finally, G.A. produces the best population for interaction parameters in a final generation (Jinafei et al., 2012; Konak et al., 2006; Holland, 1992).

For the optimization, the genetic algorithm was used. The summary of the mechanism of the G.A. is as below:

1. Determine the iteration, population, the number of variable, n-mutation, and the range of difference of variables. N-mutation is the number of good answers that use to cross over and mutation.

2. Change the first guess at the numbers that are between the specified range.

3. Use the modified initial guess to obtain the value of the O.F. and the variables.

4. Save the n-mutation number of good answers in a matrix and use them to cross over the operation.

5. Mutate the specified number of answers that obtain after crossover.

6. Save the newly obtained answer of mutation and cross over with an n-mutation number good answers in a matrix and use of them for the next iteration.

2.2. Obtaining the objective function (O.F.)

The steps to obtain O.F. and the constraint in each step are as follows:

1. Calculate the volumetric flow of vapor, light liquid, and heavy liquid as below:

$$Q_v = \frac{W_V}{\rho_v}, Q_{LL} = \frac{W_{LL}}{\rho_L}, Q_{HL} = \frac{W_{HL}}{\rho_H} \tag{1}$$

Where Q_v, Q_{LL}, and Q_{HL} are volumetric flows of vapor, light liquid, and heavy liquid, respectively and the unit of them is m3/s. W_v, W_{LL}, and W_{HL} are mass flow of vapor, light liquid, and heavy liquid, respectively and the unit of all of them is kg/s. ρ_v, ρ_L, and ρ_H are the density of vapor, light liquid, and heavy liquid, respectively and the unit of them is kg/m3.

2. Calculate the vertical terminal velocity (UT) and set U_V=0.75U_T. U_V is vapor velocity (m/s) (Monnery & Svrcek, 1994):

$$U_T = K(\frac{\rho_L - \rho_V}{\rho_V})^{0.5} \tag{2}$$

K is terminal velocity coefficient and is specified from table1.

Table 1

K-value at different pressure for multiphase horizontal separator (Monnery & Svrcek, 1994)

Pressure (kPa)	**K**
6.7<P<101.3	$k = 0.02843 + 1.28 \times 10^{-4} + 0.01402\ \ln p$
101.3<P<276	k=0.1067
276<P<37911	k=0.1445-0.007 lnp

3. Calculate hold-up volume (V_H) and surge volume (V_S) which are shown in Fig.2.

$$V_H = T_H(Q_{HL} - Q_{LL}) \tag{3}$$

$$V_S = T_S(Q_{HL} - Q_{LL}) \tag{4}$$

T_H and T_S are hold-ups and surge times (Konak, 2006), respectively.

Constraints 1&2: 4min <T_H, T_S<15 min

4. Calculate the diameter of separator (D) (Konak, 2006).

$$D = 3(\frac{(V_H + V_S)}{\pi(L/D)})^{\frac{1}{3}} \tag{5}$$

The separator aspect ratio is changed under different operating pressure. Table 2 shows the value of L/D under different pressure.

constraint 4: B-L/D=0

separator aspect ratio is determined in Table 2.

Table 2

The value of the separator aspect ratio at different operating pressure (Couper et al., 2009)

Vessel operating pressure (kPa)	L/D
0<P<1700	2-3
1700<P<3400	3-4
3400<P	4-6

5. As can be seen in Fig. 2, the total length of the separator is divided into two parts L_1 and L_2. Initially, the length of L_2 is calculated as follows.

$$L_2 = \frac{V_H + V_S}{A_T - A_V - A_{LLL}} \tag{6}$$

A_T, A_V, and A_{LLL} is the total cross-section area, the cross-section area of vapor, and the cross-section area of low liquid level, respectively, which are shown in Fig. 3.

$$A_T = \frac{\pi}{4} D^2 \tag{7}$$

A_V is calculated as follows:

$$\frac{Av}{A_T} = \frac{A_{LLL}}{A_T} = \frac{4.756 \times 10^{-5} + 0.175x + 5.699x^2 - 4.916x^3 - 0.145x^4}{1 + 3.292x - 6.359x^2 + 4.018x^3 - 1.802x^4} \tag{8}$$

To calculate A_v and A_{LLL}, $x=H_v/D$ and $x=H_{LLL}/D$, respectively. H_{LLL} and H_v are low liquid levels and vapor levels, respectively.

Constraint 5: 0.2D<H_V<D

Constraint 6: H_{LLL} is determined from Table.3.

Table 3

The low liquid level (H_{LLL}) for different diameters of three phase horizontal separators (Monnery & Svrcek, 1994)

Vessel diameter (m)	Low liquid level (m)
≤ 1.219	0.229
1.829	0.254
2.438	0.279
3.048	0.305
3.658	0.330
4.572	0.381

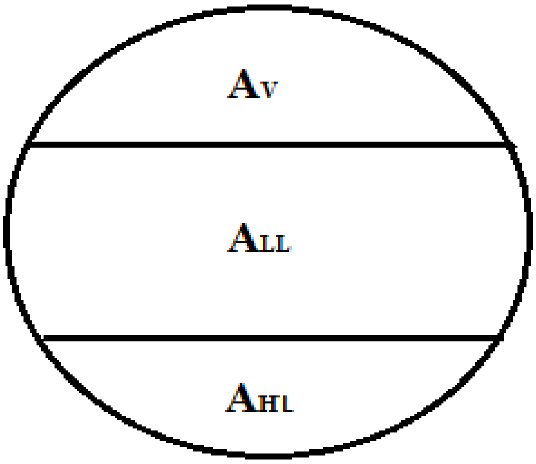

Figure 3

A schematic of cross section of separator

6. Calculate the settling velocity of heavy liquid droplets out of the light liquid (U_{HL}) and the rising velocity of light liquid droplets out of the heavy liquid (U_{LH}) (Monnery & Svrcek, 1994). The unit of both of them is m/s.

$$U_{HL} = \frac{k_s(\rho_H - \rho_L)}{\mu_L} \tag{9}$$

$$U_{LH} = \frac{k_s(\rho_H - \rho_L)}{\mu_H} \tag{10}$$

ks is the velocity coefficient and is specified from Table 4.

Table 4

Typical values of k_s at different conditions (Monnery & Svrcek, 1994)

Light phase	**Heavy phase**	**Min droplet dia (μm)**	**k_s**
Hydrocarbons			
S_G at 290 K<0.8	Water or caustic	127	0.333
S_G at 290 K<0.85	Water or caustic	89	0.163
Water	Furfural	89	0.163
Methylethyl ketone	Water	89	0.163
Sec-butyl alcohol	Water	89	0.163
Methyl isobutyl ketone	Water	89	0.163
Nonvl alcohol	Water	89	0.163

7. Calculate the settling time of heavy liquid droplets out of light liquid (t_{HL}) and the rising time of the light liquid droplets out of the heavy liquid (t_{LH}) (Monnery & Svrcek, 1994). The unit of both of them is s.

$$t_{HL} = \frac{H_{LL}}{5U_{HL}} \tag{11}$$

$$t_{LH} = \frac{H_{HL}}{5U_{LH}} \tag{12}$$

H_{HL} and H_{LL} are the height of heavy and light liquid in the separator.

Constraint 7&8: $0 < H_{HL}، H_{LL} < D$

Constraint 9: $H_{HL} + H_{LH} < 2$

Constraint 10: $D - H_V - H_{HL} - H_{LL} = 0$

8. Calculate L1 as Eq.(13):

$$L_1 = \max\left(\frac{t_{LH}Q_{HL}}{A_{HL}}، \frac{t_{HL}Q_{LL}}{A_{LL}}\right) \tag{13}$$

A_{HL} and A_{LH} are cross-section areas of heavy and light liquid, respectively, and calculate from Eq. (8).

9. Calculate the total length of the separator (L):

$$L = L_1 + L_2 \tag{14}$$

10. Calculate Lmin as below (Monnery & Svrcek, 1994):

$$L_{min} = \frac{H_V Q_V}{U_V A_V} \tag{15}$$

.If $L < L_{min}$ then set L=Lmin.

Hw is the height of the weir which is obtained by the difference between D and H_v.

11. Calculate the weight of the separator (W).

$$W = 16.64 \times t \times (A_{shell} + 2A_{head}) \tag{16}$$

Ashell and Ahead are an area of the shell and head of separator, respectively. t is the wall thickness of the separator (m). Ashell, Ahead and t are specified in Table 5.

Table 5

Wall thickness and surface area of different parts of three-phase separator (Monnery & Svrcek, 1994)

Component	Wall thickness	Surface area
shell	$(2P/(2SE-0.2P))+t_c$	πDL
2:1 Elliptical Heads	$(PD/(2SE-0.2P))+t_c$	$1.09 \times D^2$
Hemispherical Heads	$(PD/(4SE-0.4P))+t_c$	$1.571 \times D^2$
Dished Heads	(0.885PD/(SE+0.1P))+tc	$0.842 \times D^2$

The head of the separator is the dished head type which is specified with separator diameter and an operation pressure, which is shown in Table 6, so the wall thickness and surface area of the separator can be calculated. E is joint efficiency and is in range from 0.6 to 1, S is allowable stress and tc is corrosion and the range from 0.0016 to 0.0032 m. Table 6 is used to specify the sort of head.

Table 6

Different kinds of vessel heads at different operating conditions (Monnery & Svrcek, 1994)

Conditions	Typical Heads Used
D<4.57 m and P<690 kPa	Dished with knuckle radius=0.06D
D<4.57 m and P>690 kPa	2:1 Elliptical
D>4.57 m, regardless of pressure	Hemispherical

Where P is the design pressure and D is the separator diameter. As mentioned above considering the pressure and diameter of the separation, the dished type was used. By considering 3 multiparameter equations (constraints 4, 9 & 10) and the weight of the separator, the O.F. is obtained as Eq. (17).

$$\mathrm{O.F.} = \mathrm{W} + [\mathrm{K_1} \times \mathrm{abs}(\mathrm{D} - \mathrm{H_V} - \mathrm{H_{LL}} - \mathrm{H_{HL}})] + \left[\mathrm{K_2} \times \mathrm{abs}\left(\mathrm{B} - \frac{\mathrm{L}}{\mathrm{D}}\right)\right] + [\mathrm{K_3} \times \mathrm{abs}(2 - \mathrm{H_{HL}} - \mathrm{H_{LH}})] \quad (17)$$

K_1, K_2, and K_3 are constant and should be at the same factor of W to give the exact and correct result. These constants were applied to accelerate the running of the process which will be described in the next section.

The flowchart of obtaining O.F. and optimizing it by the G.A. method is presented in Fig. 4.

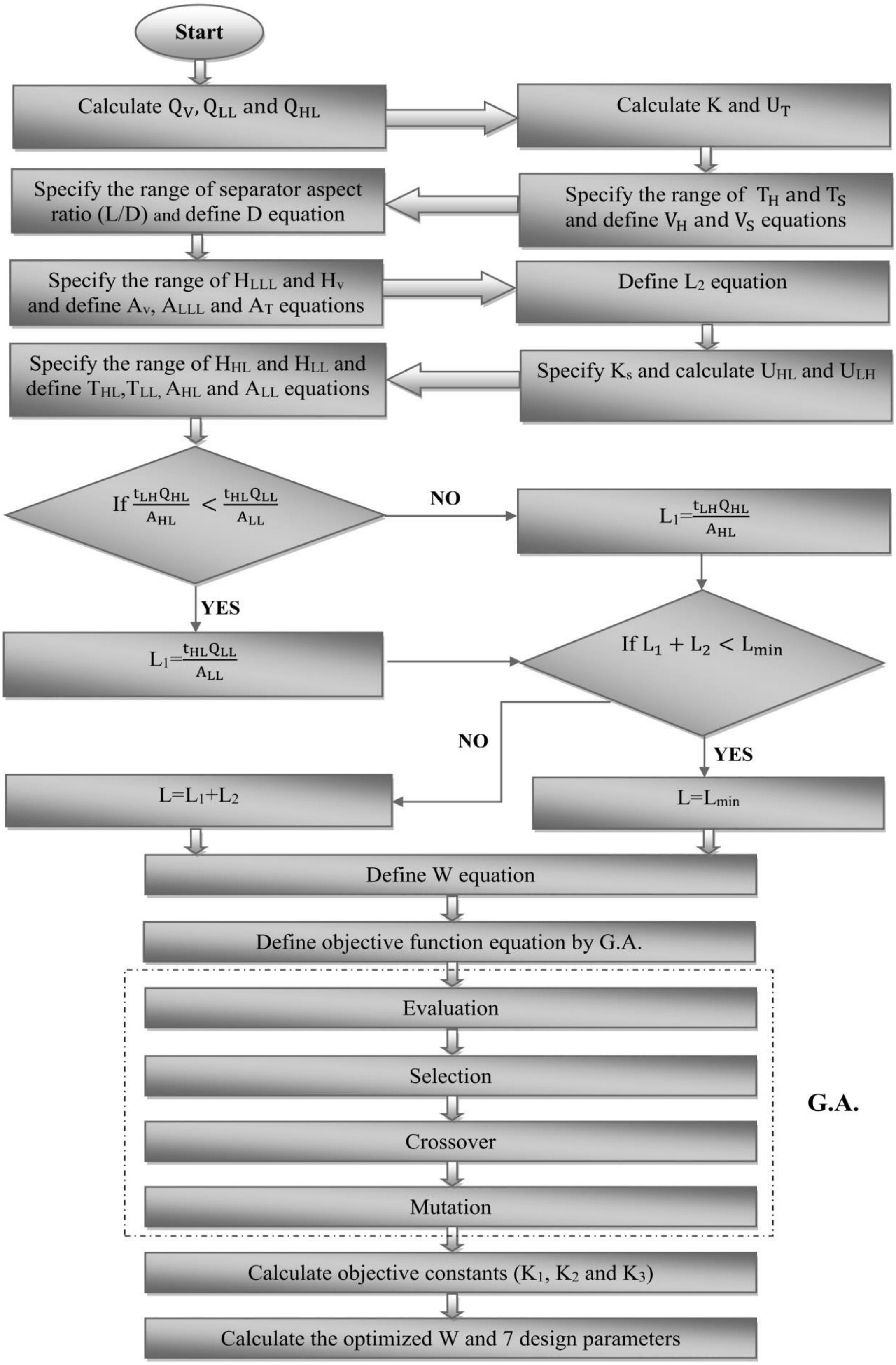

Figure 4

Flowchart of the objective function and G.A. training

3. Results and discussion

3.1. Modeling results

The goal is to optimize the separator weight and finally decrease the total cost of a horizontal separator with a weir. The specification of the mixture is shown in Table 7 (the real weight of the separator is 8131 kg). The operating pressure and temperature are 172 kPa and 311 K, respectively.

For this problem the following assumption is considered: E= 0.85, S (allowable stress) =120645 kPa, and t_c (corrosion) = 0.0016 m, which are the common assumptions in separator design.

Table 7

The physical condition of vapor, light, and heavy phases

Component	**Mass flow (kg/s)**	**ρ (kg/m^3)**	**μ (kg/m.s)**
Vapor	29.61	3	-
Hydrocarbon liquid	5.67	650	24×10^{-5}
Water	0.945	1000	68.2×10^{-5}

The optimization was done with 200 iterations and 300 populations. As it is shown in Table 8, there are 8 variables in this optimization that we consider as design parameters: T_H, T_S, B, H_{LL}, H_{HL}, H_V, and H_{LLL}. The allowable range of design parameters is shown in Table 8.

Table 8

The allowable range of design parameter

Variables	**Min**	**Max**
T_H	4 (min)	15 (min)
T_S	4 (min)	15 (min)
L/D	2	3
H_{LLL}	0.254 (m)	1
H_V	$0.2D_{max}$=0.78 (m)	D_{max}=3.83 (m)
H_{HL}	0 (m)	D_{max}=3.83 (m)
H_{LL}	0 (m)	D_{max}=3.83 (m)

The O.F. as shown in Eq. (17) is used for the specification of design parameters. As can be seen, the equation has four parts, in which the first part shows the weight of the separator and the others are related to the size of the separator. These three parts are a multitude of the K_i factors that are near the three parameters to the weight amount which facilitate the optimization program. So, it is obvious that with changing in the amount of K_i factors, the amount of weight separator is changed.

The changing of W with different K_i (existing in O.F.) coefficients can be seen in Table 9. As is clear after the amount of 10^4 for K_i, the large change in W was not shown. As a result, K_1, K_2, and K_3 are chosen 2×10^{13}, 1.5×10^{13} and 2×10^{13}, respectively fixed during the optimization process.

Table 9

Effect of different values of Ki on the optimized weight of the separator

K_1	**K_2**	**K_3**	**W (kg)**
10	10	10	839.6
100	100	100	972.5
1000	1000	1000	822.4
10^4	10^4	10^4	5987.4
10^5	10^5	10^5	6088.1

2×10^5	1.5×10^5	2×10^5	5979.7
10^6	10^6	10^6	6109.9
2×10^6	1.5×10^6	2×10^6	6225.6
10^7	10^7	10^7	6003.7
2×10^7	1.5×10^7	2×10^7	6028.2
2×10^8	1.5×10^8	2×10^8	5962.5
2×10^9	1.5×10^8	2×10^9	5965.5
.	.	.	.
.	.	.	.
2×10^{13}	1.5×10^{13}	2×10^{13}	5962.9

The method works as follows; the O.F. will be minimized by considering determining the design parameters. The design parameters are determined in a valuable range that is mentioned earlier. This range is a kind of limitation that helps and facilitates the optimization process.

After the specification of the final K_i value, the optimizations were run in 30 sets. According to the values of selected K_i above and the weight change by iteration is shown in Fig 4. Separator weights were obtained 6001 kg in comparison with the actual weight (8131 kg), 27% improved which is very significant. The difference between the real weight and the optimized weight for the separator is 2.130 tons. Another important parameter is the aspect ratio of a separator whose average value is 2.921. In addition, the total elapsed time to obtain the optimized separator is 10.2 s which is very small. The values of different variables exist in Table 10.

Table 10

Different separator parameters and weight at applying different program executions

Set number	**H_{HL} (m)**	**H_{LL} (m)**	**H_V (m)**	**D (ft)**	**L (ft)**	**L/D**	**T_S (min)**	**T_H (min)**	**W (kg)**
1	0.15	0.45	1.93	2.62	7.82	2.97	8.04	4.11	5928
2	0.18	0.45	1.95	2.63	7.89	3.00	6.56	5.75	5993
3	0.22	0.36	1.95	2.64	7.68	2.91	5.66	6.38	6001
4	0.15	0.45	1.95	2.63	7.59	2.86	7.51	4.28	6010
5	0.15	0.46	1.95	2.63	7.59	2.87	7.53	4.27	5989
.									
30	0.15	0.46	1.95	2.62	7.78	2.96	4.73	7.35	5977

From Table 10, it can be concluded that the optimization of the three-phase separator with the algorithm method is enough accurate and correct method. The maximum difference between the solutions obtained from the weight of the separator is 3.3% which is acceptable, completely. Table 11 shows the average of design parameters for the separator, which were obtained with the G.A. method.

Table 11

Final optimized value of different design parameters of a three-phase horizontal separator

Parameter	H_{HL} (m)	H_{LL} (m)	H_V (m)	H_W (m)	D (m)	L (m)	L/D	T_S (min)	T_H (min)	W (kg)
Value	0.15	0.46	1.95	0.41	2.63	7.59	2.86	7.51	4.28	6001

In addition, the total cost of production of industrial equipment is the most important factor among the others. The industrial separators are usually made of carbon-style metal;

Assuming that the price of carbon style is about 513 dollars per ton, it can be said that nearly 1280 $ in the purchase cost of raw materials has been saved. These amounts may be more important for the separators with higher flow rates and different operational conditions. On the other hand, one of the other important parameters for using equipment on the scale of industrial is minimizing its volume because of the limitation of industrial space. Also, the total cost is the most important factor in designing industrial equipment.

3.2. Error analysis and standard deviation of data

3.2.1. Error analyze

Error analysis of the predicted results via mentioned algorithm is calculated by mean absolute percentage error (MAPE). To calculate these errors, 30 executions of the used method are executed to acquire closing results through the algorithm. Table 12 shows the MAPE of 30 predicted data for 8 design parameters of the three-phase separator and separator weight, which are in an acceptable level of accuracy.

Table 12

Error analysis based on the MAPE method for different design parameters

Parameter	H_{HL}	H_{LL}	H_V	D	L	L/D	T_S	T_H	W
MAPE	2.12	1.53	3.39	3.63	3.84	2.86	3.52	3.21	4.74

3.2.2. Standard deviation

One of the important parameters in the validation of predicted data is standard deviation which specifies the deviation of data from the mean. Table 13 shows the standard deviation of the 8 design parameters. The result shows that the standard deviation of the data is in the satisfied range. All analyses confirm the validation of the results.

Table 13

The standard deviation for different design parameters

Parameter	H_{HL}	H_{LL}	H_V	D	L	L/D	T_S	T_H	W
Standard deviation	0.127	0.132	0.351	0.354	0.462	0.254	0.341	0.343	0.305

4. Conclusions

The optimization of a three-phase separator with G.A. can be an accurate and reliable method. It was observed that the weight of the separator obtained to 6001 kg approximately, concerning the real weight of the separator decreased by 26.2%. Finally, the total cost of manufacturing of the separator is decreased. This result is so significant and is very important to decrease the cost of designing separators. Also, the value of the aspect ratio of a separator is 2.86 for this separator. Also, the final optimized value of different design parameters is 0.15, 0.46, 1.95, 0.41, 2.63, 7.59, 7.51, and 4.28 for H_{HL}, H_{LL}, H_V, H_W, D, L, T_S, and T_H, respectively. The answers were checked and compared in 30 different sets and observed that the maximum difference between the answers is 3.3%. Also, the amount of MAPE for the 7 calculated parameters varies between numbers 1.53 and 4.54. On the other hand, the total elapsed time to solve the problem is less than 12 seconds which is very small.

Nomenclature

Q_v	volumetric flow of vapor, $m^3.s^{-1}$	H_{LLL}	low liquid level, m
Q_{LL}	volumetric flow of light liquid, $m^3.s^{-1}$	H_v	vapor level, m
Q_{HL}	volumetric flow of heavy liquid, $m^3.s^{-1}$	H_w	height of the weir, m
W_v	mass flow of vapor, $kg.s^{-1}$	H_{HL}	height of heavy liquid, m
W_{LL}	mass flow of light liquid, $kg.s^{-1}$	H_{LL}	height of light liquid, m
W_{HL}	mass flow of heavy liquid, $kg.s^{-1}$	U_{HL}	settling velocity of heavy liquid droplets out of light liquid, $m.s^{-1}$
P	pressure, kPa		
D	diameter of separator, m	U_{LH}	rising velocity of light liquid droplets out of heavy liquid, $m.s^{-1}$
K	terminal velocity coeficient		
B	separator aspect ratio	U_v	vapor velocity, $m.s^{-1}$
V_H	hold up volume, m^3	U_T	vertical velocity, $m.s^{-1}$
V_S	surge volume, m^3	L	total length of separator, m
T_H	hold up time, s	L_1	the first part of separator length (m)
T_S	surge time, s	L_2	the Second part of separator length (m)
t_{HL}	settling time of heavy liquid droplets out of light liquid, s	W	weight of the separator, kg
		E	joint efficiency
t_{LH}	rising time of light liquid droplets out of heavy liquid, s	t	wall thickness of separator, m
		S	allowable stress, kPa
k_s	velocity coeficient	μ	Viscosity, $kg.m^{-1}.s^{-1}$
A_T	total cross section area, m^2	t_c	Corrosion, m
A_V	cross section area of vapor, m^2	ρ_v	density of vapor, $kg.m^{-3}$
A_{LLL}	cross section area of low liquid level, m^2	ρ_L	density of light liquid, $kg.m^{-3}$
A_{shell}	area of the shell of separator, m^2	ρ_H	density of heavy liquid, $kg.m^{-3}$
A_{head}	area of the head of separator, m^2		

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