High Capacity of Columns of Stabilizer Unit of Shiraz Refinery Using Structured Packing

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Abstract-**In this study, results of revamping of stabilizer unit of a refinery which includes a debutanizer, and a splitter column, are presented. The products of the unit are light straight run gasoline (LSRG) and Heavy straight run gasoline (HSRG). Revamping has been carried out by commercial software. Results of simulation illustrate that revamping by structured packings is an effective method for capacity increase while maintain product quality at the same time. Debutanizer and splitter units have been simulated with regard to inlet and outlet flow rates, flooding, operating pressure and temperature. The simulation results are in good agreement with the operating data and experimental analysis. By using MELLAPAK 250X, as a structured packing in revamping process, pressure drop was decreased from 196 to 23 mbar. In addition, Sichlmair model has predicted the pressure drop very accurately. The results also demonstrate 31% capacity increase in feed flow rate and higher quality product.**

Keywords- Stabilizer; Distillation; Capacity; Revamp; Structured Packing

I. INTRODUCTION

The Chemical Processing Industries look forward to gain better quality productions and high capacity of existing units simultaneously. While increasing capacity of existing distillation columns is not unusual, great care needs to be taken when a revamp is being considered. There is an obscure boundary between success and failure in mentioned goal. Using of structured packing in distillation tower has been developed in recent decades. High efficiency in separating processes such as absorption distillation is the most advantage of structured packing applied. The mentioned types of columns have more benefits than the tray and random packing columns. They are considerably smaller in dimension and pressure drop than tray columns. In comparison to tray columns, no void space in packed towers, results in better phases contact[1]. Compared to tray and random packing, lower pressure drop, and higher capacity and efficiency are other advantages[2].

The prediction of pressure drop is very important in column design. Various prediction methods are available, including the Bravo-Rocha-Fair[3] and stichmair-Rocha-Fair models[4]. Koch-Glitsch Inc. has investigated capacity increase of an Ethylene quench unit in 1985. In this study Sieve tray has been replaced by combination/mixture of structured packing and random packing. In this revamp, HY-PAK #2 as random packing was located in upper section and in lower section FEXIPAC 3X, 4Y as structured packing. The results of this study are shown in Table I[5].

TABLE I RESULTS OF KOCH-GLITSCH INC. INVESTIGATION[3]

	Unit	Before revamping	After revamping
Total pressure	mmHg	57	21
Feed flow rate	Lb/hr	502	818
Gas flow rate	Lb/hr	373	542
Temperature	°F	84	89

In 1990, Koch-Glitsch Inc. worked on similar revamp by structured packing in depropanizer column, to reach higher production capacity. An increase from 4000 to 16000 barrels has been reported by revamping of structured packing with 16 stages of tray column[3]. By case study of available stabilizer unit of Shiraz Refinery Complex of Iran, a method of capacity increase has been proposed. To reach better operating conditions, such as unit capacity increase, separation efficiency, pressure drop and also low energy consumption, structured packing revamp has been proposed.

II. SIMULATION

Up-stream of atmospheric distillation column, as the inlet flow, is fed to the stabilizer unit.

In this process, after heating, hot feed-stream is conducted into debutanizer from stage 16. LPG as the top product and heavier components as the bottom, are separated in debutanizer column. Consequently, bottom product of debutanizer is used as the splitter feed to produce LSRG and HSRG as shown in Fig. 1.

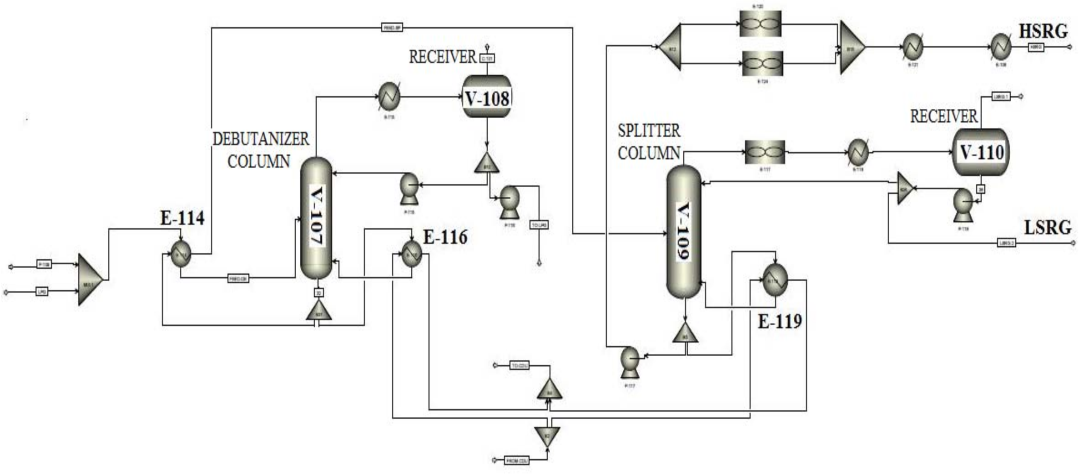

Fig. 1 Stabilizer unit of Shiraz Refinery Complex

Table II presents splitter and debutanizer columns specifications. The splitter feed includes heavy components such as pentane, hexane and heptane, which is fed to the column from Stage 14.

TABLE II DEBUTANIZER AND SPLITTER COLUMNS SPECIFICATIONS[6, 7]

Specifications	Splitter column	Debutanizer column
Number of trays	26	30
Feed flow rate	85	98
Type of tray	Valve Tray	Valve Tray
Height	68	74

By using commercial software, simulation has been carried out at steady state condition. The purpose of this simulation was to optimize and predict the performance of the existing process and its operating conditions.

In this simulation, the Chao-Seader method was used to predict pure component fugacity coefficients. This method is applicable for crude towers, vacuum tower, etc. in presence of hydrocarbon and light gasses such as carbon dioxide and hydrogen sulphide[8].

III. HYDRODYNAMIC MODEL STRUCTURED PACKING

In 1989, Stichlmair et al.[4] proposed an empirical model to estimate the pressure drop and flooding in packed columns. The gas and liquid are flowing in a counter current fashion. A mathematical expression to describe all flow regimes (flooding region, dry gas, loading region and irrigated gas flow below the load point), for any kind of packing materials, is as follows:

$$\frac{\Delta P_{irr}}{r_L g Z} = \frac{\Delta P_{dry}}{r_L g Z} AB \tag{1}$$

$$A = \frac{1}{1-\varepsilon}\left\{1-\varepsilon\left[1-\frac{h_o}{\varepsilon}\left[1+20\left(\frac{\Delta P_{irr}}{r_L g Z}\right)^2\right]\right]\right\}^{(2+c)/3} \tag{2}$$

$$B = \left[1-\frac{h_o}{\varepsilon}\left[1+20\left(\frac{\Delta P_{irr}}{r_L g Z}\right)^2\right]\right]^{-4.65} \tag{3}$$

Where ΔP irr is the irrigated pressure drop (Pa/m), ΔP_{dry} is the dry pressure drop (Pa/m), ρ_G, ρ_L are the gas and liquid densities (kg/mρ^3), respectively, g is the gravitational acceleration (m/s^2), Z is the column height (m), ε is the porosity of the packing (m^3/m^3), h_0 is the liquid hold up in the load point (m^3/m^3) and c is an exponent given by:

$$c = \frac{1}{f_o}\left(-\frac{c_1}{\mathrm{Re}_G} - \frac{c_2}{2\sqrt{\mathrm{Re}_G}}\right) \tag{4}$$

The friction factor for a single particle is[9]:

$$f_o = \frac{c_1}{\mathrm{Re}_G} + \frac{c_2}{\sqrt{\mathrm{Re}_G}} + c_3 \tag{5}$$

Packing constants to evaluating of friction factor have been given in Table III.

TABLE III CONSTANTS FOR FRICTION FACTOR EVALUATION

Packing Type	c_1	c_2	c_3
Rasching Rings (metal)	48	8	2
Rasching Rings (ceramic)	60	1	7.5
Pall Rings	33	7	1.4
Saddles	32	7	1
Structured Packing	18	4	0.2

Where c_1, c_2 and c_3 are the fitting parameters and Re_G is the Reynolds number of the gas flow.

Gravity forces the liquid to move downward through the packing. Several forces oppose gravity: (a) liquid buoyancy (important at high pressures), (b) vapour pressure drop, and (c) drag on the liquid film by the vapour. On the basis of data analysis for the sake of simplicity, as well as to maintain positive values of g_{eff} at all times as a result of the equilibrium of forces, a value of 1025 Pa/m was selected for the flooding pressure drop.

$$g_{eff} = g\left[\left(\frac{\rho_L - \rho_G}{\rho_L}\right)\left(1 - \frac{\Delta P / \Delta Z}{1025}\right)\right] \tag{6}$$

The pressure drop is calculated iteratively in the loading region, near the 1025 Pa/m criterion, or up to 90 % flooding, using Equation (1).

In order to determine c_1, c_2 and c_3 the *Levenberg-Marquardt Method* is used and the experimental pressure drop data. Initially the values for c_1, c_2 and c_3 are assumed, and then when the sum of squares of the differences (i.e. the experimental values minus the theoretical values) reach a minimum or they are less than or equal to the convergence parameter, c_1, c_2 and c_3 are obtained[10].

IV. REVAMP BY STRUCTURED PACKING

Revamping was carried out by testing several structured packing. Results are illustrated in Table IV.

TABLE IV PRESSURE DROP EFFECT IN MELLAPAK

Type of structured packing	Pressure Drop, mbar
MELLAPAK 250 X	23
MELLAPAK 250 Y	99
MELLAPAK 350 X	38

From Table IV, two structured packing 250X and 350X have lower pressure drop in comparison with other kind of packing. With respect to costs, 250X has been selected, and the simulation results before and after revamping are shown in Table V.

TABLE V SPLITTER TOWER: BEFORE AND AFTER REVAMP[4]

Specifications	Original Column	revamp
Column Diameter (m)	1.89	1.89
Bottom Temperature (°C)	130	114
Pressure Drop (mbar)	196	23

V. RESULTS AND DISCUSSION

Effects of pressure drop and flooding in splitter column, quality of LSRG and HSRG, as final products of splitter column, have been evaluated before and after revamping.

An important parameter in high-grade quality of LSRG is Reid vapor pressure (RVP). For Reid vapour pressure, there is a maximum value as a limiting parameter which has been obtained in agreement with the experimental data as it shown in Table VI.

TABLE VI COMPARISON OF EXPERIMENTAL AND SIMULATION FOR RVP IN PSIA[6]

Product	RVP TEST	Experimental RVP	RVP Before Revamping	RVP After Revamping
LSRG	MAX 12	9.1	9.54	8.87

Pressure drop in the column has been compared with two pressure drop models which are Eckert[11] and Stichlmair[12]. Operating pressure drop is actually 23 mbar and predictions by using Stichlmair model and Eckert, were 28 and 61 mbar respectively. Obviously Stichlmair model which was proposed for random and structured packing, can predict pressure drop with higher accuracy.

Flooding in packed beds is characterized by unstable operation and loss of efficiency. Flooding is causing liquid to be entrained in the vapour up the column and is known as negative phenomenon. The increased pressure from excessive vapour also backs up the liquid in the down comer, causing an increase in liquid holdup on the plate above. Depending on the degree of flooding, the maximum capacity of the column may be severely reduced. Flooding is detected by sharp increases in column differential pressure and significant decrease in separation efficiency.

In splitter unit, effect of flooding parameter with tray column and embedded type by using structured packing have been compared and results are shown in Table VII.

TABLE VII COMPARISON OF FLODDING PARAMETER IN SPLITTER COLUMN

Flooding (structured packing)	**Flooding (Tray)**	**Feed flow rate (m^3/hr)**
67%	80%	85
79%	94%	112

From the results of Table VII, the feed flow rate in splitter column can be increased from 85 to112 m^3/hr after revamping by structured packing.

Product quality has also been compared with the results obtained after revamping. These are shown in Fig. 2 and Fig. 3 from these results it can be seen that the qualities of the products are not decreased after revamping and capacity increase.

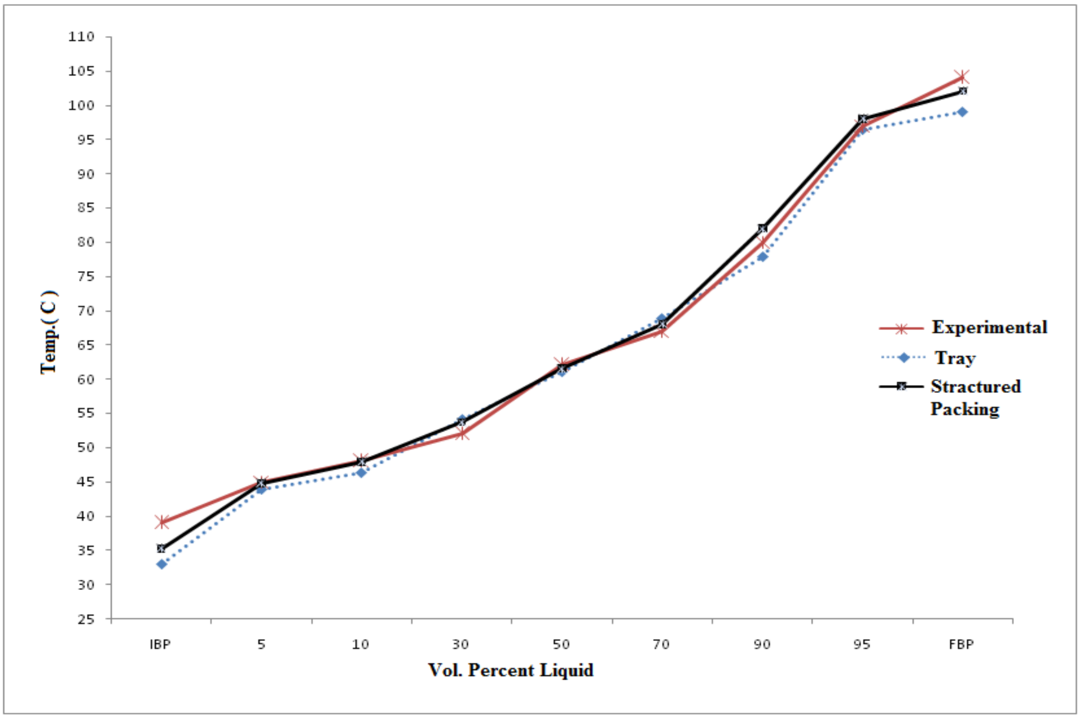

Fig. 2 Quality of LSRG

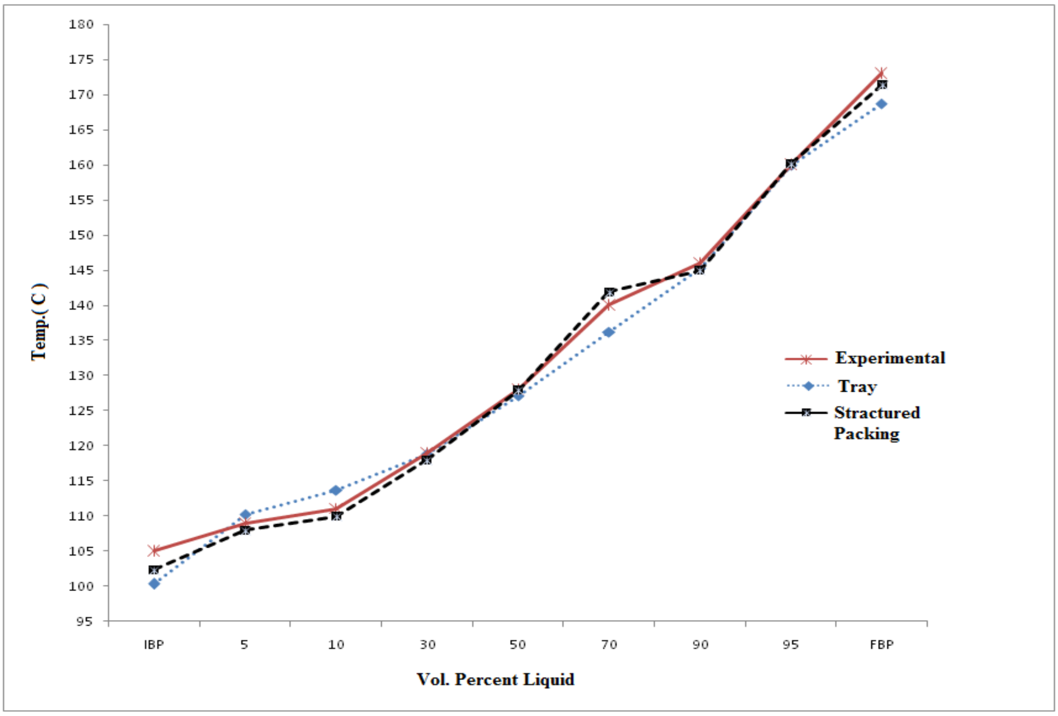

Fig. 3 Quality of HSRG

VI. CONCLUSION

The use of structured packing is a practical way for capacity increase in atmospheric distillation tower. Because of low pressure drop MELLAPAK 250 X was used in column revamp. In splitter column, compared with the Eckert model, the Stichlmair model predicts the pressure drop in the column very accurately. In stabilizer unit of Shiraz Refinery Complex, structured packing revamp results in 31% increase in unit capacity in comparison with tray column.

ACKNOWLEDGEMENTS

The authors acknowledge the support from Shiraz Refinery Complex and University of Sistan and Baluchestan.

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