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Comparison packed bed and structured packing for optimum operating condition of Natural gas dehydration

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Abstract

An approach for reduction of triethylene glycol (TEG) losses and energy consumption in dehydration Facility is presented.

Dehydration of natural gas in an industrial packed column absorber has been investigated .Calculations of minimum TEG concentrations required for given conditions and dew point temperature required were made. A rate based model has been given for simulation of random and structured packing columns .The model equations are included material and energy balances of Dehydration unit. The model results show the structured packed bed has higher performance than random packed bed.

Keywords: Dehydration – Structured packing – Random packing – column -TEG

1.Introduction

Water vapor is the most common undesirable impurity in gas streams. Usually, water vapor and hydrate formation, i.e. solid phase that may precipitate from the gas when it is compressed or cooled. Liquid water accelerates corrosion and ice (or solid hydrates) can
Plug valves, fittings, and even gas lines. To prevent such difficulties, essentially gas stream, which is to be transported in transmission lines, must be dehydrated as per pipeline specifications.

Most of the liquid free water associated with extracted natural gas is removed by simple separation methods at or near the wellhead.
However, the removal of the water vapor requires more complex treatment, which usually involves one of the two processes, either Absorption or Adsorption.

1.1. Dehydration by absorption

The most common method for dehydration in the natural gas industry is the use of a liquid desiccant contactor-regeneration process. In this process, the wet gas is contacted with a lean solvent (containing only a small amount of

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In case of absorption based natural gas dehydration processes the gas is dried by countercurrent scrubbing with a solvent that has a strong affinity for water. The solvent is usually a glycol, although other liquid desiccants are met which are calcium chloride, lithium chloride, zinc chloride, etc. The dehydrated gas leaves at the top of the column. The glycol leaving the bottom is regenerated by distillation and recycled (Carroll, 2002; Rojey et al., 1994).

Several liquids possess the ability to absorb water from a gas stream. Few liquids, however, meet the criteria for a suitable commercial application. A suitable solvent should have the following properties (Carroll, 2002; Rojey et al., 1994, Campbell, 1992):

a) strong affinity to water (the absorbing liquid should be highly hygroscopic)
b) low cost
d) low affinity for hydrocarbons and acid gases
f) easy regeneration to higher concentration for reuse, usually by the application of heat, which drives off the absorbed water
g) low viscosity
h) low vapor pressure at the contact temperature to reduce the amount of solvent losses due to vaporization

The most common glycols for dehydration applications are (Rojey et al., 1994):

a) Monoethylene glycol (MEG) which is commonly known as simply ethylene glycol (EG)
b) diethylene glycol (DEG)
c) triethylene glycol (TEG)
d) tetraethylene glycol (TREG)

Table 1.1 lists the main physical properties of commercial glycols. They can be obtained in the pure state by fractionation by vacuum distillation.

The heaviest glycols are most hygroscopic. Triethylene glycol (TEG) offers the best cost/benefit compromise, and is the most widely used.

In absorption, dehydrating agent (e.g. glycols) is employed to remove water vapors and in adsorption, solid desiccants like alumina, silica gel, and molecular sieves can be used. The absorption process has gain wide acceptance because of proven technology and Simplicity in design and operation.

The general tendency of chemical engineering is to reach increased efficiency and capacity of separation units at possibly minimal cost. This has brought about a novel generation of column internals, providing enhanced mass transfer performance and relatively low pressure drop. Among these internals, corrugated packing of the regular type, also referred as structured packing, has gained a wide acceptance. View any type of random packing in (Fig. 1)

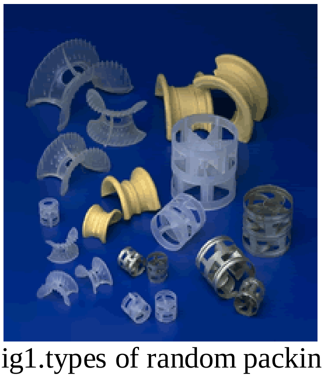

Fig1.types of random packing

1.2. Structured packing

The general tendency of chemical engineering is to reach increased efficiency and capacity of separation units at possibly minimal cost. This has brought about a novel generation of column internals, providing enhanced mass transfer performance and relatively low pressure drop. Among these internals, corrugated packing of the regular type, also referred as structured packing, has gained a wide acceptance.

In this case, the partial differential equations of convective mass transfer offer the most rigorous way to describe the transport phenomena. However, even for the regular geometry provided by corrugated sheet structured packing, the exact localization of the phase interface represents a difficult problem; due to intricate inter phase interactions dictated by packing geometry and surface characteristics. Therefore, most often, the modeling of separation processes is accomplished with the traditional stage concept, either using the equilibrium or rate-based stage models.

Fig2.types of structured packing

2. Process description

2.1. Equilibrium stage model

The equilibrium stage model was largely used for the description of separation processes during the last century.

Since 1893, after the first equilibrium stage model was put forward by Sorel, numerous publications have appeared in the literature, discussing different aspects of its further development and application. Equilibrium stage model

assumes that the streams leaving a stage are at thermodynamic equilibrium. This idealization is usually far from real process conditions, and therefore, process equipment is designed using the “height equivalent to a theoretical plate” (HETP), a gross parameter including the influence of packing type, size and material.

This model is not able to consider the packing geometry characteristics, which play a key role in actual mass transfer.

2.2. Rate-based stage model

The so-called rate-based stage model presents a different way to the modeling of separation processes, by directly considering actual mass and heat transfer rates. A number of models fall into the general framework of the rate-based stage.

In most cases the film or penetration and surface renewal models find application, whereas the necessary model parameters are estimated by means of correlations. In this respect, the film model appears advantageous due to numerous correlation data available in the literature.

According to the film model, all the resistance to mass transfer is concentrated in two thin films adjacent to the phase interface.

The film thicknesses represent model parameters which can be estimated using the mass transfer correlations

3. Hydrodynamic analogy for structured packing

Generally, corrugated sheets structured packings are installed into a column as a bed of certain height and diameter .It is composed of a number of stacked elements (segments).

The segments are perpendicular to each other to produce the mixing effects for both gas and liquid at each transition from one packing segment to another. Each packing segment consists of a number of corrugated sheets manufactured from gauze, metal, ceramics or plastics and additionally mechanically or chemically treated to improve their wetting characteristics.

A typical geometry of such corrugated sheets is sketched in Fig.3.

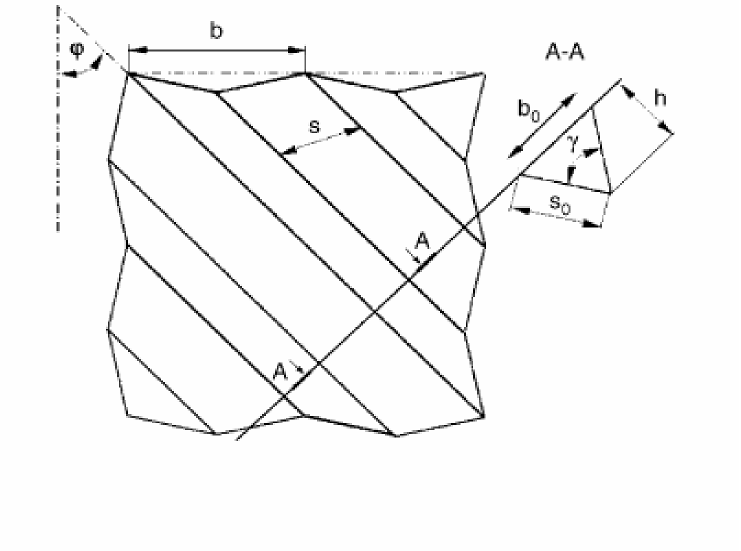

Fig.3. Geometry of a corrugated sheet.

The structured geometry of corrugated sheets results in a geometrically ordered fluid flow, which is different from the flow through random packings. The geometric characteristics of structured packings provide valuable information which helps to capture the gas and liquid flow patterns.

3.1. Gas flow

The corrugated sheets are installed counter course in such a way that they form channels crossing each other at a certain angle j with column axis (see Fig. 3).

Therefore, the packing segment can be visualised as a set of triangular flow channels, with identical cross sections and lengths dictated by the channel proximity to the column wall. Each channel is formed by the two wall sides s0 and one open side b0, which faces a neighbouring channel and is shared between the both channels.

Based on geometry and spatial arrangement of corrugated sheets and taking into account previous studies, we assume that the gas flow through a packing segment can be approximated by a flow through a bundle of channels with dimensions derived from the corrugation geometry (Fig. 3).

For simplicity, we assume round channels, based on the widely used hydraulic diameter approximation. Furthermore,

We consider the gas flow in the channels as laminar and fully developed, being ideally mixed at regular intervals. The mixing points subdivide the laminar flow into fragments of a certain length. They are necessary to take into account the experimentally observed mixing of the gas flow due to an abrupt change in the gas flow direction towards the subsequent channel, either at the column wall or at a transition between the neighbouring packing segments.

To be on line with experimental observations, we assume the length of the undisturbed laminar flow to be equal to an average channel length in a packing segment.

3.2. Liquid flow

The main purpose of corrugated sheet structured packings is to ensure continuous thin film flow. In reality, the form of liquid flow over the packing surface is an intricate function of both liquid and surface properties as well as the packing geometry.

Further, they confirmed experimentally that liquid flow over structured packing surfaces can be approximated by a sequence of fully developed laminar viscous films flowing over flat surfaces with alternating inclinations.

Based on these considerations we assume that liquid motion over packing surface represents a laminar and fully developed film flow. This film wets the inner surface of the channels inclined in accordance with the gravity flow angle (see Fig. 4).

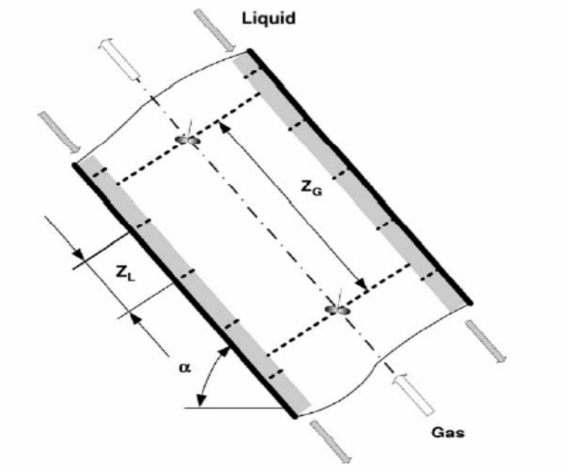

Fig.4. Physical model for the flow structure

We also assume that for all channels, the film thickness is the same. This means that, at this stage, any radial maldistribution is neglected. Similar to the gas flow model, we apply the approximation of the periodic ideal mixing at regular intervals.

Thus, the length of the undisturbed laminar flow is assumed equal to the distance between the two neighboring corrugation ridges. The total inner surface of the channels represents a model parameter, which is calculated based on the packing wetted area.

4. Mathematical model

The inner diameter of a channel is set equal to the hydraulic diameter of the corresponding triangular channel:

$$d_h = \frac{b_0 \times h}{S_0} \qquad \textit{Equ.}1$$

A schematic view of the flow in the channel is given in Fig. 5.

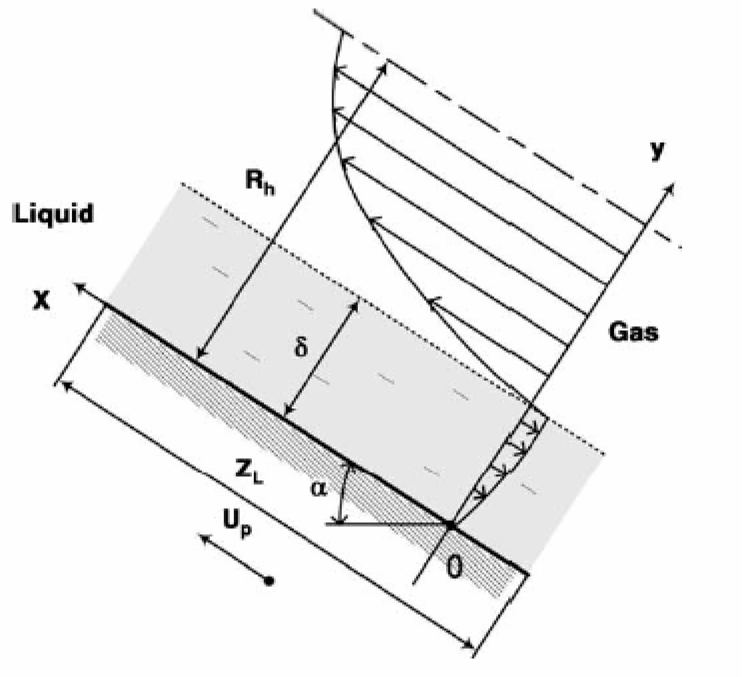

Fig.5. Two-phase gas–liquid laminar countercurrent flow in a channel.

Main result

The corrugated sheets are installed counter course in such a way that they form channels crossing each other at a certain angle φ with column axis (see Fig. 3). Therefore, the packing segment can be visualized as a set of triangular flow channels, with identical cross sections and lengths dictated by the channel proximity to the column wall. Each channel is formed by the two wall side's $s0$ and one open side $b0$, which faces a neighboring channel and is shared between the both channels.

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Comparison of dehydration in structured packing and random packing

In Fig. 6, the concentration profiles for water are compared in two cases. Fig. 6 shows the efficiency of absorption tower with structured packing is higher than random packing.

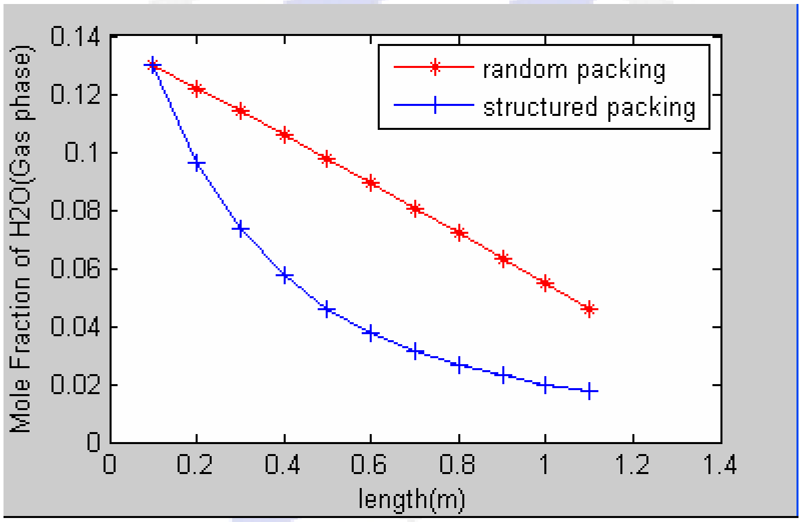

Fig.6. Comparison of dehydration

Comparison of HETP of tower with two cases

With use of equation derived by (murch, 1999) the HETP for tower with structured packing and random packing calculated and show in table

Type of packing	HETP
Random packing	0.137
Structured packing	0.0502

Table 1. Comparison of HETP

Affect of specific area on the amount of water absorption

(Fig .7.) shows that with increase the specific area afford the increase the amount absorption of water

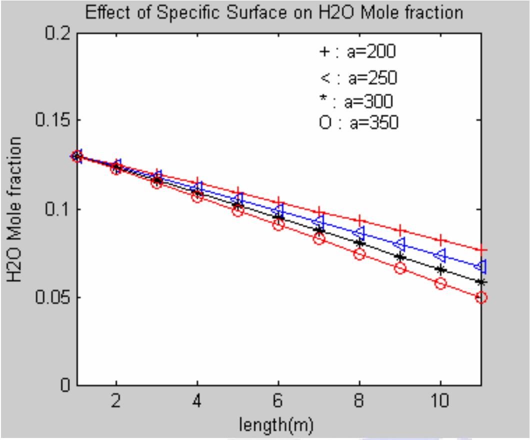

fig.7. Affect of specific area on the amount of water absorption

Conclusions

The design gas velocity in a structured packing tower is more than the velocity in a random packing tower, hence gives more capacity with the existing column.
The HETP in structured packing tower is less than random packing tower.
Dehydration of natural gas in structured packing tower is more than random packing tower.
Specific area of structured packing tower is more than random packing tower.

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