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Design of Vertical Gas-Liquid Separator and Examination its Effective Parameters in Sarkhoun & Qeshm Treating Company

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ABSTRACT

The gas-liquid separator with 2845 m^3/hr of gas phase and 24.54 m^3/hr of liquid phase is designed in Sarkhoun and Qeshm gas refinery. As for operation conditions and physical Properties of feed, five design methods for design of vertical gas-liquid separator by gravity are applied. The methods are: Iranian Petroleum Standard (IPS), Svrceck and Monnery method from university of Calgary, Scheiman and Gerunda, National Iranian Gas Company (NIGC) and one of French petroleum company (TOTAL). The physical Properties of feed are evaluated experimentally. The experimental results compared with five methods results and TOTAL method has shown the best compatibility with experimental results with 94%. The design parameters for this study are : separation factor K=0.07 m/s, gas terminal velocity U_v=0.17 m/s, height H=3000 mm , diameter D=2450 mm , that is contain three levels for liquid control, LLL=300mm , NLL=475, HLL=560mm

KEY WORDS*:* Design, Separation, Gas-liquid separator, Mist eliminator, Hold up time, Surge time.

INTRODUCTION

Gas-liquid separation processes applied in variety industrial place are based on "Gravity Settling", "Impingement" and "Centrifugation", mechanisms. Sometimes, they use either one or a combination of them and also "Filtration" can apply in this field. [1] Types of mechanical separation can be classified as momentum, gravity and filtration. As for a general rule, mechanical separation happened when the phases are not miscible and have different densities. In momentum separation, Fluid phases with different densities and have different momentum. Due to change of a two phase stream direction suddenly, the heavy phase of fluid (greater momentum) separated from the light fluid. Gravity separation when occurs that liquid droplets settle out of a gas phase and the gravitational force on the droplet is greater than the drag force of the gas flowing around the droplet. Also in filtration, a fluid-solid or liquid-gas mixture will pass through a porous barrier which traps most of the solid or liquid particulates contained in the mixture.

Gas-liquid separators are one of the fixed process equipment that. This article attempts to five methods of two-phase separator design. [2] Two-phase separators can employ either vertically or horizontally. In some cases, Sometimes, Separators may be having inlet diverters or designed with or without mist eliminator pads.

Vapor-liquid separation is often achieved in three stages. In the first stage, primary separation is designed with an inlet diverter or distributor so that the momentum of the liquid entrained in the gas causes the largest droplets to impinge on the diverter or distributor and then drop by gravity. In The next stage, in order to separation of smaller droplets is used through the disengagement area so that disengagement area can be subsequently determined. The final stage is mist elimination where just the smallest droplets are coalesced.

Generally, vertical gas-liquid separators are preferred for the following reasons:

- When the gas-liquid ratio is high.
- A smaller plan area is required (critical on offshore platforms).
- Easier solids removal.
- Liquid removal efficiency does not vary with liquid level.
- Vessel volume is generally smaller. [3]

Figure1 is shown a vertical gas-liquid separator.

According to younger's comment[4] gas-liquid separators can applied in horizontal or vertical status so that he founded if L/D be 1.7 to 3.6, the separators should be used vertically also Branan [5] has proved that if L/D > 5, a horizontal separator should be used. In continue, some equations for sizing vertical gas-liquid separators are summarized. One more point, the volume of the dished heads is negligible in the calculation. [5]

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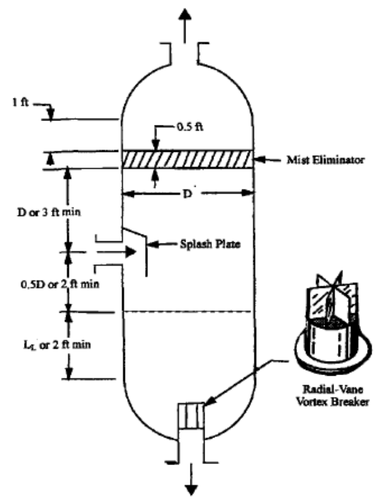


Fig.1. A vertical gas-liquid separator

After considering to vertically or horizontally separators, is turn calculate the droplet settling length so that can identify this is the length from the center line of the inlet nozzle to the bottom of the mist eliminator. As for Scheiman's recommendation [5] the settling length should be to 0.75 D or a minimum of 12 in (0.305 m) whereas Gerunda [6] has specified a length equal to the diameter or a minimum of 3 ft (0.914 m). Also, according to Scheiman's comment [5] to prevent flooding the inlet nozzle is a minimum of 6 in (0.152 m) from the bottom of the nozzle to the liquid surface or a minimum of 12 in (0.305 m) from the center line of the nozzle to the liquid surface. Branan [5] has recommended using 12 in (0.305 m) plus 0.5 of the inlet nozzle outside diameter or 18 in (0.4570 m) minimum too. Thereby Gerunda [6] has specified a length equal to 0.5 D or 2ft (0.610 m) minimum, which is used in Figure 1.

Thereafter achieve the liquid height, Can sized the separator by sufficient liquid residence time or surge time in the separator. In this case Scheiman [5] has recommended a surge time in the range of 2 to 5 min, whereas Younger [4] has recommended 3 to 5 min. Patterson was shown [4] that with change the liquid velocity in the outlet nozzle the lower liquid level varies slightly so that for a velocity of 7 ft/s (2.13 m/s) in the outlet piping of a tank with no vortex breaker, a vortex forms at a liquid level of about 5 in (0.127 m). Thus, as for Gerunda's recommendation, permitting a 2ft (0.610 m) minimum liquid level should be enough.

Finally, in order to obtain uniform flow distribution across the eliminator is added to an additional 12 in (0.305 m) above the eliminator. Also for prevent reducing efficiency of the eliminator; the eliminator shouldn't be too near to the outlet nozzle because a large part of the flow will be directed to the center of the eliminator. To calculate the total length of the separator can sum up the dimensions shown in Figure 1.Can say according to Branan [5], if L/D > 5, a horizontal separator could be used.

As for Watkins's comments [7] to improve of separation efficiency greater than 95 %, should be installed a wire-mesh mist eliminator, near the gas outlet.

Design principals

When the net gravity force, given by Eq. 1,

$$F_g = \tfrac{\pi}{6}.d_p^3.(\rho_l - \rho_v).g \qquad (1)$$

Balance the drag force, given by Eq. 2,

$$F_d = \tfrac{\pi}{8}.U_T^2 d_p^2.\rho_v.C_d \qquad (2)$$

The heavier liquid droplets will settle at a constant terminal velocity, U_T Equating Eqs.1 and 2 results in,

$$U_T = \sqrt{\frac{4.g.d_p(\rho_l - \rho_v)}{3.C_d.\rho_{v'}}} \qquad (3)$$

Hence, as long as $U_V < U_T$, the liquid droplets will settle out. Typically, U_V, is set between 0.75 U_T and U_T Eq. 3 can be rearranged as Eq. 4, a Sauders-Brown type equation (1):

$$U_T = K\sqrt{\frac{(\rho_l - \rho_v)}{\rho_{v'}}} \tag{4}$$

Where

$$K = \sqrt{\frac{4.g.d_p}{3.C_d}} \tag{5}$$

Practically, very small droplets cannot be separated by gravity alone. These droplets are coalesced to from larger droplets which will settle by gravity. Coalescing devices in separators force the gas to follow a tortuous path and the momentum of the droplets cause them to collide with other droplets or the coalescing device, forming larger droplet diameter is not adequately predictable so the K values for mist eliminators are typically empirical.

For vertical separators, the vapor disengagement area is the entire cross-section area of the vessel so that vapor disengagement diameter can be calculated from Eq. 6:

$$D_{VD} = \sqrt{\frac{4.Q_v}{\pi.U_v}} \tag{6}$$

Technically, this is the eliminator diameter and the inside diameter of the vessel must be slightly larger so that the mist eliminator can be installed inside the vessel. Typically, the calculated value is taken up to the next six in. This value is taken as the required diameter of the vessel, D, and the corresponding cross-section area, A, is calculated using this diameter. The next step in sizing a vertical separator is to determine the height. For two-phase vertical separator, the total height can be broken into sections. The separator height is then calculated by adding the heights of these sections. If a mist eliminator pad is used, additional height is added, the calculations of the diameter and height are detailed in the "Design Methods" section of this article.

DESIGN METHODS

The following design methods and heuristics are result of a review of literature source and accepted industrial design guidelines .In this paper as for properties of inlet fluid (feed), operation conditions and design methods, is designed reasonable vertical gas-liquid separator by gravity for liquid elimination. Finally, this is compared with a practical pattern. Design methods are:

1- Iranian petroleum standard (IPS) [1].
2- Svrceck and Monnery from university of Calgary [2].
3- Scheiman and Gerunda [5, 6].
4- A French petroleum company (TOTAL) [8].
5- National Iranian Gas Company (NIGC) [9].

For calculate of design parameters, require to operation condition and properties of feed so that those obtained by measurement in site.

Operation conditions and properties of feed shown in table 1 and table 2.

Table 1: Operation condition is measured in Sarkhoun & Qeshm refinery

	Overall	Vapor Phase	Liquid Phase
Temperature (c)	53	53	53
Pressure (KPa)	6771	6771	6771
Molar Flow (kgmole/hr)	8411	8194	217.5
Mass Flow (kg/hr)	1.789e+005	1.654e+005	1.353e+004

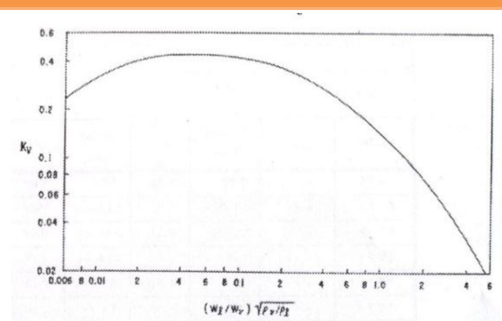
Table 2: Properties of gas and liquid obtained

properties	Overall	Vapor Phase	Liquid Phase
ρ[kg/m^3]	62.34	58.13	551.3
Cp [kJ/kgmole-c]	53.75	51.04	155.8
μ [kg/ms]	---	1.436e-002	0.1470
Q [m^3/hr]	2870	2845	24.54
Z Factor	---	0.8670	0.2818
σ [cSt]	---	0.2470	0.2667
W [kg/hr]	1.789e+005	1.654e+005	1.353e+004
Phase Fraction [molar Basis]	0.9741	0.9741	0.0259
Phase Fraction [vol. Basis]	0.9536	0.9536	0.0464

Also for obtain K in Svercek-Monnery method can use from table 3.

Table 3: Separator K values

Experimental Method



Separation factor : $\frac{W_L}{W_G}\sqrt{\frac{\rho_L}{\rho_G}}$

Design velocity factor of vapor in vertical gas-liquid separators at 85% fooling velocity

Mist Eliminator

$$1 \ll P(psia) \ll 15 \rightarrow$$
$$k = 0.1821 + 0.0029\,P + 0.046\,In(P)$$

$15 \ll P(psia) \ll 40 \rightarrow \quad k = 0.35$

$40 \ll P(psia) \ll 5500 \rightarrow \quad k = 0.43 - 0.023\,In(P)$

Theoretical (no mist eliminator)

$$K = \sqrt{\frac{4.g.d_p}{3.CD}} \qquad d_p:(ft)$$
$$CD = \exp(Y)$$
$$Y = 8.411 - 2.243\,X + 0.273\,X^2 - 1.865 \times 10^{-2}X^3 + 5.201 \times 10^{-4}X^4$$
$$X = In\left(0.95 \times 10^8.\rho_v.\frac{D_P^3(\rho_L - \rho_V)}{\mu_V^2}\right)$$

$(1\,micron = 3.28084 \times 10^{-6}ft)$

GPSA (Gas Processors Suppliers' Association)

$$0 \ll P(psig) \ll 1500 \rightarrow$$
$$K = 0.35 - 0.001\,(P - 100)$$

Most vapor under vacuum K=0.20
For vertical vessel amine solutions multiply K by 0.6-0.8.
For vertical vessels without mist eliminator divided K by 2.
For compressor suction, scrubbers, mole sieve Scrubbers expender inlet separators multiply K by 0.7-0.8.

Another theory method

$$x = ln\left(\frac{W_L}{W_G}\sqrt{\frac{\rho_L}{\rho_G}}\right)$$
$$K = \exp\,(A + BX + CX^2 + DX^3 + EX^4 + FX^5$$

$A = -1.942936 \quad B = -0.814894 \quad C = -0.17939$

$D = -0.012379 \quad E = 0.000386235 \quad F = 0.00025955$

For obtain hold up and surge times can use table 2 in reference [2]. The K values obtained according to difference methods shown in table 4.

Table 4: K values obtained according to difference methods

Method	EXPER.Data	York Demister	Schieman – Gerunda	GPSA	Other EXPER.Data	NIGC	Yanger
K	0.25	0.271	0.03045 -0.107mpd	0.131	0.37	0.05-0.1	0.01 -0.107mpd

Mesh Pad Demister (mpd)

RESULTS

After design of separators by mentioned methods according to operation conditions and properties of gas obtained parameters shown in table 5.

Table 5: Obtained parameters from difference methods

Design Method	K (m/s)	Ut (m/s)	Uv (m/s)	L (m)	D (m)	L/D
Svrcek-Monnery	0.131	0.388	0.291	2.92 Div	1.93	1.5
	0.262 mpd	0.776	0.582	2.73	1.37	1.99
TOTAL	0.04	0.116	0.1	3.83	3.2	1.19
				4.082 mpd		1.25
IPS	0.041	0.12	-	3.43	3.11	1.1
NIGC	0.05	0.146	0.146	5.85	2.63	2.22
	0.1	0.291	0.291	4.65	1.68	2.76
Scheiman – Gerunda	0.03045	-	0.087	6.24	3.42	1.86
	0.107 mpd		0.312	3.76	1.8	2

Mesh Pad Demister (mpd), Diverter (Div)

In this study, the separators parameters are calculated for two situations, with mist eliminator and without mist eliminator. The calculated Parameters are shown in table 5.

In order to, verifying models of predication. The experimental data [10] are compared with models predication. The diameter of separator in Sarkhoun and Qeshm refinery (2450mm) is selected for verifying. The corrected diameter (2450mm) is the base diameter and predication of different methods for L/D is calculated and has shown in table 6.

In table 6, so that sounds, K, U_V, U_T values in some methods are close together but L, D values have more different each other. Experimental data are shown in table 7.

Table 6: Coincident parameters

Design Method	K (m/s)	Ut (m/s)	Uv (m/s)	L correction(m)	D correction(m)	L/D
Svrcek-Monnery	0.131	0.388	0.291	3.7	2.45	1.5
	0.262 mpd	0.776	0.582	4.87		1.99
TOTAL	0.07	0.2	0.17	2.93	2.45	1.19
				3.062 mpd		1.25
IPS	0.041	0.12	-	2.7	2.45	1.1
NIGC	0.05	0.146	0.146	5.44	2.45	2.22
	0.1	0.291	0.291	6.76		2.76
Scheiman – Gerunda	0.03045	-	0.087	4.46	2.45	1.82
	0.107 mpd		0.312	4.9		2.08

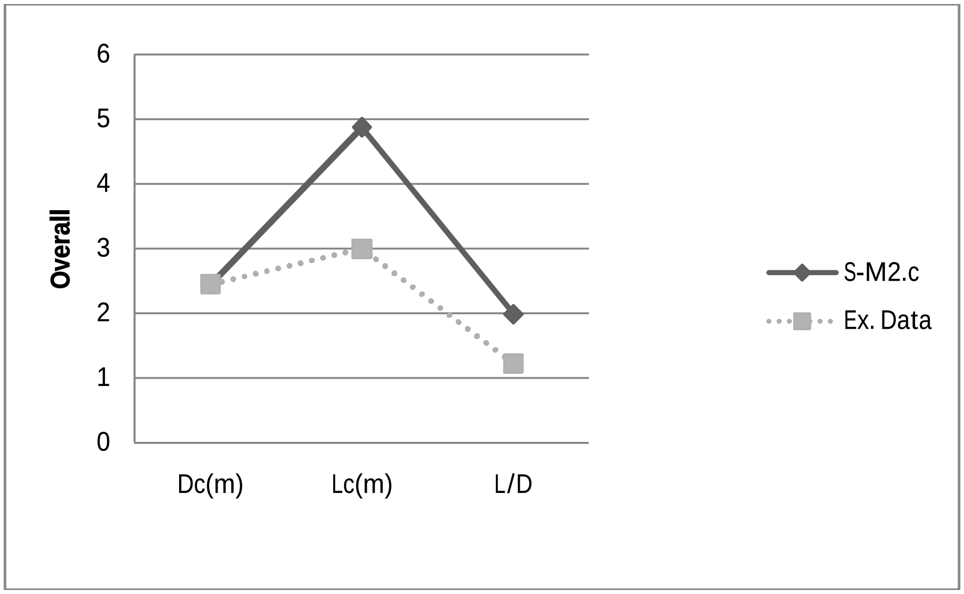
Mesh Pad Demister (mpd).

Table 7: Experimental data

Experimental Data	L(m)	D(m)	L/D
D-101(KTI)	3	2.45	1.224

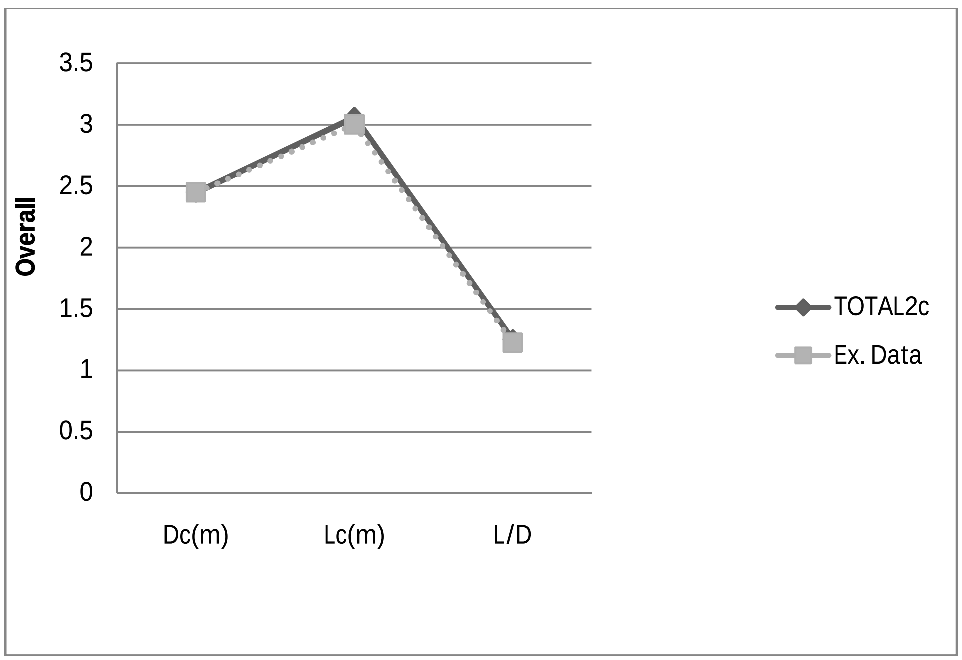
Results of design is compared with experimental data [10] at operation conditions and shown in figures 2 to 7.

Graph: 1



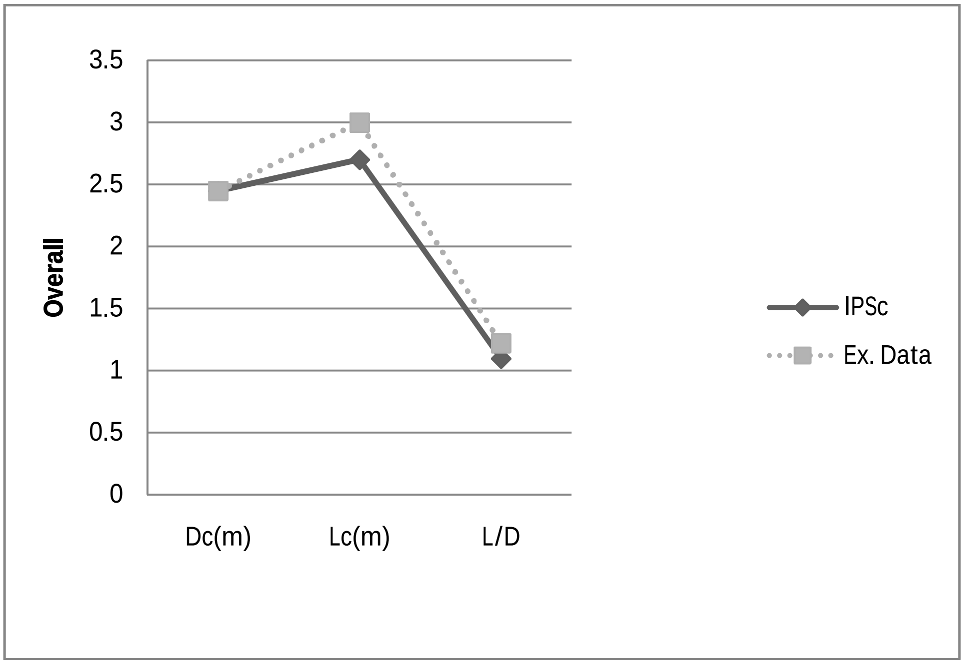
Svreck-Monnery method

Graph: 2



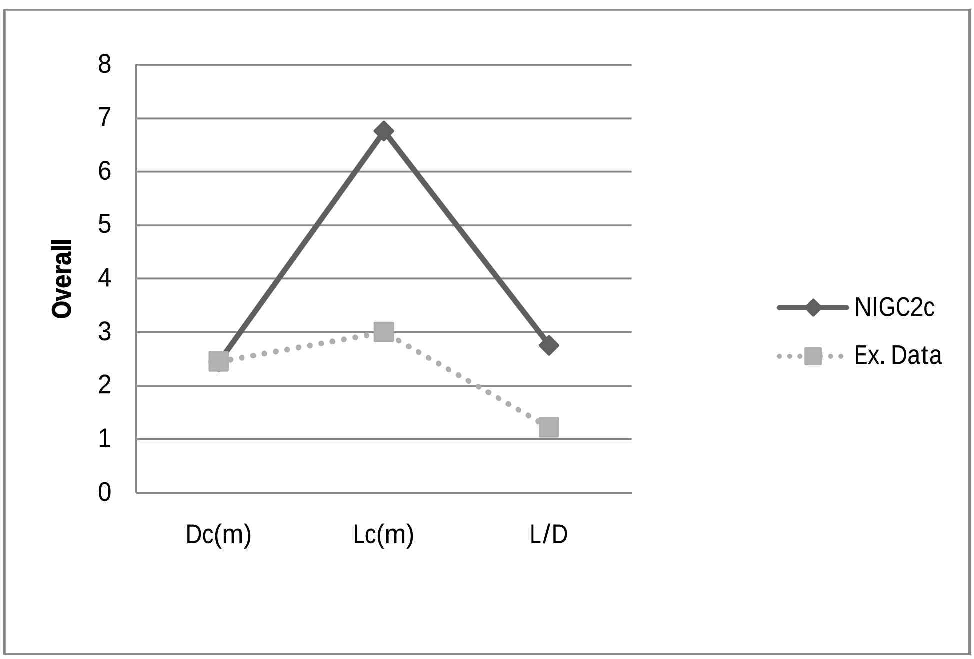
TOTAL method

Graph: 3



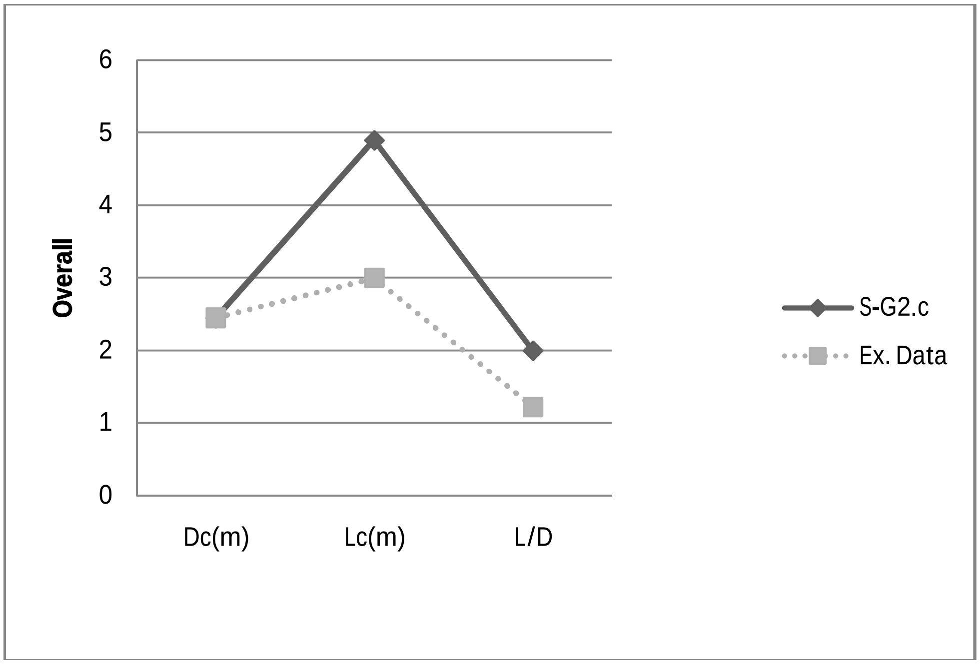
IPS method

Graph: 4



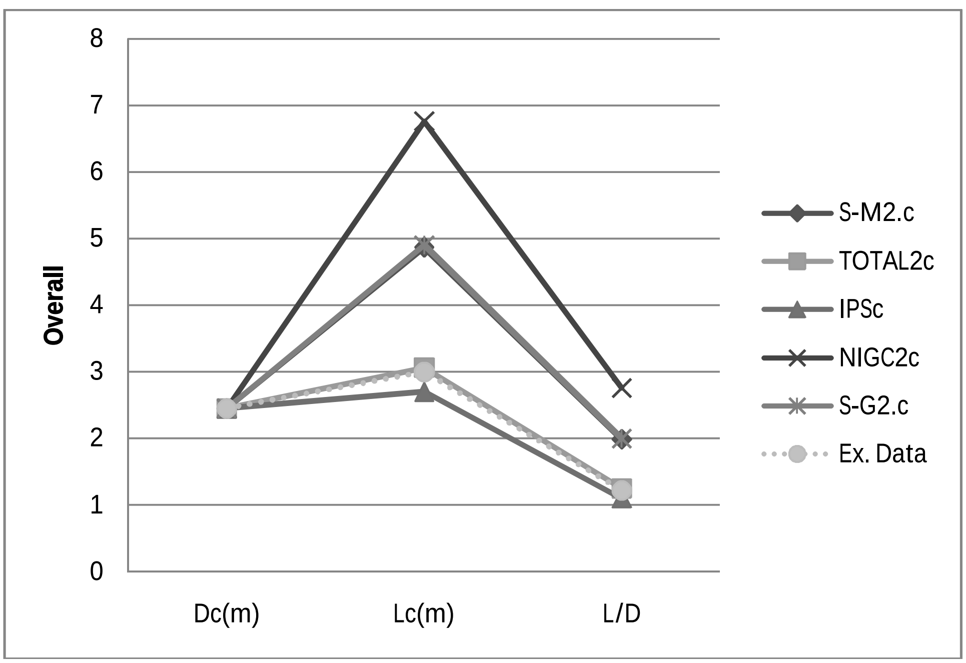
NIGC method

Graph: 5



Scheiman-Gerunda method

Graph: 6



All methods together

Conclusions

In order to compare between results and experimental data for five mentioned methods, the result has shown in figure 2-7. As shown in figure 2-7 TOTAL method has shown the best compatibility with experimental results. The design parameters in this separator are: separation factor K=0.07 m/s, gas terminal velocity U_v=0.17 m/s, height H=3000 mm, diameter D=2450 mm, that is contain three levels for liquid control, LLL=300mm, NLL=475, HLL=560mm.

The function to gives rise to more compatible with experimental data is K factor. It is duo to K value in TOTAL method that agreeable to relation of particle diameter and drag factor. However, both of parameters are principal function and have the most influence on governing equations, also it is direct influence the terminal velocity.

Maximum deviation is in first method that its K value is accomplished by GPSA method. Hence, assumptions of models are portion of governing parameters for solution of problem. However the separator with eliminator, the influence of K value is essential due to increasing high level liquid to nozzle center line. In other words, increases total height of vessel. Also disengagement height in separator with eliminator is less than dry separator, diameter of internal nozzle change according to density and volume flow that influence the liquid level height. As shown in table 8, hold up and surge times can influence the design.
Also M1 to M5 are design methods abbreviation that are shown in table 8.

Table 8: Assumptions of design methods

Assumptions	M1	M2	M3	M4	M5
Hold up time(min)	4	2	-	2	3
Surge time(min)	-	5	5	5	-

Finally, results of design are compared with experimental data [10] that have 94% compatibility. As for need to use vertical two-phase separators in refinery and similar units, can use present methods and obtained results for design and increase internal gas quality to others units.

NOTATION

F_g gravity force, N
d_p particle diameter, m
ρ_l liquid density, kg/m^3
ρ_v vapor density, kg/m^3
g gravitational acceleration, m/s^2
U_T terminal velocity, m/s
C_d drag coefficient, dimensionless
K separation factor, m/s
D_{VD} vessel diameter, m
Q_v vapor flow rate, m^3/s
U_v vertical velocity, m/s

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